A Comparison of Various Online Strategies to Account for Interfractional Variations for Pancreatic Cancer

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Software:
• Prowess Panther
• ABAS (CMS)
Introduction

• Prognosis for pancreatic cancer is poor (5% at 5 yrs)

• Target dose limited by adjacent OAR (organs at risk) tolerances (e.g. duodenum) due to large margins caused from significant inter- and intra-fractional variations

• Intra-fractional errors
  – Respiratory motion

• Inter-fractional errors
  – Translation, rotation, deformation, relative motion of organs

• Strategies to account for these errors could help reduce margins, in turn, allow higher doses to tumor.
Pancreatic Tumor IGRT in clinic

Intra-fraction motion:
• 4D CT planning
• Gated CT-on-rails with gated delivery

Inter-fraction Errors:
Daily volumetric imaging with CT-on-Rails

Diagnostic quality CT
Inter-fractional Variations: pancreas head
Soft-tissue based registration with gated CT

PTV 10 mm margin

Liu et al, 2011
Relative OAR (Kidney) position change
Online replanning

- Online replanning would eliminate all the inter-fractional errors, maintain best achievable target coverage, with inter-fraction margin = 0.

- The challenge:
  - time to generate a new dedicated plan using the CT of the day
RealArt

Image Acquisition via CT-on-Rails

Contour generation (auto segmentation with manual editing) 2-5 min

Segment Aperture Morphing (SAM) & Segment Weight Optimization (SWO) 2 min

Dose/DVH evaluation and comparison 1 min

ART plan transferring & QA verification with software 2 min

Delivery and documentation

8-12 min for prostate cancer
Segment Aperture Morphing Algorithm

- Fast and simple algorithm:
  - Stretching apertures based on relative distance from edge of PTV projection
  - New PTV projection is always covered by the combined intensity map from the beam

No shifting of patient (couch) required

Ahunbay et al, MP, 2008
Online Adaptive Replanning

- realART (SAM+SWO) allows smaller (3-5mm) PTV margin, compared to repositioning with typical ~10 mm margin)
Adaptive v.s. Repositioning

- Duodenum

10 cases
Major Challenge of Online Replanning

**Time for target/OAR contouring**

- difficult for auto-segmentation due to large deformations
- a large number of OARs
  - Duodenum
  - Bowels
  - Stomach
  - Kidneys
  - Liver
  - spinal cord
Explore Nine Possible Online Scenarios

1. IGRT Repositioning (original plan with shifts from rigid registration, the current standard IGRT practice)
2. IGRT Repositioning with 2 mm additional margin
3. IGRT Repositioning with 5 mm additional margin
4. IGRT Repositioning (same as the Scenario 1) with dose scaled to maintain 95% coverage
5. Reoptimization starting from scratch
6. Reoptimization starting from the original plan (MLC positions and MUs)
7. Segment Aperture Morphing (SAM)
8. SAM + Segment Weight Optimization (SWO)
9. Reoptimization starting from the SAM plan
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Planning Details

- Daily CTs acquired using respiration-gated in-room kVCT for 10 patients, 249 daily CTs

- Direct Aperture Optimization based IMRT planning (Prowess)

- Daily contours populated from the original plan CT by auto-segmentation (ABAS, Elekta) with manual editing

- 3 mm PTV margin to account for residual variations

- Same constraints used for all plans for each case
RESULTS
Simple margin expansion can not eliminate underdosing of target (PTV3mm)

Repositioning with additional margin = 0mm
Repositioning with additional margin = 2mm
Repositioning with additional margin = 5mm

5mm margin expansion can not eliminate underdosing for ~40% of days

All other scenarios (SAM, SWO, rescaled repositioning, and reoptimizations have all days 95% coverage at Rx dose.)
1-Way ANOVA Analysis

Mean Duodenum Dose

- Mean values over all patients and all days
- The 5% confidence range of statistical significance

- Difference is statistically significant if horizontally separated
Mean Duodenum Dose (cGy)

IGRT reposition with additional margins of 2mm and 5mm result in highest mean duodenum dose, difference is statistically significant.
Reoptimization plans resulted in lowest dose, significantly lower than IGRT Repositioning (with 0mm AM).

They are statistically equivalent to each other.
Mean Duodenum Dose (cGy)

SAM and SWO resulted slightly higher MDD (statistically insignificant) relative to optimizations.
IGRT repositioning with rescaling resulted in equivalent (statistically insignificant) MDD compared to w/o rescaling.
Other Duodenum Parameters

The results of V-Rx are similar to MDD (prev. graphs)

Duodenum D2% results are rather different, SAM and SWO has significantly larger doses (~5160cGy and 5200cGy on average respectively)
Other OAR Mean Doses

Large bowel

Small bowel

Stomach

Liver
Conformity Index
(Total Volume Receiving Rx Dose / PTV3mm Volume)

Difference btw. SAM and IGRT with rescaling is statistically significant

Difference btw. reoptimization from scratch and SAM is statistically significant
Target dose Inhomogeneity was worst with SAM followed by SWO.

The target dose is most uniform with larger margin plans, as they provide a larger area of uniform dose.
No daily contours
- Repositioning with 0mm additional margin results in underdosing in ~50% of days.
- Adding 2mm or 5mm margins would significantly increase the OAR doses (e.g. mean duodenum dose by 15% and 22% respectively), while eliminating underdosing (49% and 40% of days with D95< Rx, respectively).

Only the target volume
- Rescaling to maintain 95% coverage everyday ascertains target coverage everyday and results slightly lower OAR doses than no-rescaled IGRT (because most plans needs to be scaled down).
- SAM results in even lower OAR doses, with adequate target coverage (SAM takes <1second).

All daily contours (target & OARs)
- Reoptimizations generate the best plans (dosimetrically best is the reoptimization from scratch).
- Optimization takes a couple of minutes. Optimization from existing plan or SAM takes < 1 min, similar to SWO.
Pre-Tx QA for Daily Plans?

Of all MLC positions that were used by either the daily or original plans, 42% changed more than 3mm for SAM, and 28% were more than 5mm. The amount that exceeded 5mm (step size for Prowess optimization) for REOPT_OR, REOPT_SAM and REOPT_0 were 31%, 35% and 40% respectively.
Conclusions

- IGRT repositioning cannot fully address interfractional variations for pancreas cancer.

- Reoptimization methods would generate best dosimetric results however they require extensive target and organ delineation.

- Segment aperture morphing SAM yields comparable dosimetry but requires only target delineation, and is a practical strategy.
Future Direction

- Online reoptimization with only the target contour and the "directional ring structures"

- Requires only the target structure delineated

- Directional rings are generated automatically for the daily CT
  - they maintain the dose gradient toward the OARs