From 2D to 4D Radiotherapy - When Bony Landmarks are Replaced by Biological Tumour Information for Adaptive Treatment

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In the era of 2-dimentional radiotherapy, bony structures on x-ray imaging were commonly used as landmarks for tumours (e.g., prostate, rectum) and lymph nodes. Thus, the resulting irradiation fields were large, limited the radiation dose that could safely be applied, and sometimes caused severe toxicity. During the last decade, tremendous progress has been made with respect to the radiation planning and delivery techniques, due to advances in software (e.g., computational speed, memory) and hardware (e.g., multi-leaf collimator, cone-beam CT). Intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) nowadays enable the delivery of high doses to the tumour while sparing the surrounding radiation-sensitive healthy tissues. In order to accomplish this, (daily) position verification is compulsory and can be facilitated by cone-beam CT imaging. Furthermore, cone-beam CTs may be used for in vivo dosimetry comparing the planned dose to the actually delivered dose to the patient [van Elmpt]. Finally, linear accelerators may be equipped with technology enabling respiratory gating, thus resulting in 4D radiotherapy delivery, e.g. for stereotactic radiotherapy of small primary lung tumours.

Radiotherapy treatment planning heavily relies on CT imaging that bears information on electron density. However, biological tumour information not present in standard CT imaging may augment personalised medicine – i.e., increasing radiation dose to hypoxic subvolumes [Bentzen] or altering the treatment strategy in non-responding patients. PET is an excellent means to non-invasively depict tumour characteristics prior to and during treatment [Ling, Troost]. The most widely available PET-tracer, FDG, has been intensively investigated in numerous solid tumours and is routine clinical practice in some of these. Tracers that more specifically depict the tumour microenvironment (e.g., hypoxia, proliferation) are slowly leaving the research arena and entering phase II/III clinical trials. However, their benefit regarding decreased toxicity (e.g., by progressively reducing the volume receiving a high-dose based on biological information), and increased locoregional control and disease-specific survival (e.g., by increasing the radiation dose) needs to be awaited.

References

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