A step towards true delivered dose with dose accumulation in radiotherapy

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Background

- Fractionation regimens are defined in the planning phase of radiotherapy (RT) to maximize tumor destruction and minimize damage to surrounding tissues. However, the **planned dose is not accurate in representing the delivered dose due to inter-fractional anatomical changes** that occur during treatment, such as tumor regression.
- **Dose accumulation can more accurately represent the delivered dose. It consists of doses recomputed on longitudinal images during treatment based on the delivered fractions**.
- These recalculated doses are then mapped to a reference image before being summed. The dose mapping process depends on deformable image registration (DIR), which establishes a voxel-voxel correspondence between two images. However, **the precision of DIR can be affected by tumor response, thus confounding the ability to estimate the total dose delivered accurately.** Tumor response is mainly divided into **inelastic regression**: the tissue usually remains intact and does not move along with the tumor and **elastic regression**: the healthy tissue moves concentrically with the tumor.

Work impact

- **To our knowledge, this will be the first workflow in RT to define tumor regression. This will allow more accurate delivered dose estimation which can be linked to the toxicity information in follow-up images, ultimately improving treatment outcomes.**

Objective

- **To determine the fractionation scheme and identify tumor regressions of non-small cell lung cancer (NSCLC) patients** treated with standard-fractionated RT using weekly four-dimensional computed tomography (4DCT) images.

Methods

I. Fractionation scheme determination

4DCTs images of NSCLC patients were imported to RayStation, a treatment planning system.

4DCT	Date
Planning week	7/13/2012
Week 1	7/25/2012
Week 2	8/1/2012
Week 3	8/8/2012
Week4	8/15/2012
Week 5	8/22/2012
Week 6	8/29/2012

Table 1. Patient total 4DCTs with corresponding dates.

Accessed MOSAIQ to view the treatment dates.

Session	Date
1	7/23/12
2	7/24/12
3	7/25/12
4	7/26/12
5	7/27/12
6	7/30/12
7	7/31/12
8	8/1/12
9	8/2/12
10	8/3/12
11	8/6/12
12	8/7/12
13	8/8/12
14	8/9/12
15	8/10/12
16	8/13/12
17	8/14/12
18	8/15/12
19	8/16/12
20	8/17/12
21	8/20/12
22	8/21/12
23	8/22/12
24	8/23/12
25	8/24/12
26	8/27/12
27	8/28/12
28	8/29/12
29	8/30/12
30	8/31/12

Fig 1. Fractionation assigning.

MOSAIQ fraction dates examined and matched with 4DCTs dates.

4DCT	Date	Fraction
Planning week	7/13/2012	30
Week 1	7/25/2012	5
Week 2	8/1/2012	5
Week 3	8/8/2012	5
Week4	8/15/2012	5
Week 5	8/22/2012	5
Week 6	8/29/2012	5

Table 2. Completed fractionation scheme.

II. Tumor regression identification

Step 1

- Physician approved gross tumor volume (GTV) contours (purple) in the planning week.
- Using deep-learning based automatically segmented GTV contour (green) in the last week, the GTV volume change was quantified.

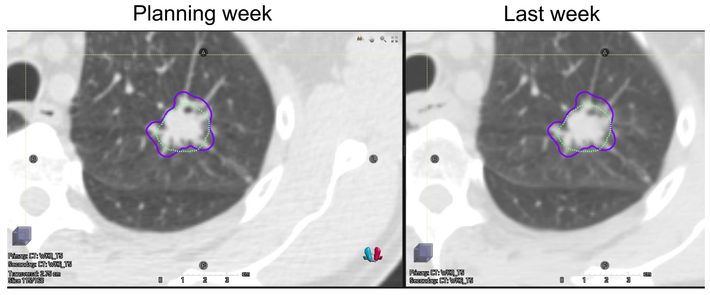

Fig 2. Tumor regression identification in planning week and last week 4DCTs of one NSCLC case.

Step 2

- Evaluation of the GTV percent change.

GTV percent change evaluation

Lower than -25%

Regression, go to step 3.

Step 3

- For each patient, four landmarks were placed at vessel bifurcations around the tumor to classify inelastic or elastic change. Inelastic cases were defined if the tumor regressed while the surrounding normal tissue remains intact, and elastic regressions were defined if the tumor regressed with the surrounding normal tissue moving concentrically with the tumor border.

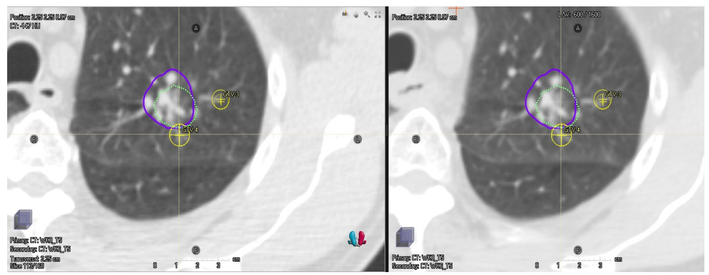

Fig 3. Planning and last week 4DCTs of one NSCLC case with landmarks around the tumor.

Results

I. Fractionation scheme determination

- 65 fractionation schemes defined to date.

II. Tumor regression identification

- 16 patients have been evaluated for tumor response to date.

GTV PW	GTV LW	Percent change	Type of regression
9.63	5.8	-39%	inelastic
11.09	5.04	-54%	inelastic
44.22	32.76	-25%	inelastic

Table 3. Sample summary of tumor regression identification. The rest of the data can be provided to the interested reader.

Conclusions

I. **This work will facilitate the determination of the accumulated dose at each week where 4DCTs were taken.**

II. **The tumor regression identification will reduce the inaccuracy of image registrations, improving accuracy of delivered dose estimation.**

Future directions

- Improve the robustness of the identification of the type of regression for difficult cases where tumor have non-uniform changes.

References

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