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Plan Comparisons of Scanned Proton, Passive-scattered Proton, and Passive-scattered Carbon Ion Therapies of Lung Cancer with Various Isodose Prescriptions

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Objectives:

We compared the dose distributions of **proton pencil beam scanning (PBS), proton beam passive-scattering (PPS), and carbon ion beam passive-scattering (CPS)** methods in stereotactic body radiotherapy using various isodose prescription levels to evaluate the feasibility of treatments for lung cancer patients.

Methods:

Patients and Treatment Planning

- ✓ Patients: five isolated lung cancer patients
- ✓ Targets: GTV, CTV (GTV+5 mm), PTV (CTV+5 mm)
- ✓ Organs at risk (OARs): Lungs-GTV, Chest wall, Spinal cord, Trachea, and Esophagus.
- ✓ Prescribed dose: 66 GyRBE at 95% PTV
- ✓ Isodose prescribed levels: 50, 60, 70, and 80% (132.0, 110.0, 94.3, 82.5 GyRBE)
- ✓ Number of fields: 4, 10, and 4 for PBS, PPS, and CPS.
- ✓ Multi field optimization (PBS)
- ✓ Robust optimization: setup (±5 mm) and range (±3.5%) error

Evaluations

- ✓ D_{max}, D_{98}, and D_{mean} for CTV
- ✓ Homogeneity index (HI) for CTV
  $HI = (D_2\text{-}D_{98})/D_{50} * 100$ (%)
- ✓ D_{mean} for PTV
- ✓ Paddick's conformity index [1] (CI) for PTV
  $CI = TVPIV^2/(TV*PIV) * 100$ (%) ※1
- ✓ Mean doses (D_{mean}) and Maximum doses (D_{max}) for all OARs
- ✓ Volume doses (V_5, V_{20}, and V_{30}) for Lungs-GTV
- ✓ Bonferroni post-hoc test for multiple comparisons

[1] Paddick. J. Neurosurg. 93(Suppl 3):219–22; 2000

※1 **TVPIV: The volume of overlap between the TV and PIV**
TV: The volume of the respective target
PIV: The total volume covered by 95% of the prescription dose in the target.

Result:

Targets

- ✓ The CTV D_{98} for those plans averaged at least 117.5-147.1% of the prescription dose (Fig. 1).
- ✓ The CPS achieved significantly higher CTV D_{98}, D_{mean}, and HIs relative to both PBS and PPS ($p<0.05$, Fig. 2).

OARs

- ✓ The D_{mean} of Lungs-GTV was reduced with lower percent isodose in three methods.
- ✓ D_{mean} of Lungs-GTV tended to decrease in the order of CPS, PBS, and PPS across all isodose prescriptions ($p>0.05$).
- ✓ No significant differences were observed in D_{max} and D_{mean} among the four OARs for the three methods ($p>0.05$). This tendencies were true for all four isodoses.
- ✓ Furthermore, no particular irradiation method showed a tendency to reduce doses significantly for each OAR.

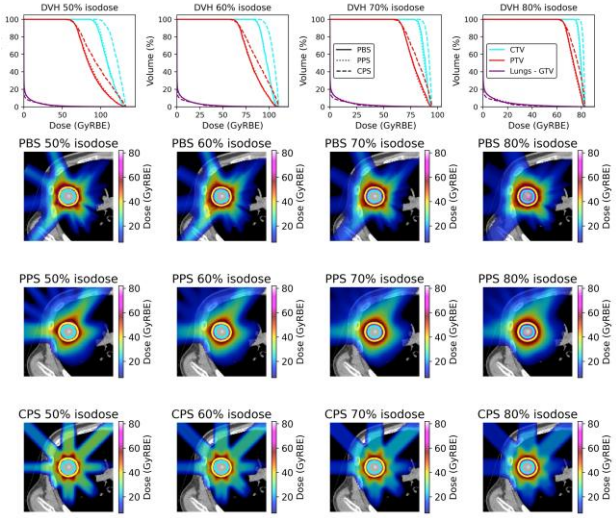

Fig. 1. Dose volume histograms and dose distributions of a representative patient for PBS (upper), PPS (middle), and CPS (lower) plan. Yellow contour: PTV, Cyan contour: CTV.

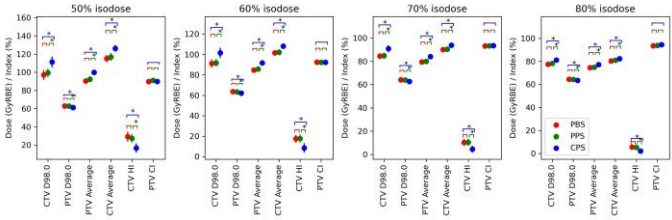

Fig. 2. Summary of dose statistics and multiple comparisons among three irradiation methods in CTV and PTV for four isodose prescriptions. The * marks indicate $p < 0.05$.

Conclusion:

- ✓ All three methods demonstrated that isodose prescriptions in the range of 50%-80% were achievable. Of the three, CPS achieved the best treatment plans in terms of coverage and normal lung dose.
- ✓ We also demonstrated that proton therapy is almost equivalent between PBS and PPS.