A novel methodology for deriving set-up margins using dose accumulation and bidirectional local distance

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INTRODUCTION

Purpose

This study presents the first application of the bidirectional local distance (BLD) to planned and accumulated isodose surfaces as a tool to derive set-up margins.

Bidirectional Local Distance

BLD enables quantitative visualization and statistical analysis of local discrepancies between reference and test surfaces.[1] To compute the BLD for a point, P_{ref}, on the reference surface:

1. **Compute forward minimum distance, FMinD(P_{ref}, T):** minimum of distances from P_{ref} to all points on test surface T.
2. **Compute backward maximum distance, BMaxD(T, P_{ref}):**
   i. For each point P_T on T, calculate the distance $d_{min}(P_T, R)$ to the closest point on reference surface R.
   ii. Points P_T on T are selected whose $d_{min}(P_T, R)$ is found at P_{ref}.
   iii. BMaxD(T, P_{ref}) is the maximum distance from the set.
3. **Compute bidirectional local distance, BLD(P_{ref}, T):** select the maximum value between FMinD(P_{ref}, T) and BMaxD(T, P_{ref}).

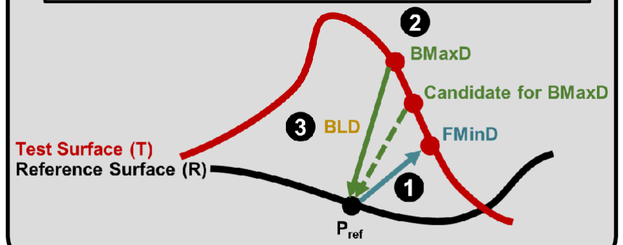

Figure 1: Description of the BLD measure scheme.

METHODS

Patient Population

- 10 early-stage breast cancer patients
  - Accelerated partial breast irradiation delivered using IMRT (27 Gy in 5 fractions) with daily CBCT imaging
- 3 oropharyngeal cancer patients
  - VMAT (70 Gy in 33 fractions) with weekly CBCT imaging

Retrospective Analysis

For each patient:

1. Re-optimize clinical treatment plan with 0 mm PTV and normalize to achieve minimum target coverage criterion (D98% = 95%).
2. Use deformable image registration of planning CT to CBCTs to accumulate the dose of the zero-margin plan on the planning CT.
3. Compute BLD between planned and accumulated 95% isodose surfaces relative to each CTV contour point.
4. Define isotropic set-up margin as the 95th percentile of BLDs in regions where the accumulated 95% isodose surface shifted towards the CTV.
5. Repeat steps 1 – 2 but with the derived set-up margin applied to the CTV. Evaluate resulting accumulated CTV coverage (D98% ≥ 95%).

RESULTS AND DISCUSSION

- The median (range) set-up margin was 3 mm (2 – 8) for the breast patients and was 2 mm for all three oropharyngeal patients
- When treatment plans were re-optimized with the derived set-up margin applied for each patient case, the median (range) accumulated CTV D98% was 96% (95 – 99)
- All patients met the criteria for adequate CTV coverage
- 3D visualization of BLDs on a patient-to-patient basis suggests that this approach may be extended to derive asymmetric set-up margins

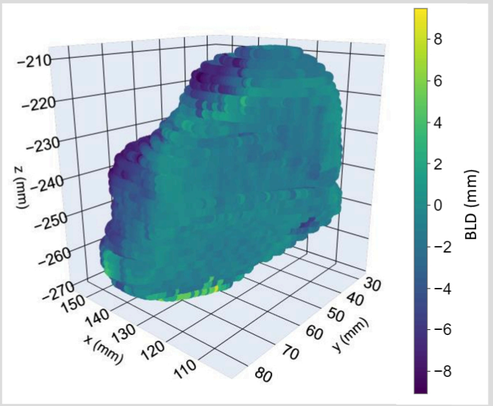

Figure 2: BLDs between planned and accumulated 95% isodose surfaces are shown in colour scale for each CTV contour point for a patient case. Contour points are plotted in the DICOM coordinate system. Positive BLDs indicate that the accumulated 95% isodose surface shifted towards the CTV from the planned 95% isodose surface.

CONCLUSIONS

- Application of the BLD to planned and accumulated isodose surfaces for zero-margin treatment plans can be used to derive appropriate isotropic set-up margins
- These results can be combined with other uncertainties in the external beam radiotherapy workflow to define evidence-based PTV margins

REFERENCES

[1] Kim *et al*. Med. Phys. 39(11), 6779–6790 (2012)

ACKNOWLEDGEMENTS

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