Central concept is **uncertainty**

Tumour control probability

- Large GTV needs higher dose compared to small GTV
- GTV needs higher dose compared to CTV

- Infiltrations - 50 Gy
- GTV - 65 Gy
- Large GTV - 80 Gy
### Present indications Radiotherapy

<table>
<thead>
<tr>
<th></th>
<th>distant</th>
<th>CTV</th>
<th>GTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemo</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>RT</td>
<td>-</td>
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</tr>
<tr>
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<td>--</td>
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Based on: TCP models clinical experience

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### Development MRI guided RT

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Introduction on line MRI soft tissue guidance
Development MRI guided RT

Introduction on line MRI soft tissue guidance

- Better local control
- Less surgery

Improve local control by tailored dose escalation

Present step: SIB for GTV. GTV gets its own PTV

Next step: Boosting GTV while keeping the CTV uniform dose
**Improve local control by tailored dose escalation**

Last step: tailoring the full dose distribution

Uncertainty kills dose painting

---

**Vision**

- To bring such a certainty in the treatment process that tailoring the dose distribution becomes possible
- By such improving local cancer therapy
- Making local therapy non-invasive
- Better control with less toxicity

---

**Seeing helps: hit the sailing boat**
Success stories RT thanks to better imaging and a tailored dose distribution

Sites
• Brachytherapy cervix (MRI)
• Prostate (fiducial gold markers)
• Lung peripheral (conebeam CT contrast)

Results
• Higher GTV dose
• Good local control
• Hypo fractionation
• Lower toxicity
• Lower integral dose

 Failures RT
• Esophagus
• Pancreas
• Kidney
• Liver
• Rectal
• Colon
• Stomach

 Troubles RT
• Bladder
• Breast
• Larynx
• Lymph nodes

 What is needed
• High quality imaging at the moment of treatment
• Certainty
Lung, irregular breathing (sBFFE)

Cervix

Intra fraction motion in the pelvis
2D monitoring (2Hz)
Visualisation oesophagus tumour

CT
No triggering + free breathing
Triggering + breath hold

Courtesy Astrid van Lier

T2w MRI tumour oesophagus

T2w MRI tumour oesophagus
Validation of larynx MR

Small field targeting larynx

Small field targeting larynx
**MRI offers great soft-tissue contrast**

Rectum

The rectum, anatomy on MRI, from inside to outside:

- Lumen
- Three rectal wall layers:
  - Mucosal layer
  - Submucosal Layer
  - Muscle layer
- Mesorectal fat
- Mesorectal fascie

**Breathing related motion**

irregular breathing von Hippel Lindau kidney tumour

New 3D T2-FFE sequence with unique visualization lymph nodes breast cancer patients

- 3D T2-FFE with some intrinsic diffusion weighting, fat suppression and black blood imaging
- Resolution 0.7x0.7x1 mm
- Geometrically correct, targeting 1.5 T MRL

3D T2FFE image quality

Next step is finding lymph vessels to define which nodes are related to arm only

Stereotactic boost individual lymph nodes

Courtesy Tristan van Heist
Lymph nodes visualization H&N

Lymph nodes T2-FFE MRI Head and Neck

Stereotactic boost mediastinal lymph nodes

Courtesy: Marielle Philippens

Courtesy: Astrid van Lier
Stereotactic boost mediastinal lymph nodes

Lymph node can be treated without a significant dose to the esophagus

Courtesy Astrid van Lier

Development of the ultimate MRI targeting system

Diagnostic quality MRI
Stereotactic targeting accuracy 0.5-1 mm
On line/intrafraction/breathing
Tracking organs movements/shape changes
Therapy plan update continuously
Treatment response assessment

High dose rate
Good IMRT properties (penumbra, scatter, transmission)
Fast MLC

UMCU solution: Integrating a Philips MRI scanner with a Elekta radiotherapy accelerator

1.5T 70 cm bore Philips Ingenia
Bringing the MRI linac concept to clinic

Simulation process

- Visualization
- Characterization
- Mobility
- Preparation on-line treatment planning process
Simulation process

- Characterization mobility

Liver, irregular breathing

Pancreas: undersampled radial balanced SSFP

Thanks: Baudouin Denis de Senneville, UMCU HIFU Group
Motion management in a patient

- No 1D motion, but more complex
- Requires (ideally) 4D imaging
- Alternative:
  - multiple 2D slices and 1D pencil-beam navigators to capture main modes of motion
  - Acquisition strategies, under-sampling eg in combination with radial read-out

Radial under-sampling

MRL treatment planning (MRLTP):

Conventional treatment planning procedures are sequential

Treatment planning process takes typically between two and four hours
MRL treatment planning (MRLTP):

Characterization anatomy and mobility

MRL treatment planning procedures are feed back loops (there is no table control)

Has to become a real time process

MRL treatment planning (MRLTP):

MRL treatment planning (MRLTP):

Fast IMRT planning system

- System requires on-line treatment planning
- No table related positioning

MRLTP:
- Beamlets: GPUMCD
- ITP: FIDO (From Goldman et al. 2009)
- DA sequencing (Cao et al., 2006)

Kidney IMRT plan in 15 sec.
(1 GTX480 per beam)

Bel et al., PMB, 2012, 57, 1375-85
VCS of phantom and cervix case

48 translations in x,y,z direction: 1,2,3,5,8,13,21,34 mm
42 rotations around x,y,z axis: 1,2,3,5,8,13,21 degrees

Bol et al., PMB, 2013, 58, 2989-3000

Radiotherapy UMC Utrecht goes MRI

- Tumour characterization
- MRI simulation: delineation
- MRI guidance
  - MRI treatment guidance external beam
  - MRI guided brachytherapy
  - MRI guided HIFU
  - MRI guided protons
  - MRI guided radioembolization
- MRI treatment response assessment
7 MRI systems for therapy

- 3x MRI
- 1x 1.5 T and 1x 3.0 T simulator
- 1x 1.5T HIFU
- 1x 1.5T brachytherapy

Team MRL

Acknowledgement