Dear Dr. Dahele et al.

Your letter and your translational research work support the question posed in the review:[1] Are we at the tipping point for the era of real-time radiation therapy? Your research adds additional clinical evidence that real-time 3D IGRT can be performed on standard-equipped cancer radiation therapy systems. Indeed, had it been published or known to us before we wrote the review your clinical translation of the markerless spine tracking [2] would have been included as a fourth real-time 3D IGRT implementation on standard-equipped systems. Your additional retrospective work, based on clinical data, paves the way for further translation for markerless lung [3] and bronchus [4] tracking applications.

We also agree that the hardware for cancer radiotherapy can be substantially improved. X-ray imagers, originally added to the linac gantry to facilitate pre-treatment imaging are being repurposed for real-time image guidance applications that were not part of the original design specifications. Certainly, decoupling the x-ray imager from the treatment gantry with technologies such as couch-mounted or robotic CBCT systems will improve x-ray-based image guidance. Similarly, multileaf collimator hardware originally developed for replacing fixed blocks, is being routinely used for IMRT/VMAT and more recently for real-time tracking applications. It is pleasing to see a vendor investigating changing hardware and software to add real-time adaptive radiotherapy capabilities to a traditionally non-real-time radiotherapy system. [5] Limitations of existing radiotherapy systems have triggered the development and clinical adoption of MRI-guided radiotherapy systems.

However exciting newer and yet-to-be-developed technology is, there are still over ten thousand standard-equipped cancer radiotherapy systems in the world, and they will be a mainstay of cancer treatment for the medium term. Therefore, the question of how we can turn these ‘standard’ systems into real-time 3D IGRT systems is significant. Even with existing standard-equipped systems there is much that can be achieved through software development alone. These low-cost improvements may also more easily and more rapidly benefit low and middle income countries where standard-equipped linacs are already a scarce resource [6] and newer technologies will remain unavailable for the foreseeable future.

Advanced software developments yet to be clinically applied to standard cancer radiotherapy systems include real-time volumetric visualization of the anatomy as it evolves during treatment, e.g. Li et al., [7] real-time online dose reconstruction [8] and the ability to evaluate the motion-induced dose errors in real-time [9]. Combining these tasks with fast planning will facilitate volumetric real-time adaptation of the radiation beam to the dynamic patient and tumor anatomy.

The prospect of the integration of technologies to monitor the target and adjust the radiation beam in real-time to maximally hit the tumor and avoid healthy tissue of our dynamic patients, and the commensurate improvements in patient outcomes, is indeed very exciting.

Sincerely

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References


