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Focus where it matters, optimizing 4D and 5D imaging tools for extracranial radiosurgery

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Introduction: Extracranial radiosurgery involves shooting surgical doses of radiation for the management of moving targets cancer/oligomets and is characterized by accurate target delineation, robust motion management and fast dose delivery (3-8 fractions).

Method: Basic 3D medical imaging acquisition and reconstruction principles are based on the assumption that the object being imaged is static over the course of the acquisition. Patient motion and organ distortion, whether the result of voluntary patient movement or natural functions such as respiration, can impact target design due to artifacts and thus delivered doses will be less accurate and precise. Instead, a common strategy employed was to expand the target volume by a safety margin to accommodate the estimated motion of the target volume and then to irradiate larger fields under the expectation that this would compensate for the unknown motion which would lead to higher toxicity when we are treating stereotactic targets (measuring less than 5 cms).

Results: In the past two decades, imaging, planning and delivery technologies have progressed to the point that it is now possible to deal with a 4D model of the patient (consisting of three spatial dimensions plus time as the fourth dimension) which is simply called 4D radiotherapy. The introduction of 4DCT into radiation therapy was quickly followed by 4D MRI, 4D cone beam CT and 4D PET. All these tools have enabled us to capture the motion information accurately and can be utilized in the delivery of the treatment.

Conclusion: 5D imaging, are dynamic 3D images (4D) that are acquired at multiple time points and patterns of deformations are analyzed. The correlations in 5th dimension using deformable image registration softwares (e.g. the pattern of deformation for dynamic CT imaging) can be extracted for recognition, tracking and diagnosis of the complications of radiosurgery. Techniques to optimize 4D imaging and 5D imaging and incorporating into the workflow for radiosurgery will be the key into the future of safe radiosurgery practice.

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