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The Use of Cone Beam Computed Tomography in Image-Guided Radiotherapy

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Editorial

In the past few decades, three-dimensional (3D) virtual simulation with computed tomography enabled more focused radiotherapy delivery such as intensity-modulated radiotherapy (IMRT), which delivers high dose to the target while simultaneously sparing nearby critical tissues. More recently, image guidance at the treatment sessions further promoted these advances in ensuring accurate localization of the target and reducing required setup margins. Cone beam computed tomography (CBCT), especially, has played an increasingly important role in contemporary image-guide radiotherapy (IGRT). With either megavoltage (MV) or kilovoltage (kV) x-rays, CBCT is so named because it utilizes a two-dimensionally collimated rectangular or cone-shaped beam and a flat-panel detector (FPD). It provides soft-tissue detectability for more precise target localization, and generates 3D images capable of treatment adaptation. New advances in CBCT technology correlate the images with respiration, enable image acquisition during the treatment, further improve the image quality, and reduce the imaging dose. Therefore, this important imaging modality has gained enormous popularity and is quickly replacing 2D based IGRT.

The two main categories of CBCT used in IGRT are MV CBCT, which uses the treatment beam and an opposing FPD, and kV CBCT, which uses a kV source and an FPD mounted perpendicular to the treatment beam on the gantry [1,2]. Although with sub-optimal beam energy for imaging, MV CBCT requires fewer hardware components and has advantages in imaging patients with metal prosthesis. On the other hand, kV CBCT enjoys distinctly better image-quality and better dose tradeoff, therefore finds wider applications in IGRT.

Currently, the most prevalent clinical application is for patient setup. CBCT in-room imaging allows accurate inter- and intra-fraction target localization. Studies have demonstrated the feasibility of using CBCT-based patient setup to replace fiducial markers [3], immobilization frames [4], and reduce the setup margins for many anatomical sites including lung, prostate, head-and-neck, etc. [5-7]. A great example is body stereotactic radiotherapy of the lung: CBCT image guidance has substantially improved inter- and intra-fraction target positioning and reduced required treatment margins.

Another advanced utilization of CBCT is for treatment adaptation. During the treatment course, patient may have inter-fractional and intra-fractional anatomy changes, such as tumor shrinkage and patient weight-loss often seen in head-and-neck cancer, target deformation prominent in prostate and uterine cancers, and respiratory-correlated target motion present in lung, liver, and pancreas cancers. There has been a paradigm change from the single plan treatment that is based only on the static planning CT, to adaptive radiotherapy that incorporates the above variables and adapts the treatment accordingly. Treatment fraction CBCT provides the most convenient and "real-time" 3D images for plan adaptation, resulting in the delivered treatments that are truly optimized throughout the treatment course [8-11]. Furthermore, new CBCT acquisition techniques have been devised to incorporate the breathing motion, such as respiratory-correlated or 4D, gated, and breath-hold acquisitions [12,13]. These advanced images are used for analyzing inter- and intra-fractional motion for thoracic tumors, and for delivering gated, or 4D-adaptive treatments [14].

Thus far, CBCT has mostly been acquired prior to the treatment for IGRT. With increasing utilization of the volumetric modulated arc therapy (VMAT), simultaneous CBCT acquisition during the VMAT delivery has also been investigated [15].

Despite its vast applications and important potentials in IGRT, CBCT is also criticized for the sub-optimal image quality and for the ionization radiation dose. Going hand-in-hand with the intense research efforts to further expand the CBCT applications in IGRT, research on perfecting the technology and reducing/optimizing the imaging dose [16], is therefore important in making the best of this prominent technology.

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