The TechnoPhysics Year: Transformation of Diagnostic Radiology's Clinical Year as a Matter of Necessity

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Given that artificial intelligence and machine learning is now a reality of modern existence, rapidly being applied to medicine, and especially radiology, we submit a new educational perspective. By codifying technology education during the diagnostic radiology internship, we believe it is not only possible but necessary, to reframe the identity of diagnostic radiology. This paper describes the restructuring of the radiology clinical internship, limiting clinical rotations to high-yield essentials, thereby allowing for the introduction of data and technology science, and comprehensive medical physics training. By linking modality-immersion based training with the physics of each technology, we postulate a more thorough understanding and, ultimately, the mastery of current and future technological innovations. Concurrently we advocate for the study of artificial intelligence and machine learning in order to understand how radiologists can apply this technology to help patients on the precision and population health levels. This training would allow interns to spend the majority of their time under the umbrella of a radiology department, in lieu of multiple rotations on an assortment of clinical services. An in-depth technology and physics exam at the end of the internship would be a natural transition to the start of the R1 year, allowing for the application of this newly attained knowledge throughout their residency. Diagnostic radiologists have led medicine into the digital era, and now we should lead the medical community into this transformational era as the "Data-Driven Physician" of the 21st century.

Key Words: Artificial intelligence; Machine learning; Education; Radiology; Clinical year; Internship; Modality-immersion; Physics.

INTRODUCTION

Due to the exponential rise of computational resources in the form of artificial intelligence (AI), informatics, and big data science, radiology education in the United States is quickly reaching a vital crossroads. In 2006−2007, there were scarcely over 100 radiology publications on AI per year. As of data collected in 2016−2017, there were over 800 publications per year, a number which has doubtlessly increased since then (1). The increasing use of machine and deep learning, combined with the expanding complexity of novel imaging modalities, threatens to outpace the current educational training curriculum. Overall, few physicians report the necessary readiness concerning the abundance of emerging technologies on the horizon as evidenced by the Stanford Medicine Health Trends Report 2020 (2), a comprehensive survey of 523 U.S. physicians and 210 medical students and residents. Only 18% of medical students and residents reported that their education was "very helpful" in preparing them for new technologies in healthcare (2). Moreover, 44% of practicing physicians said that their education was either "not very helpful" or "not helpful at all" in dealing with these new technology challenges. The Stanford report describes these survey responses as a "transformational gap" that is emerging amongst physicians who feel insufficiently prepared to cope with the "ongoing seismic shift" being experienced by the healthcare sector. Given that diagnostic radiologists were at the forefront of the digital era of medicine and presumably are the most digitally informed of healthcare specialties (3), one might assume we are ready to bridge the looming technology chasm. However, without taking convincing action to modernize the current educational curriculum, we are hesitant to assume that diagnostic radiologists will remain the medical information technology leader of this new age.

RECLAIMING AN IDENTITY

An evolving program within radiology, interventional radiology (IR), has redefined its identity via the advent of a distinct but codependent residency, allowing multiple pathways into its fold. While maintaining a graft to the rootstock of diagnostic radiology, IR has seen a veritable renaissance (4) by "becoming a primary specialty with uniquely trained physicians (5)" and "an almost autonomous clinical subspecialty

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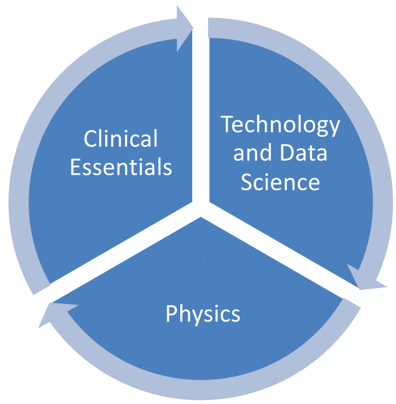

Figure 1. Triad of disciplines that represent the foundation of the "TechnoPhysics Year." Technology to emphasize machine learning-based AI. AI, artificial intelligence.

(6)". By assertively defining their reality, rightly staking claim to the vast majority of patient contact in radiology and even proposing different training, IR has ostensibly created an arm's length distance from its diagnostic counterparts. In a similar vein, the exponential growth in machine learning-based AI tools (ML-based AI tools) offers an opportunity for diagnostic radiology to redefine itself by developing a unified identity, also built on unique training. While ML remains an abstract concept to many and that it is still in its early phase with regard to advanced imaging modalities, we are hopeful that our educational leaders recognize the potential of incorporating meaningful technology education into our curriculum (7). By adopting a technocentric pedagogy at the initiation of training, using a triad of core disciplines (Fig 1), we believe that diagnostic radiology would rightly stake its claim to the "data-driven physician" of the 21st century (2).

A NEW ERA

We propose the reframing of diagnostic radiology's niche based on the incorporation of a comprehensive technology and physics-based educational curriculum in lieu of the current 12-month clinical internship. We call this new preliminary year the "TechnoPhysics Year", based on the following elements: clinical essentials, technology (emphasizing ML) with data science, and physics. The clinical exposure would, in theory, be distilled into three essential blocks: emergency medicine, general surgery, and intensive care unit. We propose that these three blocks are adequate for providing radiology trainees with the necessary initial exposure to clinical environments. Specifically, these blocks were selected because they provide a setting in which imaging plays a direct role in clinical management, forgoing, arguably less relevant rotations. Our clinical colleagues rely on us to master the complex technical aspects of medical imaging just as we rely on their clinical expertise to culminate in the best patient care. While preserving the most salient aspects of the clinical internship, we posit that it is becoming more important for us to emphasize our mastery as imaging and technology specialists over our modest homage devoted to clinical skills during the current PGY-1 year. The remainder of the intern year would be dedicated to a technology and physics-rich curriculum.

PHYSICS AS A BEDROCK

A comprehensive devotion to physics training is one of the foundational stones of the TechnoPhysics Year. As profoundly stated by Samei in 2016, "A solid understanding of the underlying principles of imaging science and processes gives the radiologist a distinct competency that distinguishes him or her from other physicians, enabling him or her to bring that knowledge to bear in understanding the subtle nuances of image features and attributes during interpretation (8)." We believe that an intense focus on physics training serves as the catalyst for imaging innovation in the future, and that training in the U.S. could be restructured to be more in-depth and befitting of special certification. When one considers the ever-increasing accessibility of imaging technology to nonradiologist providers, some of which is even hand-held, the importance of demonstrating mastery in this domain becomes even more apparent. We propose that diagnostic radiology interns be eligible to sit for a specialized technology and physics exam at the end of the TechnoPhysics Year, rather than with the core exam, currently taken during the R3 year. The R3 core exam questions would then be comprised exclusively of clinical radiology in lieu of the comprehensive physics exam taken at the end of the PGY-1 year. This concept is not unprecedented, as the physics section has been offered as a separate portion of the American Board of Radiology (ABR) exam in years past. This change would allow diagnostic radiology residents to apply their newly acquired expertise throughout their residency.

TEACHING TECHNOLOGY

Coursework for the TechnoPhysics Year would take place primarily in the radiology department where interns would undergo immersion in topics of imaging technology, physics, data science, and medical applications for ML. While these topics would dominate the non-clinical coursework, one could envision detailed instruction in report composition, electronic medical records, and radiobiology to prepare interns for day one of residency. Time could be allowed for radiology-relevant research methods and scholarship, biostatistics, and study design. Nonclinical skills such as medical economics and physician payment policy systems could also be introduced as part of the curriculum. Further requirements might include rotations with the hospital's Chief Information Officer in an effort to understand the role that radiology plays in the broader information technology picture. Participation in intra-departmental research or quality improvement projects during the TechnoPhysics Year would reinforce the application of this newly found knowledge on a contemporaneous basis. Supplemental online coursework could further help to standardize the experience across residency programs; however, over time and with proper guidance, many of these courses could be adopted by attending faculty radiologists as part of an integrated lecture series. An existing web-based interactive informatics course, developed by the National Imaging Informatics Curriculum and Course, could be used as a model (7).

The use of "modality-immersion" is a suggested learning technique that melds the aforementioned physics regimen with technology and innovation. We believe that embedding diagnostic radiology interns in modality-based rotations, in order to learn the basics of scanning actual patients, would benefit those interns more than multiple clinical rotations that provide little with regard to radiology education. Such "practical" rotations would involve instruction by, observation of, and interaction with technologists in multiple modalities. The remainder of the day would be devoted to the study of technical knowledge involved in the operation and function of imaging equipment, including physics and elementary engineering. For example, during an embedded MR rotation, the intern would learn the basics of scanning patients by working with technologists for part of the day, with the remainder of the day devoted to the study of MR physics. It is through this process of modality-immersion that the essence of these technologies becomes more relevant for future radiologists. Zhang et al. designed a short-term pilot study and found that hands-on training was useful in bridging the gap between rote knowledge of concepts and the application of this knowledge to solve clinical problems. He incorporated a hands-on laboratory that included the disassembly and reassembly of an X-ray tube in order to understand the relation of fundamental components to each other while learning how these components affect image quality (9). Participants in the study unanimously agreed that learning physics in this manner would benefit their future radiology rotations (9). While some residencies might offer a version of this type of training, it is likely not as thorough as it could be, given the unremitting clinical demands faced by most departments. We believe that interns trained in this manner will gain a deeper understanding of imaging technology, an

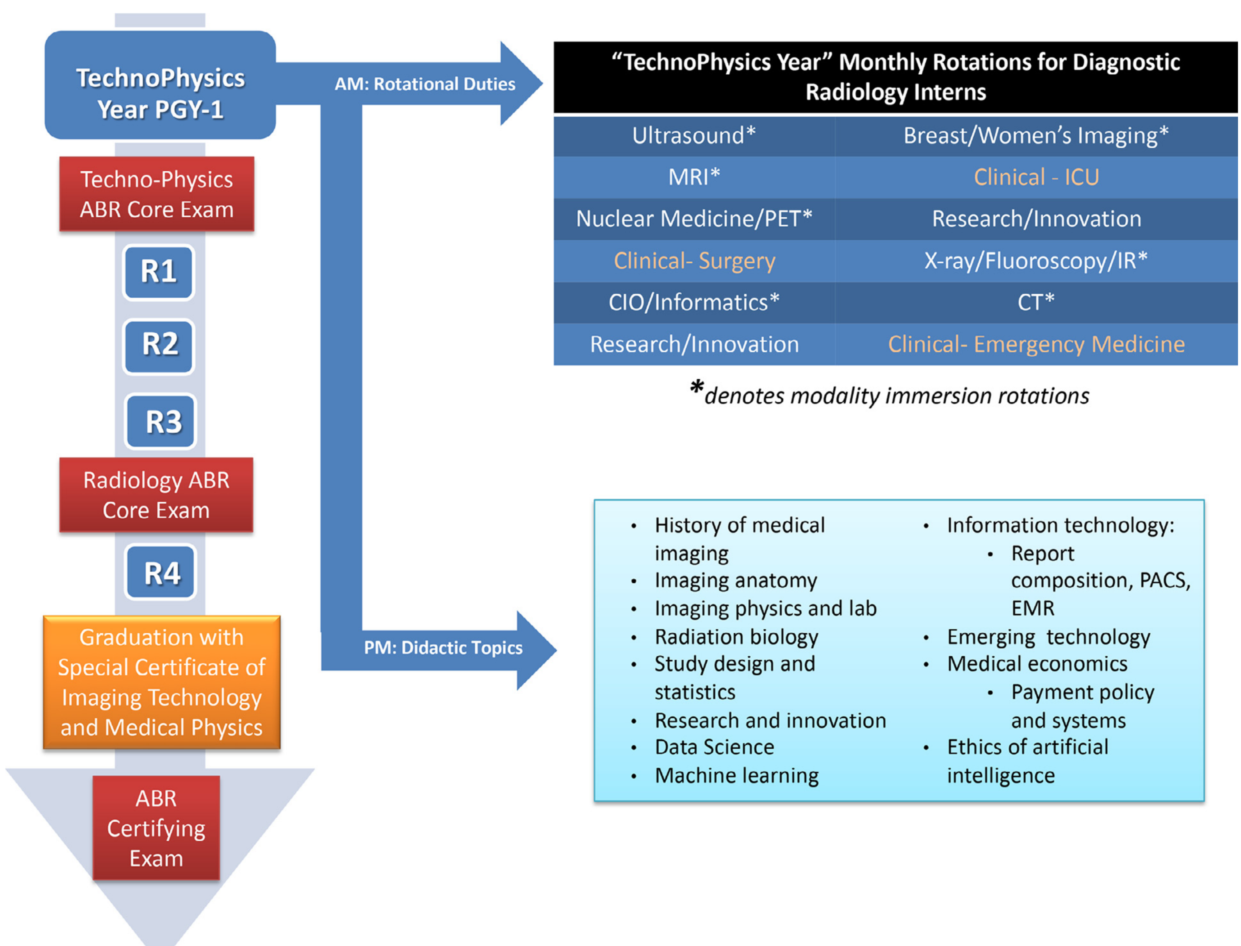

Figure 2. Diagnostic Radiology Residency Milestone Timeline: proposed curriculum detailing the "TechnoPhysics Year" with a variable daily schedule designated by morning and afternoon. At the end of the PGY-1-year, diagnostic radiology interns would be eligible to sit for a comprehensive technology and physics exam, ultimately, qualifying them for a special certificate upon graduation of R4 year. Note that the content of the Radiology ABR core exam at the end of the R3 year would be clinical radiology, without physics, in lieu of the prior TechnoPhysics exam.

appreciation for the patient experience, and familiarity with the daily challenges that technologists face. It could also be argued that learning more about the duties and responsibilities of radiology technologists would be essential before assuming the role of a physician leader in this field.

MOVING FORWARD

While any changes to the current system would be subject to approval by the Accreditation Council for Graduate Medical Education Residency Review Committee (10), and may generate a certain level of debate due to several bold proposals, the main goal of our paper is indeed to foster conversation about the evolving palette of applicable skills needed by incoming residents. It is understood that radiologists-in-training should learn to relate to their clinician colleagues and obtain a satisfactory level of clinical acumen; however, devoting an entire year for this purpose seems excessive (11). Likewise, with the average student loan debt of graduating medical students of $196,520 (12), any thoughts of prolonging radiology training are unpalatable. We believe it is time for our educational leadership to acknowledge and address these themes lest they risk appearing tone-deaf to the next generation of radiologists. In this spirit, we have drafted a generic template of what the TechnoPhysics Year would look like (Fig 2).

The TechnoPhysics Year seeks to provide more relevant training and incentives specifically with the diagnostic radiology resident in mind. Ultimately, we propose a capstone project that leads to the granting of special certification in imaging technology and medical physics, bestowed upon graduation, at the end of the diagnostic R4 year. This unique training is intended to provide a distinct skillset and identity for diagnostic radiologists and is, therefore, not designed for integrated or early specialization in IR (ESIR) residents. It is possible for independent IR residents to obtain the benefits of the TechnoPhysics training curriculum; however, they would have to graduate from the diagnostic radiology program and then enter an independent IR residency, all of which would take place after the PGY-5/R4 year.

As with all changes of this magnitude, where there are alternate uses for limited resources, one must weigh the potential risks and benefits of such decisions. It is beyond the scope of this article to discuss in depth why three essential clinical blocks are better than 12, seemingly random transitional year blocks. However, one must admit that when the "clinical internship year" was reinstated in 1997, after a 26-year hiatus, PACS, EMR, and voice recognition, let alone machine and deep learning, were in their infancy, at best. The point is that spending 12-months in a clinical internship at that time may have been a viable consideration; however, the internship should now be optimized for the challenges that lie ahead. Likewise, whether the Centers for Medicare and Medicaid Services, via Graduate Medical Education, will balk at the idea of funding the TechnoPhysics Year is also a separate debate. It may be incumbent on us to convince them that it is in the best interest of patient care to have a group of physicians highly versed in these disciplines. Perhaps a pilot study of the TechnoPhysics program, after the development of a specific curriculum, is in order.

CONCLUSIONS

While Drs. Gunderman and Tobben questioned the usefulness of the clinical internship entirely in their 2016 article (11) we posit that the current clinical internship requires reframing so that trainees graduate with relevant technological skills. We believe that our proposed PGY-1 curriculum, focusing on clinical essentials, physics, and technology with data science is required in order to emerge as the physician technology leader. These concepts dovetail with the emerging technologies often referenced by the American College of Radiology's Data Science Institute (13). Except for the three essential clinical months, diagnostic radiology interns would benefit from spending the majority of their time within the radiology department where they would also participate in research and innovation projects, develop camaraderie, and initiate mentorships. Such a structure would work well with categorical internships and could be applied to advanced internships, especially if a standardized curriculum was developed.

Machine learning-based AI tools will "have the potential to reach beyond the core radiology workflow and fundamentally change the experience of residency and fellowship" (14). By formalizing training in ML-based AI tools during the PGY-1 year, we assert that patients will benefit on the precision and population health levels (15,16). Machine learning is on the verge of transforming the practice of radiology; however, a framework for education in this technology is lacking, leaving radiologists potentially ill-prepared (7). In the decades since the resuscitation of the clinical internship, the field of radiology has dramatically changed with regard to technological knowledge and integration. It is time to recognize this change and adapt the training of the next generation of diagnostic radiologists accordingly.

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