Dose restoration in lung cancer proton therapy : an online adaptive strategy to account for inter-fractional density changes

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INTRODUCTION

In proton therapy, inter-fractional density changes can severely compromise the effective delivery of the planned dose distribution. Such dose distortion effects can be accounted for by treatment plan adaptation, that requires considerable automation for widespread implementation in clinics.

Dose restoration[1] (DR) was proposed as an **intermediate and fast solution** instead of full adaptation.

AIM

DR aims to **stabilize the dose** in every fraction i.e **restore** the clinically approved IMPT **dose distribution on the treatment day image** (repeated-CT), containing new density information.

Our objective was to assess to what extent dose restoration could replace the need for a comprehensive offline adaptive strategy.

METHOD

Patient data

14 lung cancer patients with a planning-4DCT (pCT) and two repeated 4D-CTs (rCT1, rCT2)

Workflow

(1,2) **Preparation** at planning stage : optimization of the regular plan (1) and the isodose based optimized plan (IBO plan) (2)

(3) **Fully automatized re-optimization** on the treatment day

(4) **Robustness evaluation**

(1,2), (4) are offline and (3) is online

Evaluation metrics

- **Local dose differences** for prescribed, high, medium and low dose regions. Not adapted/Restored dose differences respect to the reference dose were calculated and absolute dose errors at maximum 2% of the volume were reported.
- **DVH metrics** for nominal (nom) and worst-case (wc) scenarios were extracted from the robustness evaluations

RESULTS

- Based on D95(nominal) CTV coverage criteria (D95%(CTV) > 95%PrescribedDose) in not adapted plans, **35% (5/14)** in rCT1 and **23% (3/13)** in rCT2 of patients **would have benefit from adaptation to ensure clinical acceptable target coverage**. After dose restoration, only one patient (7%) needed comprehensive offline adaptation.
- Dose restoration managed to mimic the initial planned dose in repreated-CTs. The **reduction of local dose differences in all regions after dose restoration** is clearly shown in Fig 1.
- **DVH-parameters were improved** after dose restoration for nominal and worst-case scenarios compared to not adaptation strategy (Fig 2).
- As shown in Fig. 3, cold and hot spots could be handled by dose restoration. Target coverage and robustness levels were recovered close to the initial values.

(1) Local dose differences

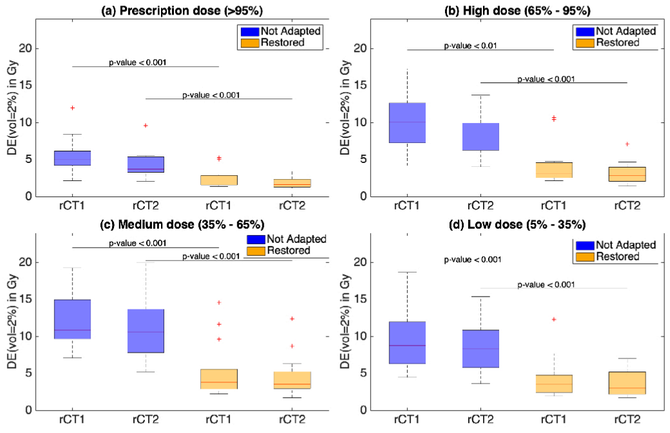

Fig 1. Dose differences respect to the initial planned dose for restored and not adapted dose distributions in four different dose regions. After restoration, Median(DEvol=2%) < 4 Gy in all regions.

(2) DVH metrics (nominal/worst case)

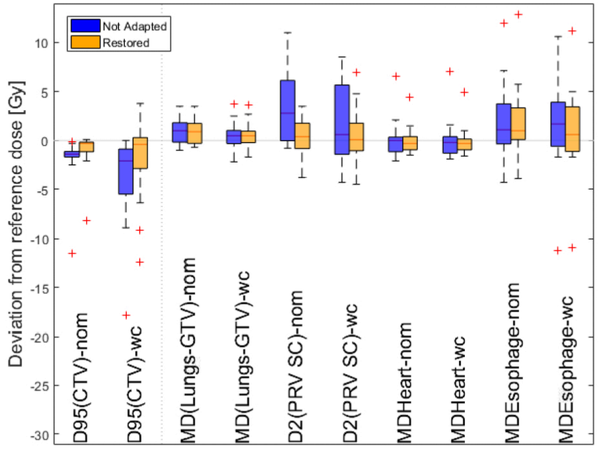

Fig 2. Differences in DVH-parameters for restored and not adapted plans respect to the planned dose. Target (CTV) and organs at risk metrics from rCT2 are shown. *Abbreviations: nom = nominal, wc = worst case, MD = mean dose, D2 = D2% dose received at 2% of the volume; PRV SC = Spinal Cord.*

(3) Patient case – Dose distributions and robustness evaluation

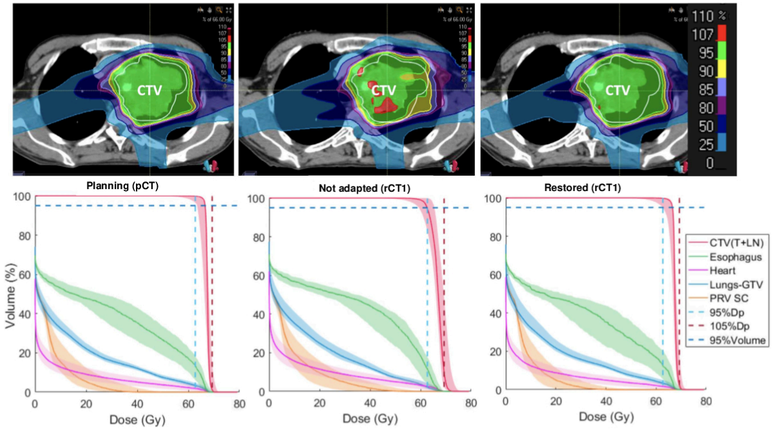

Fig 3. An example of a very visual case is represented here. All the scenarios used in the robustness evaluations are collected in the DVH-bands for the initially planned, not adapted and restored dose distributions. Dash lines correspond to the clinical limits 95% and 105% of the prescribed dose (Dp).

1. 4D-robust **PLANNING** in MidP-CT(pCT)
   Setup error = 5 mm, range error = 3%, breathing motion = 3 phases (63 optimization scenarios)
2. **IBOplan (Isodose Based Optimized plan)**
   - Create isodose volumes from the dose distribution generated in (1)
   - Find appropiate weights for min and max isodoses objectives in order to reproduce (1)
   - Save patient specific *IBOtemplate* (min and max objectives with their corresponding weights)
3. **Fully automatized dose restoration (DR)** — ONLINE
   - Rigid registration between planning CT and repeated-CT
   - "Copy-pate" contours and isodoses
   - Re-optimization using *IBOtemplate*
4. **Robustness Evaluation** using the same scenarios used in the optimization

CONCLUSIONS

- ✓ We have implemented a simplified online adaptive workflow based on fully automatic dose restoration.
- ✓ Dose restoration aims at compensating density changes by reproducing the planned dose distribution.
- ✓ In lung cancer cases treated with intensity modulated proton therapy, dose restoration mitigates the impact of inter-fractional density changes.
- ✓ The need of offline comprehensive adaptation is reduced by introducing dose restoration.
- ✓ Dose restoration improves target coverage and robustness respect to no adaptation strategy.

REFERENCES

[1]Bernatowicz K et al. Feasibility of online IMPT adaptation using fast, automatic and robust dose restoration. Physics in Medicine & Biology 2018; 63(8):085018.

CONTACT INFORMATION

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