Effects of Anatomical Changes on Pencil Beam Scanning Proton Plans in NSCLC Patients

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Introduction

• In 5% of lung cancer patients, our standard dose of 24x2.75 Gy cannot be delivered with IMRT due to OAR constraints

• About 55% of lung cancer patients are treated with our standard dose 24x2.75 Gy with high mean lung dose (MLD > 16 Gy)
Aim

Test the feasibility of proton treatment for these cases
Challenge: taking into account slow (interfraction) and fast (intrafraction) anatomical changes
Study data

Patients
- 16 locally advanced NSCLC patients treated with IMRT
- Mainly excessive mean lung dose in IMRT planning (24x2.75Gy)

Treatment planning system (TPS)
- Philips Pinnacle³ v9.100 (research)
- Spot Scanning

Data
- 4D Planning CT
- Daily Cone Beam CT (CBCT) (8 – 23 scans)
Treatment planning

planning CT
Treatment planning

Optimization methods:
- SFUD and IMPT using PTV margins ($M = 2.5\Sigma + 0.7\sigma$)
- Robust weighted scenario based approach ($\pm 3\text{mm}$ / $\pm 3\%$)

GTV
IGTV
PTV
Involved lymphnodes (LN)
Heart
Spinal chord
Oesophagus

$\Sigma = \text{systematic errors}$
$\sigma = \text{random errors}$
$A = \text{respiration amplitude}$
Planned dose

planning CT

RT Plan

Planned dose
Fraction dose recalculation

Planning CT → CBCT

RT Plan
Planned dose

Fraction dose
Modify CT to CBCT anatomy

CT

modified CT (mCT)
(CT numbers + CBCT anatomy)

Deformable registration

CBCT
Dose accumulation I
(day – day variations)

mCT

Planning CT

\[ \sum_{\text{fractions}} \text{Fraction dose} \]

Estimate of delivered treatment dose

Deformable registration

RT Plan

Planned dose

CBCT
Dose accumulation II
(day – day variations + respiratory motion)

\[ \sum_{\text{fraction}} \sum_{\text{phase}} \text{Phase dose} \rightarrow \text{Estimate of delivered treatment dose including respiration motion} \]

- mCT
- mCTresp
- Deformation vector field
- Deformable registration
- 4DCT
- RT Plan
- Planned dose
\(D_{99}\) of GTV

- Primary tumour up to 5 Gy loss
- Lymph nodes up to 10 Gy loss
- SFUD more robust
- Respiratory motion has only small effect on the target coverage

\(D_{99}\) = minimum dose to 99% of the volume
OARs: $D_1$ of mediastinal structures

- Increase of $D_1$ up to 5 Gy for IMPT and 2 Gy for SFUD

$D_1$ = maximum dose to 1% of the volume
Conclusion

• Day to day anatomical changes have a very large influence on the dose distribution
• Respiratory motion has a much smaller effect
• SFUD is more robust to these changes than IMPT
• Day to day changes need to be taken into account!
Limitations

• TPS is research prototype
• Specification proton machine outdated
• Disregarded interplay effect between intrafraction motion and spot delivery time
• Disregarded irregular breathing motion
• Inaccuracies in deformed CTs
Thank you for the attention!