TEACHING LECTURE:

SP-0001
Imaging in prostate cancer: State of art
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Image Guided RadioTherapy (IGRT) is currently considered the golden standard in radiotherapy. Especially IGRT is required for prostate cancer, as the prostate is a small organ, which can show large movements and where the actual tumor inside the prostate is difficult to detect. Imaging in prostate cancer IGRT can be divided into (1) imaging before treatment for patient selection and treatment planning, (2) imaging during treatment to compensate for movement and (3) imaging after treatment to evaluate treatment success or to detect a local recurrence.

1. Imaging before treatment consists of a CT-scan and an MRI scan for delineation and planning purposes. MRI has optimal soft-tissue contrast and adds to the CT delineation, especially as it is able to show the location of the tumor inside the prostate. MRI usually consists of both anatomical sequences (T1-, T2-weighted) and functional imaging, like perfusion (DCE-MRI), water diffusion (DWI), metabolites (MRS), and several other possibilities (Figure 1). As the information on the location of the tumor in most sequences does not overlap, decisions are required to delineate the tumor. Predictive models are currently developed to help this decision. For detection and possible treatment of regional metastases and / or bone metastases MRI and Choline-PET are currently investigated.

2. Imaging during treatment is meant to compensate for movement. Visualization of gold fiducial markers can be used for this purpose, but also Cone-beam CT is commonly used. An MRI-linac is under development. In brachytherapy, ultrasound is generally used for intra-fraction decisions. Currently, brachytherapy (HDR and LDR) applications is being developed in the MRI.

3. Post-radiotherapy a Choline PET is used to detect local recurrences. MRI has optimal soft-tissue contrast and adds to the CT delineation, especially as it is able to show the location of the tumor inside the prostate. MRI usually consists of both anatomical sequences (T1-, T2-weighted) and functional imaging, like perfusion (DCE-MRI), water diffusion (DWI), metabolites (MRS), and several other possibilities (Figure 1). As the information on the location of the tumor in most sequences does not overlap, decisions are required to delineate the tumor. Predictive models are currently developed to help this decision. For detection and possible treatment of regional metastases and / or bone metastases MRI and Choline-PET are currently investigated.

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IGRT for prostate cancer two issues are currently explored: focal therapy and extreme hypofractionation. These two issues have very high demands with regard to imaging, like spatial accuracy, detection accuracy, movements, deformation, a.o.

SP-0002
The physics of ablative alternatives to (SB)RT
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Several alternative ablative technologies, based on local temperature elevation, are used in medicine. They can be based on electromagnetic waves in the microwave, optical, radio-frequency spectrum, or mechanical waves. If high spatial precision is required, High Intensity Focused Ultrasound (HIFU) is the only technology capable of achieving a high temperature increase deep inside the human body in a non-invasive way. This presentation will deal mostly with HIFU technology. MRI guidance of the procedure allows in situ target definition and identification of nearby healthy tissue to be spared. In addition, MRI can be used to provide continuous temperature mapping during HIFU for spatial and temporal control of the heating procedure and prediction of the final lesion based on the received thermal dose. The primary purpose of the development of MR guided HIFU was to achieve safe non-invasive tissue ablation. The technique has been tested extensively in preclinical studies, and is now accepted in the clinic for ablation of uterine fibroids, and for palliative treatment of painful bone metastases. MR guided HIFU for ablation shows conceptual similarities with radiation therapy. However, thermal damage generally shows threshold like behavior with necrosis above the critical thermal dose, and full recovery below. MR guided HIFU is being clinically evaluated in the cancer field for prostate, breast, liver, kidney and brain. The technology also shows great promise for a variety of advanced therapeutic methods such as gene and / or drug delivery.

MR guided HIFU of mobile organs as kidney and liver is particularly challenging. Three central issues are addressed here together with preclinical validation:

1) Rapid temperature mapping. Ideally, MR-Thermometry should achieve a sub-second temporal resolution, with minimal processing latencies. MR-Thermometry method was evaluated for liver and kidney of volunteers, and showed a precision of ~2 °C in >70% of the pixels while delivering temperature and thermal dose maps on the fly.

2) Intercostal HIFU firing to avoid excessive heating around the ribs. The ribs can be visualized on anatomical images acquired prior to heating and manually segmented. The resulting regions of interest are then projected on the transducer surface by ray tracing from the focal point. The transducer elements in the rib “shadow” are then deactivated.

3) Real Time MRI tracking of mobile targets for guidance of HIFU with sub-second 3D HIFU beam steering. The target position can be visualized in 3D space by coupling rapid 2D MR imaging with prospective slice tracking based on pencil beam navigators.

In summary, MR guided HIFU is a promising alternative or complementary technology for ablation of tumors in many organs. It appears also feasible in liver and kidney but requires integration of technologically advanced methods.

SP-0003
Techniques and pitfalls in image registration for radiotherapy
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Image registration - the fusion of volume image data sets acquired with different modalities or at different points in time - has become a vital tool for radiotherapy planning in cases where hybrid imaging techniques are not available or not feasible. Applications range from comparison of target volumes over time to multimodal image fusion, compensation of inter- and intrafractional target volume motion, adaptation of dose plans and precise patient setup in image-guided radiotherapy. The topic of this lecture is to introduce the basic methods of image registration and to highlight the possibilities and limitations with a special view on the requirements of radiotherapy. An overview of clinical applications and research perspectives will be given.