Within the next ten years treatment planning will become fully automated without the need for human intervention

Michael B. Sharpe, Ph.D.
Radiation Medicine Program, UHN Princess Margaret Cancer Centre and Department of Radiation Oncology,
University of Toronto, Toronto, Ontario MSG 2M9, Canada
(Tel: 416-946-4501 ext. 5025; E-mail: Michael.Sharpe@rmp.uhn.on.ca)

Kevin L. Moore, Ph.D.
Department of Radiation Medicine and Applied Sciences, University of California,
La Jolla, San Diego, California 92093-0865
(Tel: 858-822-6056; E-mail: kevinmoore@ucsd.edu)

Colin G. Orton, Ph.D., Moderator
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OVERVIEW
Radiotherapy treatment planning is rapidly becoming more-and-more automated or, at least, semiautomated, in order to relieve the human planner of tasks that can be readily handled by computers, such as autosegmentation and optimization. How far this can go in removing the need for human intervention is controversial, but some believe that treatment planning can be fully automated within the next ten years. This is the premise debated in this month’s Point/Counterpoint.

Arguing for the Proposition is Michael B. Sharpe, Ph.D. Dr. Sharpe obtained his Ph.D. in Medical Biophysics in 1997 from the University of Western Ontario, London, Canada, having worked for several years at the London Regional Cancer Centre before moving to William Beaumont Hospital, Royal Oak, MI, in 1995. He worked there until 2002 at which time he moved to the Princess Margaret Cancer Centre, Toronto, where he is currently Associate Head of Radiation Physics and Associate Professor in both Radiation Oncology and Mechanical and Industrial Engineering, University of Toronto. Since 2010, he has also served as Radiation Physics Quality Lead, Radiation Treatment Program, Cancer Care Ontario. He is certified in Radiation Oncology Physics by the American Board of Medical Physics. Dr. Sharpe’s major research interests are focused on advancing practice through the development, validation, and application of radiotherapy and imaging technologies on which he has published over 70 papers in peer-reviewed journals and 11 book chapters, and has authored several patents.

Arguing against the Proposition is Kevin L. Moore, Ph.D. Dr. Moore obtained his Ph.D. in Physics from the University of California, Berkeley, subsequently training and working at Washington University in St. Louis before moving back west to the University of California, San Diego. He is certified in Therapeutic Radiological Physics by the American Board of Radiology and is currently Associate Physics Director and Medical Physics Residency Director in the UC San Diego Department of Radiation Medicine and Applied Sciences. Dr. Moore’s major research interests lie in knowledge-based treatment planning, treatment plan quality control, and informatics applications in clinical radiotherapy. He has published nearly 30 peer-reviewed papers and one book chapter, and is lead inventor on a patent regarding knowledge-based dosimetric prediction.

FOR THE PROPOSITION: Michael B. Sharpe, Ph.D.
Opening Statement

Within a decade, radiation treatment planning will become fully automated without the need for human intervention because (i) we will exploit pertinent trends in the
manufacturing and informatics industries, (ii) the precedent is already established, and (iii) it is imperative to improving quality and continuing advancements in care.

Impressive technological advances have occurred in radiation oncology over the past two decades. Image-based planning, optimization, and guidance progressed rapidly from compelling concepts to routine tools because outside influences like high-performance computing, networking, and robotics became widespread and affordable. IMRT and IGRT have become ubiquitous tools and have altered the paradigm of treatment. But we wish to do more for our patients. The “adaptive” concept was also described more than 15 years ago. The concept has been developed extensively and now includes biologically motivated adaptation. However, more effort is needed to overcome the complexities and impact on workflow to realize adaptation as it was conceived. Future efforts will benefit surely from the “third wave of computing” from which image processing and information technologies will produce insights from large quantities of unstructured treatment planning data.

The need to estimate dose distributions made automation central to the earliest developments of computerized treatment planning. Today, even more advanced functions are automated, such as image registration, organ delineation, and dose optimization. Using commercial tools, it is now possible to control workflow so as to fully create, evaluate and document a plan with minimal intervention. Interestingly, applications involving tangential breast irradiation remain controversial: In spite of the obvious improvements in personalization and efficiency afforded by IMRT and related automation techniques, modern innovation is discouraged because entrenched reimbursement guidelines confuse the technologies and the “modality” they enable.

Providing healthcare is one of the most complex and demanding of human endeavors. Radiation oncology treatment relies on distributed decisions and tasks that are shared across highly skilled medical and technical staff. We strive to assess and respond to each patient’s personal needs; but our tools, skills, and processes are stretched to the limit. Procedures can become error prone, sometimes with tragic and very public consequences. Consequently, practice guidance is limited to the structures and inspections required to achieve safety today. The dynamic nature of patients and their response to treatment were recognized long ago as a control problem. Adaptive control provides a means to account for anatomical and physiological variations and supports highly personalized treatment. Adaptive radiation therapy must become “more than safe.” It must embrace a broader definition of quality to ensure that clinical decisions and technical procedures are evidence based, effective, equitable, timely, and highly tailored to each patient. A higher level of robust quality is required and we must do more than embrace automation. Robust quality is achieved by design rather than through organic innovation followed by inspection for quality control. Adaptation requires a framework to achieve robust quality that is safe, consistent, and highly customized. Within such a framework, care will become more complex unless automation is used to make it “merely complicated.”

AGAINST THE PROPOSITION: Kevin L. Moore, Ph.D.

Opening Statement

As someone who intends to spend the next decade working to advance the proposition, I nonetheless contend that the odds of fully automated treatment planning being the norm in ten years’ time must be rated as extremely unlikely.

A close read of the proposition could make my task relatively easy, i.e., interpreting “fully automated” treatment planning to imply end-to-end automation, whereby all steps between radiotherapy simulation and first treatment are performed without human intervention. Impressive though the last decade has been for the field of autosegmentation, it strains credulity that a decade’s time would be enough to herald a universal autosegmentation platform that not only identifies all normal anatomical structures across all imaging modalities but also flawlessly incorporates every patient’s unique clinical circumstances into fully automated tumor volume contouring.

Making my task somewhat more difficult, we could interpret the proposition to “merely” imply full automation from segmentation to treatment. Both my opponent and have clinically implemented automated treatment planning using present-day technologies, and, undoubtedly, research and commercial offerings in this space will advance in the next ten years. However, we should appreciate the enormity of the challenge in effecting universal automation for all clinical scenarios. Using the impressive work of my opponent as an example, tangents in early-stage breast cancer can clearly be automated to a great effect, but I am skeptical that this algorithm can be easily extended to all breast cancer treatments, e.g., bilateral postimplant chest wall irradiation with internal mammary chain and axillary lymph node involvement, including electron scar boosts, for a patient with cardiac comorbidities. Such a case is both complicated and outside of normative experience, making the work of algorithmic development simultaneously more difficult, more time consuming, and less beneficial (in a utilitarian sense). As automated treatment planning advances, by necessity it will expand from common and standardized treatment sites to infrequent and nonstandardized cases. To automate everything we treat in radiotherapy will take time, and ten years is simply not enough of it.

In fairness to the spirit of the proposition, I feel I should stake my own claim for 2024. Semiautomated (i.e., computer-assisted) treatment planning will be used in the large majority cases, with some form of knowledge-based and/or computer-aided multicriterial optimization removing most of the present-day human variability from the optimization process. The clinical expertise of humans will still be regularly employed to evaluate and adjust plans for patients whose circumstances fall outside of normative treatments. Automated software systems will be commonly available for online plan adaptation. Some reductions in treatment planning staff will occur, although job descriptions might expand to encompass increased needs in clinical informatics and adaptive plan management. Ironically, human-driven planning will probably retain the largest foothold in
3D-conformal/palliative treatments, where patient anatomical variations can be very large and nonstandard clinical considerations are a frequent occurrence.

These changes will be breathtaking and practice altering, but will fall short of delivering fully automated treatment planning by the year 2024. As for 2034…

Rebuttal: Michael B. Sharpe, Ph.D.

I appreciate Dr. Moore’s flexible viewpoint and the challenges he presents. Indeed, image segmentation is a major hurdle; contours are vital for communicating decisions and intent. We are poised to exploit vast stores of images and manually delineated organs,14 but current clinical practices may not provide what is required for algorithm training. We do build on “shifting sands” to some degree as technologies and practice standards evolve. But, the proposition does not “strain credulity” if manual contouring is approached with consensus and consistency.

Dr. Moore believes clinical variation limits our capacity to automate planning. I agree to the extent that the “Pareto Rule” governs progress; i.e., 20% of our efforts will succeed for 80% of the cases. Clearly outliers require significant human effort, but reducing arbitrary variation and building anatomically related evidence to support continued development could help.

Dr. Moore also speculates that automation will reduce staffing, but concedes it could free skilled staff to add value to challenging cases and to advance appropriately personalized adaptation. As automation is introduced, it influences the tasks remaining, i.e., what staff are asked to do. Will we continue in familiar territory, or will new tasks differ qualitatively or become disconnected? We must also assure that it is possible to monitor and compensate for system deficiencies. If these deficiencies are ignored, there is a risk of new types of errors and system failures. In short, automation does not solve all problems.15

In his opening statement, Dr. Moore contends that the “odds” of fully automated treatment planning being the norm in ten years’ time must be rated as extremely unlikely. In my opinion, the future should not be left to chance. We must move to achieve robust quality by design. I conclude by quoting Dr. Dennis Gabor, the Nobel Laureate who invented holography: “The future cannot be predicted, but futures can be invented.”16

Rebuttal: Kevin L. Moore, Ph.D.

I absolutely align myself with the large portion of Dr. Sharpe’s statement dedicated to how automation could improve radiotherapy, and thus will focus on the narrow portion of my opponent’s argument that attempts to explain how automated treatment planning might come to pass.

Relying on a third wave of computing to make this happen perhaps confuses more data with more knowledge. I would respond that analyzing prior information is a necessary but not sufficient condition, and while we must exploit prior information, we cannot expect that the mere possession of large quantities of data will herald miraculous gains. The recent advance of knowledge-based planning yielded useful predictions only when new techniques were brought to widely available data.2,11,13,17,18 Extending automation will rely on further research and development and, as argued in my opening statement, this will take time to expand to all clinical scenarios.

As for the precedents that Dr. Sharpe introduced—image registration, organ delineation, and dose optimization—I would argue that none of these are yet fully automated. Image registration comes close, but in my experience automatic registrations are ultimately adjusted more often than not. I have contended (with great respect) that autosegmentation is not fully automated even after more than a decade’s development. As for optimization, this is unfortunately the least automated of all, demanding further technological development to eliminate human-caused variability.12 Examples of full automation in radiotherapy are actually very few. One example is beam aperture definition, now automated by programmed multileaf collimators. Arguably the elimination of human block cutters did occur on a decade’s timescale, but mere citation of this does not inform predictions for other technologies.

In closing, I am not at all pessimistic about the future of automation in treatment planning; deployed in tandem with the clinical expertise of highly trained human beings, automation will improve patient care and make radiotherapy more efficient. We should, however, work toward this future with eyes open about the significant effort that remains to achieve fully automated treatment planning.

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