Adaptive planning in the context of adaptive radiotherapy

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Knowledge Based Oncology

Individualizing

Modelling

Adaptive
Tailoring a RT treatment on each patient based on **prognostic/predictive** features
to develop **multimodality predictive factors** in order to define, “in antis”, the disease progress and the following modality of treatment
to adapt the treatment **during the treatment itself** modifying the treatment based on the **actual accumulated dose** and on the **tumor response** and OaR modifications.
ADAPTIVE PLANNING

- Replanning procedures

- Plan library procedures

- Dose Painting procedures
Replanning procedures based on the systematic correction of the dose distribution following the patient shrinkage and the target and OaR volume variations.

- Replanning based on a new CT
- Replanning based on CBCT
- Replanning based on *in-vivo* dosimetry
Adaptive planning

REPLANNING ON A NEW CT

Planning CT

New CT
REPLANNING ON A NEW CT

Planning CT

New CT
REPLANNING ON A NEW CT

Adaptive planning

Replanning after a determinate dose (30/35Gy)

Dose distribution on planning TC  Dose distribution on new TC
These gland volume reductions correlated significantly with the mean dose to the irradiated glands; the spared glands showed few changes. Volume loss at higher doses (>30 Gy) to the glands was significantly larger than at low doses (<30 Gy; P < .001).

Radiation-induced volume changes in parotid and submandibular glands in patients with head and neck cancer receiving postoperative radiotherapy: a longitudinal study
Wang ZN, Yang C, Zhang ZY, et al
Laryngoscope 2009
REPLANNING ON A NEW CT

Relanning on H&N: when??

174 pts assessed by MVCT and KVCT

IPV – Age clinical predictors

$D_{\text{mean}}$ – $V_{40}$ dosimetric predictors

$\Delta v \text{ (cc)} = -2.44 + 0.076 \ D_{\text{mean}} + 0.279 \ IVP \text{ (cc)}$

$\Delta v \text{ (%) = } 34.24 + 0.192 \ V_{40}(\%) - 0.2203 \ \text{age (year)}$

A two-variable linear model of parotid shrinkage during IMRT for head and neck cancer.
Broggi S, Fiorino C, Dell’Oca I, Dinapoli N, et al.
Radiotherapy and Oncology; 2010
REPLANNING ON A NEW CT

The role of the AUTOCONTOURING systems

• MODEL BASED APPROACH
• ATLAS BASED APPROACH
• HYBRID APPROACH
REPLANNING ON A NEW CT

The role of the AUTOCONTOURING systems

- MODEL BASED APPROACH
- ATLAS BASED APPROACH
- HYBRID APPROACH
REPLANNING ON A NEW CT

AUTOCONTOURING WORKFLOW

1. Autocontouring
   - Delineation
   - Propagation of the selected volumes

2. Deformable registration

3. Independent check

4. Model based

5. Final delineation

Adaptive planning

Atlas based guidelines
Workflow efficiency: TIME FACTOR
Manual delineation VS Autocontouring
Head & Neck

Clinical validation of atlas-based auto-segmentation of multiple target volumes and normal tissue (swallowing/mastication) structures in the head and neck.
Teguh DN, Levendaq PC, Voet PW, et al.
Int J Radiation Oncol Biol Phys. 2011
"...Although editing of the autocontours is inevitable, a substantial time reduction was achieved using editing, instead of manual contouring 180 vs 66 min"

Automatic delineation for replanning in nasopharynx radiotherapy: What is the agreement among experts to be considered as benchmark?
Mattiucci GC, Boldrini L, Pasini D, et al.
Acta Oncologica, 2013; 52: 1417–1422
".....mean saved time in Structure Set B of 35 min"
REPLANNING ON CBCT

Use the modern potentiality offered by the IGRT technology
REPLANNING ON CBCT

Adaptive planning

Our experience
REPLANNING ON CBCT
REPLANNING ON CBCT

Adaptive planning
Replanning based on *in-vivo* dosimetry

Replanning methods based on the dose delivery variations detected with the in-vivo dosimetry performed by EPID.
Replanning based on *in-vivo* dosimetry

Principles on which is based in vivo dosimetry by EPID

Generally the methods is based on the use of a back-projection algorithm to reconstruct a dose plan inside the patient.
Replanning based on *in-vivo* dosimetry

2008

"patient errors are specially related to errors due to *changes* in the patient’s positioning or *anatomy* from the situation at planning"

A literature review of electronic portal imaging for radiotherapy dosimetry
Wouter van Elmpt, Leah McDermott, Sebastiaan Nijsten, Markus Wendling, Philippe Lambin, Ben Mijnheer.
Replanning based on *in-vivo* dosimetry

<table>
<thead>
<tr>
<th>Potential errors</th>
<th>Pre-treatment verification</th>
<th>Treatment verification</th>
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<tbody>
<tr>
<td></td>
<td>2D/3D</td>
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<tr>
<td></td>
<td>No phantom</td>
<td>Behind phantom</td>
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<tr>
<td>Gantry angle</td>
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<td>Possible</td>
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<td>Table arm obstruction</td>
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<td>Anatomical changes in patient since planning CT</td>
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<td>Anatomical movements during treatment</td>
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<td>Wrong patient during treatment</td>
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<td>Under/over-dose to volumes of interest</td>
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<tr>
<td>Dose distribution in patient during treatment</td>
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</tr>
</tbody>
</table>
Replanning based on *in-vivo* dosimetry

2009

Integration between in vivo dosimetry and image guided radiotherapy for lung tumors
Angelo Piermattei, Savino Cilla, Luca Grimaldi, Domenico Sabatino, Andrea Fidanzio, et al.
Replanning based on *in-vivo* dosimetry

"In this work, a patient that showed for all beams $D_{iso}$ values outside the tolerance level, **new CT scan were commissioned for an adaptive plan.**

……..the DGRT can be well integrated with the IGRT"
Plan library elaboration for choosing the “plan of the day” that takes in to account the different filling variations of the PTV surrounding structures, as bladder and rectum in the pelvis, for instance, or different extent of motion.

- Different margins
- Different position
PLAN LIBRARY

Different position

A library with plans that consider different daily PTV and organs position
Adaptive plan selection vs. re-optimization in radiotherapy for bladder cancer: a dpse accumulation comparison
A Vestergaard, LP Muren, J Søndergaard et al.
Aarhus University Hospital  Radiother. and Oncol  . 2013
Dose Painting is a biologically adaptive radiation therapy approach, that consists in an increase of dose in one or more sub-volumes identified by functional imaging.
DOSE PAINTING

18F-choline PET, IMRT dose distribution and dose prescription in accordance with the TCP model.

Fig. 5. a) 18F-choline PET activity signal in a transversal slice, which is mapped to the radiobiological parameters $\gamma$ and $\rho$. b) Voxelwise dose prescription according to the TCP model in the same slice. c) Resulting dose distribution after optimization with DMCO. The red line denotes the PTV.

Feasibility of TCP-based dose painting by numbers applied to a prostate case with (18)F-choline PET imaging.
Thomas Dirscherl, Mark Rickhey, Ludwig Bogner
DOSE PAINTING

Use of images of planned PET-CT to detect the variation of the tumor metabolism to proceed to a dose painting plan.

Three-phase adaptive dose-painting-by-numbers for head-and-neck cancer: initial results of the phase I clinical trial
Dieter Berwoutsemail, Luiza A.M. Olteanu, Indira Madani, et al.
Radiotherapy & Oncology
Volume 107, Issue 3, Pages 310-316, June 2013
“Diffusion-weighted MRI reflects the cell density of tissue and thus may indicate regions with a higher tumor load”
Recommended ESTRO Core Curriculum for RTTs - 3° edition

“the RTT perspective”

REPLANNING ON A NEW CT
REPLANNING ON CBCT
In-vivo DOSIMETRY
PLAN LIBRARY
DOSE PAINTING

M.A. Coffey, L. Mullaney, A. Bojen, A.Vaandering, G. Vandevelde. Radiother Oncol. 2012 Apr;
CONCLUSIONS

- Adaptive planning is a fundamental "tool" to perform adaptive RT
- There is an increasing number of methodologies and so complexity
- Changing of workflow and considerable increase of workload
- The perspective of an RTT with current skills is to be involved in these procedures and must be able to manage this development within the multi-professional team
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Thank you for your attention