Advanced approaches for MR guided HIFU and MR guided Radiotherapy in the abdomen

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External beam therapies

- **External Beam Radiotherapy (EBRT)**
- **High Intensity Focused Ultrasound (HIFU)**

MRI guidance of external beam therapies

- Target and OAR definition (HIFU and RT)
- Motion correction intra- and interprocedure (HIFU and RT)
- Temperature mapping during the procedure (HIFU)
- Evaluation of therapeutic efficacy (HIFU and RT)
Thermal ablation on abdominal organs: Work-flow and motion

1-5 min
Infrequent Spontaneous motion

1-3 hours
Preparation (anatomical imaging)
Therapy guidance during energy delivery
Therapy guidance between energy delivery
Validation of the therapeutic endpoint

For HIFU typically:
• Perfusion imaging for NPV validation
• T2-weighted imaging for edema detection

For HIFU typically:
• Positioning
• T1/T2-weighted planning images

For HIFU typically:
• Real-time motion compensation (gating or tracking)
• Real-time thermometry
• Measurement of slow motion for dose realignment
• Observation of near field cool-down

For HIFU typically:
• PRF-Thermometry
• Motion tracking (beam steering, gating)
• T2-Thermometry

Physiological motion

Peristaltic motion

Cervix
Prostate
Pancreas
Liver
Kidney

Physiological motion: Peristalsis

Prostate

From Ghilain et al., 2005
Physiological motion

Motion as seen by MRI 8 scans in 35 minutes

Prostate

Peristaltic motion

Table 1: Prostate parameters and imaging results for prostate with normal motion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Oral</th>
<th>Left</th>
<th>Right</th>
<th>Atrial</th>
<th>Normal</th>
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<tr>
<td>Signal strength</td>
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<td>Signal intensity</td>
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<td>Signal quality</td>
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</table>

From Chan et al., 2008
Int J Radiat Oncol Biol Phys

Thermal ablation on abdominal organs: Work-flow and motion

Preparation (anatomical imaging)
Therapy guidance during energy delivery
Therapy guidance between energy delivery
Validation of the therapeutic endpoint

1-5 min

Respiratory motion

1-3 hours

Peristaltic motion
« Slow » 3D Motion correction for abdominal HIFU

- 3D anchor images are periodically obtained and compared to a reference.

- Preparation (anatomical imaging)
- Therapy guidance during energy delivery
- Therapy guidance between energy delivery
- Validation of the therapeutic endpoint

1-3 hours
A study on 10 healthy volunteers – validation of the tracking method + proof that the targeted organs move due to slow physiological drifts beyond the acceptable therapeutic margins

An in vivo experiment on a porcine liver – validation of the proposed method during a real HIFU therapy
Propagate the initial treatment plan down the flow of the motion

In vivo porcine experiment on the liver for validation

### Slow 3D Motion correction for abdominal HIFU

- Project and accumulate the currently delivered thermal dose on the initial treatment plan upstream the flow of the motion.

#### In vivo porcine experiment on the liver for validation

#### Fast 2D motion correction

- 1-3 hours
- Preparation (anatomical imaging)
- Therapy guidance during energy delivery
- Therapy guidance between energy delivery
- Validation of the therapeutic endpoint

**Fast 2D motion correction**

- Real-time co-registration
Fast 2D motion correction

- MRI allows detailed intra- and inter-procedure motion tracking of the order of 1 mm
- A framework has been developed for 3D correction of (slow) peristaltic motion and 2D correction for respiratory motion
- Funding was provided by the project OnTrack (STW, the Netherlands, in collaboration with Philips Healthcare)

Concluding remarks

- MRI allows detailed intra- and inter-procedure motion tracking of the order of 1 mm
- A framework has been developed for 3D correction of (slow) peristaltic motion and 2D correction for respiratory motion
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