Canadian Association of Physicists Association canadienne des physiciens et physiciennes

Contribution ID: **1553** Type: **Invited Speaker / Conférencier invité**

3D ultrasound and magnetic resonance imaging for prostate tumour-targeted high-dose-rate brachytherapy

Wednesday 31 May 2017 15:30 (30 minutes)

Purpose: High-dose-rate brachytherapy (HDR-BT) is a radiation therapy technique for prostate cancer involving the temporary placement of a radioactive source within the gland to deliver a prescribed dose. The radiation source is delivered through hollow needles, which are positioned using ultrasound images. Conventional ultrasound images have limited spatial resolution and cannot distinguish between cancerous and normal prostate tissue, so the entire prostate is prescribed a uniform dose regardless of cancer location. Our group has been working to implement an HDR-BT technique combining 3D ultrasound and dynamic contrast enhanced magnetic resonance imaging (DCE-MRI) to deliver a higher dose to the tumour and lower dose to normal prostate tissue.
Methods: We will report the results from two studies validating the 3D ultrasound and DCE-MRI techniques for tumour-targeted HDR-BT. 10 patients underwent HDR-BT using a custom robotic device to acquire both conventional and 3D ultrasound images, enabling the comparison of needle localization accuracy between techniques. Two cohorts of patients underwent DCE-MRI using either a "fast, low spatial-resolution"pulse sequence (n=16) or a "slow, high spatial-resolution"pulse sequence (n=18). The patients'prostates were then removed for histological analysis, enabling comparison of imaging data with cancer location indicated by histology.
Results: The 3D ultrasound imaging technique demonstrated a significant improvement in needle segmentation accuracy, providing 84% of needle tips within 3 mm error versus 57% using conventional ultrasound. Preliminary results suggest that the increasing DCE-MRI acquisition time to achieve higher spatial resolution leads to systematic biases in measured tissue permeability, but these biases may be mitigated by normalizing values in the prostate to those of nearby muscle.
Conclusions: Robotically-assisted 3D ultrasound imaging significantly improves HDR-BT needle tip localization accuracy relative to the clinical standard. High spatial-resolution DCE-MRI shows promise in providing tissue permeability measurements for tumour localization. We will present these results in the context of tumour-targeted HDR-BT, as well as the comparison of DCE-MRI with co-registered histology.

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Session Classification: W4-4 Combined Nanotech / COMP: Imaging and Radiation Therapy (DPMB) | Nanotech / OCPM conjoints: imagerie et thérapie par rayonnement (DPMB)

Track Classification: Physics in Medicine and Biology / Physique en médecine et en biologie (DPMB-DPMB)