POINT/COUNTERPOINT

Suggestions for topics suitable for these Point/Counterpoint debates should be addressed to Jing Cai, The Hong Kong Polytechnic University, Hong Kong: jing.cai@polyu.edu.hk, and/or Habib Zaidi, Geneva University Hospital, Geneva, Switzerland: habib.zaidi@hcuge.ch. Persons participating in Point/Counterpoint discussions are selected for their knowledge and communicative skill. Their positions for or against a proposition may or may not reflect their personal opinions or the positions of their employers.

Artificial intelligence will soon change the landscape of medical physics research and practice

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OVERVIEW

Recently there has been a significant surge in applications of artificial intelligence (AI) in medicine, suggesting that AI may soon dramatically change the landscape of health care and thus medical physics. It is generally expected that AI will improve overall health care in an enormous way. Some believe that AI will similarly impact medical physics research and practice, while others believe that these expectations to be unrealistic due to issues of technical validation and practical limitations of AI. This is the premise debated in this month's Point/Counterpoint.

Arguing for the Proposition is Lei Xing, Ph.D. Dr. Xing is currently the Jacob Haimson Professor of Medical Physics and Director of Medical Physics Division of Radiation Oncology Department at Stanford University. Dr. Xing also holds affiliate faculty positions in Department of Electrical Engineering, bioinformatics, Bio-X, and Molecular Imaging Program at Stanford. Dr. Xing's research has been focused on medical imaging, treatment planning, AI in medicine, image-guided interventions, nanomedicine, and applications of molecular imaging in radiation oncology. Dr. Xing has made unique and significant contributions to each of the above areas. Dr. Xing is an author on more than 300 peer reviewed publications, a co-inventor on many issued and pending patents, and a principal investigator or co-investigator on numerous NIH, DOD, ACS, RSNA, and corporate grants. Dr. Xing is a fellow of AAPM (American Association of Physicists in Medicine) and AIMBE (American Institute for Medical and Biological Engineering).

Arguing against the Proposition is Elizabeth A. Krupinski, Ph.D. Dr. Krupinski joined Emory University in 2015 and is the Vice Chair for Research in the Department of Radiology and Imaging Sciences. Prior to that, she has worked at the University of Arizona for 23 yr. Dr. Krupinski is an Experimental Psychologist with research interests in medical image perception, observer performance, medical decision-making, and human factors as they pertain to radiology and telemedicine. Her research aims to improve our understanding of the perceptual and cognitive mechanisms underlying the interpretation of medical images in order to reduce errors, improve training, and optimize the reading environment, thereby improving patient care and outcomes.

FOR THE PROPOSITION: Lei Xing, Ph.D.

Opening statement

Artificial intelligence is evolving rapidly and promises to transform the world in an unprecedented way. The tremendous possibilities that AI can bring to medical physics have triggered a flood of activities in the field. Particularly, with the support of big data and accelerated computation, deep learning[1–3] is taking off with tremendous algorithmic innovations and powerful neural network models. Given the promising learning tools and massive computational resources that are becoming readily available, I believe that AI will dramatically change the landscape of medical physics research and practice soon. Our community should be prepared to meet the new challenges and opportunities and to take a leadership role in this new wave of the fourth industrial revolution.

Wang, Kalra, and Orton had a vivid discussion in this column on machine learning,[4] which is a core component of AI that aims to use computer programs to learn from experience. As we step into 2018, much has changed as AI is advancing in a pace much faster than many have anticipated. Recently, we have witnessed superior performance of AI in many activities that traditionally belong to the well-trained human beings, such as image classification and object detection, speech recognition and translation, driving, gaming, finance, and even decision-making in law. The domino effects resulting from the latest advances in AI are seen frequently in scientific literature as well as in public media. Notably, AlphaGo Zero,[5] a new version of DeepMind's Go software capable of "self-growing" by playing games against itself, has emerged with stunning performance improvements compared to its predecessor, AlphaGo.[6] While AI may still be a sci-fi to some people, evolution to the next generation of AI, such as artificial general intelligence and superintelligence,[7] seems to be an irreversible trend. In biomedical physics, there is apparent indication that AI will be a major driving force for future innovations and breakthroughs. Numerous studies have already demonstrated the potential of AI in revolutionizing the current schemes of image reconstruction and analysis, image guidance, tumor detection and characterization, therapeutic response and toxicity prediction, and treatment decision-making. From my perspective, the question now is not whether machines can function as well as or better than a human in many specific clinical tasks, but how to prepare the community to the new era of AI-powered medicine and to harness the enormous potential afforded by the AI to improve our patient care.

To recapitulate, we are on the verge of AI revolution that will fundamentally alter the field of medical physics and the way medicine is practiced. The list of possible impact of AI to our field is too exhaustive to list. For many problems that are either too tedious or too difficult to solve, AI may be the only viable choice to move things forward. I urge my colleagues, in particular the young generation of physicists, to stay current in the innovations and facilitate the development of enabling AI technologies for medical physics. A significant portion of future innovations in medical physics will be AI driven.

AGAINST THE PROPOSITION: Elizabeth A. Krupinski, Ph.D.

Opening statement

There is little doubt that AI will revolutionize health care and thereby medical physics. The more important question is, however, where will it not (or perhaps should not) do what many are afraid it will — take over the roles and responsibilities of the medical physicist? A fundamental role of the medical physicist is team member — working together with physicians, technologists, nurses, therapists, engineers, and even patients in the effective, efficient, and safe delivery of health care.[8–10] AI can help provide valuable and accurate information with respect to a multitude of essential care variables (e.g., repeatability and reproducibility; adaptive sequence generation; automated protocolling; assist with smart positioning to decrease retakes; assist with treatment planning). What it cannot do (at least not yet) is engage in team consultation to explain the reasons behind a given decision or proposed method of completing a given clinical task, or modify these decisions based on collaborative and interactive input derived from the knowledge and clinical experience of other team members and the uniqueness of each clinical encounter and patient.

In a similar vein, another key role of the medical physicist is education and training,[9–11] not only of junior level and medical physicists in training but also of other health care professionals including residents and fellows. AI can certainly be used to develop and provide a variety of training tools, but it cannot sit down with a trainee, listen to their problems, explain subtle concepts and the "art" of medical physics, and provide them with the mentorship and guidance and support required to foster their success as independent professionals.

Having good communication and team skills are not the only areas medical physicists will (hopefully) always outperform AI. There are numerous aspects of medical physicists that require fundamental research, integration of concepts and principles across multiple areas, and quite simply human ingenuity, creativity, and insight. One key example, was the creation of the Digital Imaging and Communication in Medicine (DICOM) Grayscale Standard Display Function (GSDF).[12] The DICOM GSDF was developed through the integration of data from a variety of sources including fundamental data derived by Peter Barten's analysis of the contrast sensitivity of the human eye, from which he developed a model that described typical performance of human observers viewing sinusoidal patterns with different spatial frequencies and sizes in uniform luminance backgrounds.[13] Based on these core psychophysical principles and significant insight, understanding and integration of data from multiple sources by medical physicists, engineers, and radiologists, a unifying standard for radiographic image display was generated and is still in use in everyday clinical practice. If AI had been around in the early days of digital radiography would it have been capable of formulating the DICOM GSDF and having the insight and creativity to realize the fundamental need to account for the capabilities of the human visual system when creating a tool to standardize image quality across displays, environments, and users? I think not. That takes human ingenuity, human factors, and human interaction.

Rebuttal: Lei Xing, Ph.D.

The impact of AI is multifaceted — the outcome ranges from simply enhancing to completely replacing its human counterparts. Will AI eventually be able to perform all the activities of medical physicists? No! But, those physicists who know little informatics/AI are more likely to be replaced by those who do, which is to say that computer agents are changing our role in life. Our field is multidisciplinary in nature, and our professional value comes from our ability to synthesize the knowledge from a diverse set of disciplines and provide the most educated decision that amalgamates the context, facts, data, and other information to answer the clinical questions at hand. AI is well suited to facilitate the decision-making process.

To me, the question is not whether our field will be changed by AI, but to what level. The activities Dr. Krupinski listed belong to the category of high-level cognition and will likely remain in the possession of humans. However, not everything that we do belongs to that category. In fact, many of them are task driven with well-defined procedures and protocols, which can be automated. It is foreseeable that, for now and for some years to come, high-level cognition and AI models will remain to be two separate types of activities. As thus, both human and AI agents will co-exist. However, it is important to realize that the separation is narrowing, and our cognitive lead is fading as AI continues to improve, and in some cases, beat out our fellow human beings.

The verdict is clearly in favor of AI. Even if it is not now, a paradigm shift must be in the not-too-distant future because of the remarkable evolution of the agents. It is in this sense that I state that the landscape of medical physics will soon be changed by AI.

Rebuttal: Elizabeth A. Krupinski, Ph.D.

Dr. Xing brings up some very solid points in his discussion of the potential for AI, and I agree that the ideal tasks for AI to automate in radiology and radiation therapy are image classification, object detection image reconstruction and analysis, image guidance, tumor detection and characterization, therapeutic response and toxicity prediction, treatment decision-making, and related tasks that can be rather “tedious” for humans. However, what deep learning and AI do (at least currently) is “mimic the data it’s been trained on”.[14] It is in fact possible to train pigeons to mimic and perform as well as human beings on the task of cancer detection in radiologic and pathologic images after training![15]

Deep learning and AI are still a long way from being creative and this has been the case from the very beginning of AI implementations. As Boden pointed out in 1998, the two major bottlenecks to AI creativity are domain expertise and valuation of results (critical judgment of one’s own original ideas).[16] I would contend that AI still has not been able to master these hurdles and display true creativity, and a significant portion of a medical physicist’s job, whether it is solving a complicated clinical problem, developing a new line of research investigation, or communicating and collaborating with colleagues and patients, involves creativity and ingenuity. Let the computers take over the tedious, monotonous, and time-consuming tasks. Humans will have more time to create, discover, and lead health care to next level.

CONFLICTS OF INTEREST

Dr. Xing serves as the principal investigator of a master research agreement (MRA) with Varian Medical Systems. He also receives research grants from Siemens Healthcare and Google Inc, and serves as the scientific advisor of Huiyihuiying Medical Technology Co., Ltd. Dr. Krupinski has no conflict of interest.

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