Combining multiple fields and ITV-PTV margins for motion mitigation using NSCLC sequential 4DCTs*

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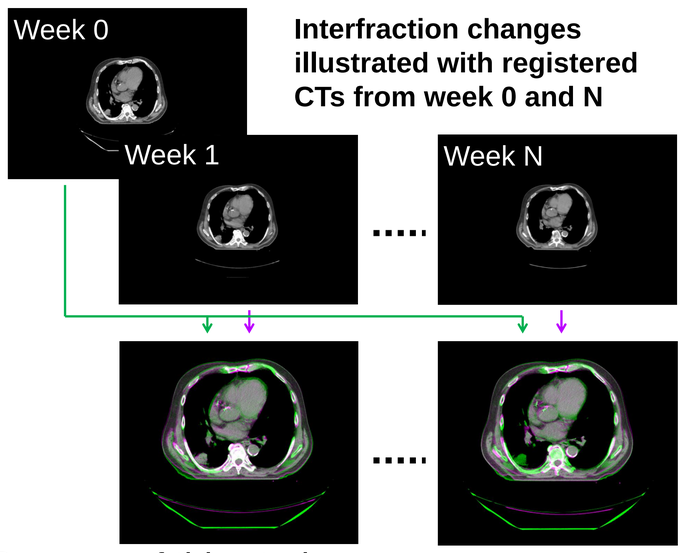
Introduction

Scanned carbon ion beam therapy:

- more conformal treatments compared to conventional radiotherapy
- but complicated treatment of moving tumors due to range sensitivity and interplay effects



Purpose of this study:

- multiple fields (SFUD) combined with ITV-PTV margins as a solution to tumor motion and interfractional patient variability
- investigated values: V95 and conformity number [1] (CN)

Materials & Methods

4DCT datasets

4DCT datasets from MDACC [2] (University of Texas MD Anderson Cancer Center):

- 38 weekly 4DCT datasets from 5 NSCLC lung tumor patients
- weekly CTs aligned using rigid registration
- weekly motion states registered non-rigidly using Plastimatch [3]

Motion trajectory

Sine square defined by Lujan [4]:

- period: 3.6 seconds
- normalized amplitude
- one starting phase: 0 degree

Number of fields	Margins	Case
1	ITV	SFITV
	PTV#	SFPTV
2	ITV	2FITV
	PTV#	2FPTV
3	ITV	3FITV
	PTV#	3FPTV

#PTV: ITV + isotropic 3mm + range 3mm+3%

Single/multiple fields and target volumes

Single and multiple fields configurations combined with:

- ITVs including range corrections composed of the CTV of 5 motion states (25% of total amplitude)
- same ITVs with additional margins.
  ⟶ six different combinations as presented in the previous table

Gating window & beam focus

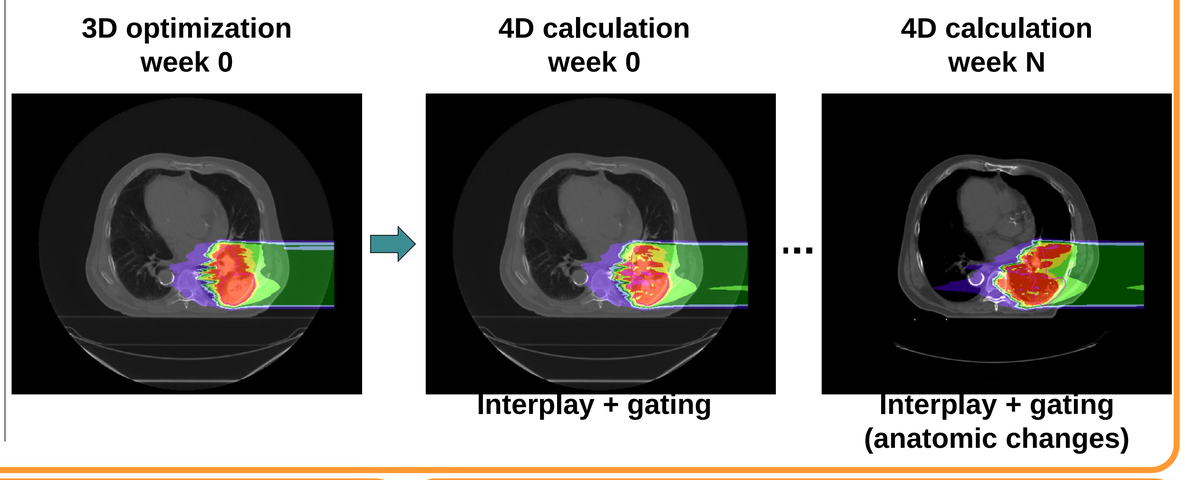
For all fields/volumes combinations, calculations performed with:

- three gating windows (GW): 11,9, 30 and 50% of the amplitude
- three beam foci (F): 6, 10 and 15mm.

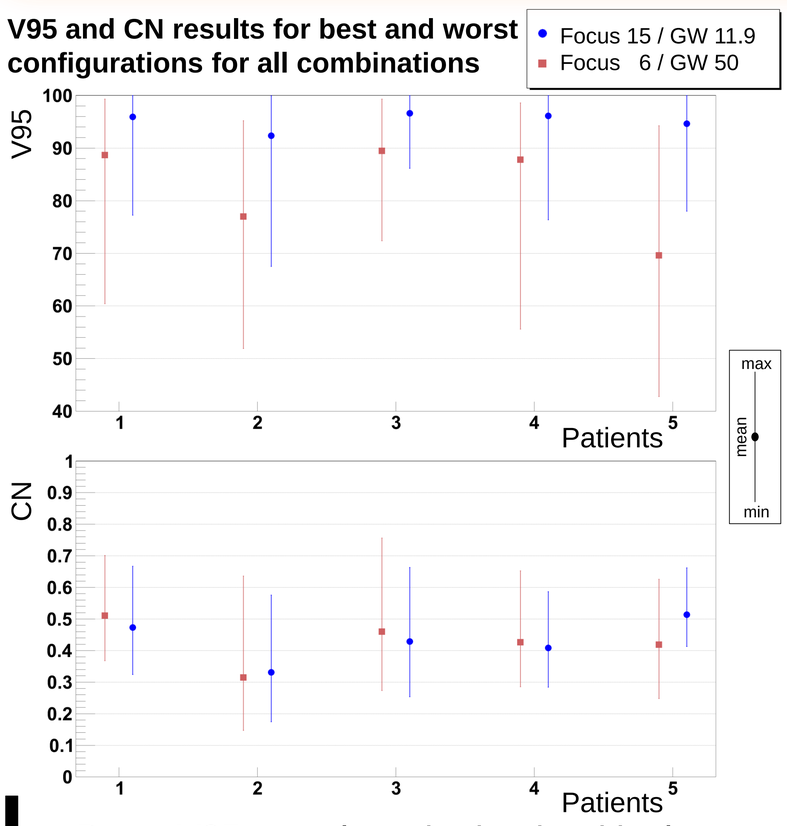
Treatment plans

All gating treatment plans performed with:

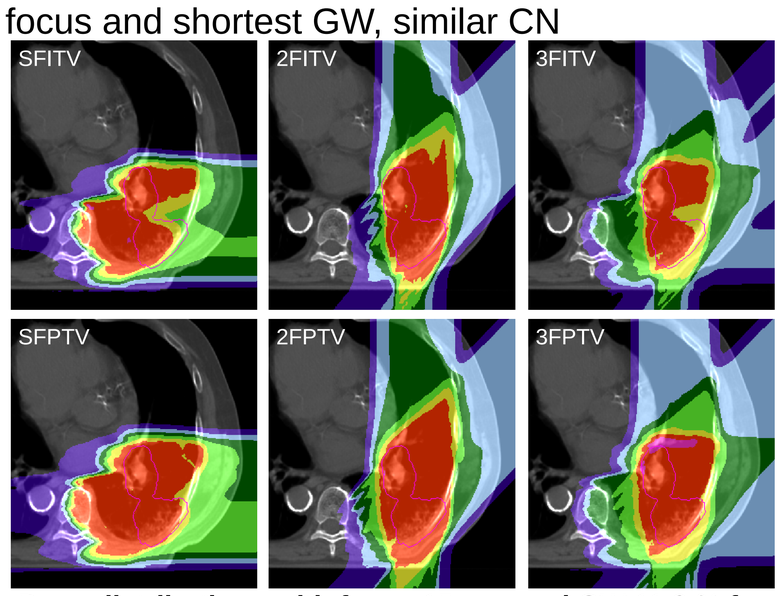
- GSI treatment planning system TRiP4D [5] with carbon ions
- optimized plans computed using the first week of each patient dataset and then used for the weekly 4D calculations



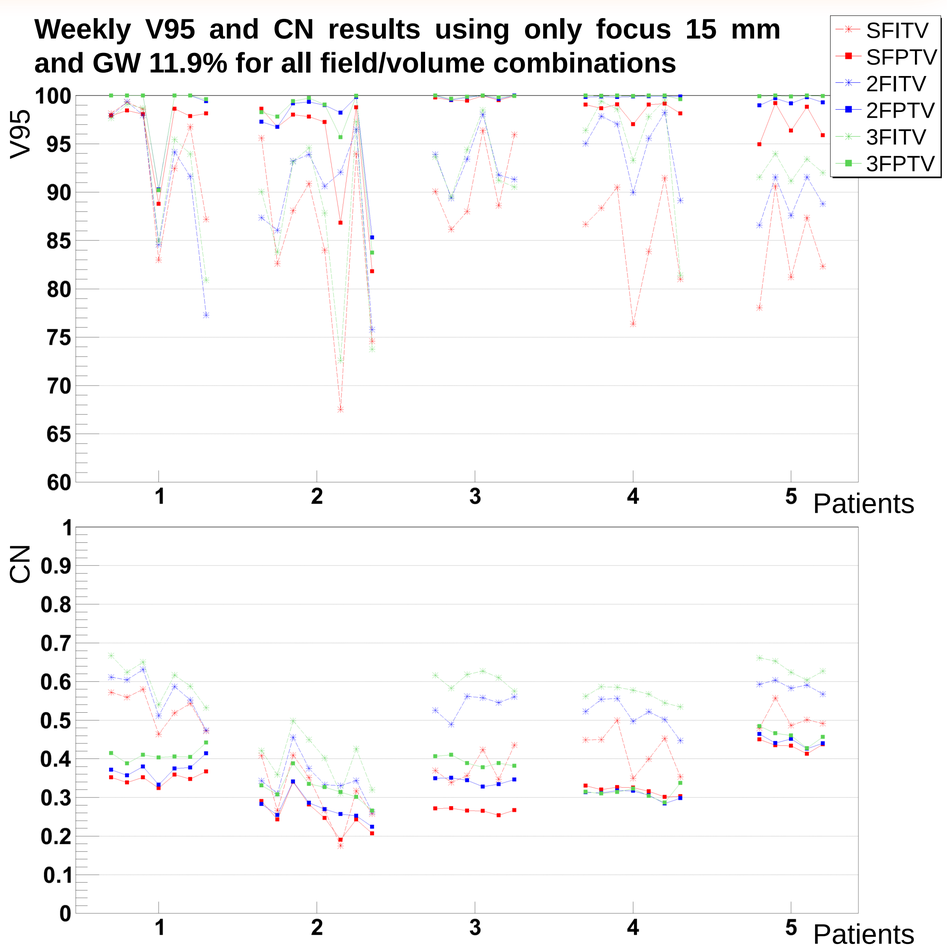
Results



⟶ Best V95 results obtained with largest focus and shortest GW, similar CN



Dose distributions with focus 15 mm and GW 11.9 % for week 6 of patient 2



- Range errors caused by anatomic changes (clearly visible with SFITV)
- Better V95 and CN results yielded using multiple fields
- Further improvement of V95 using ITV-PTV margins but lower CN

Case	**V95** (range)	**CN** (range)
SFITV	**83.4** (42.8 to 99.8)	**0.46** (0.14 to 0.68)
SFPTV	**96.5** (62.8 to 100)	**0.32** (0.17 to 0.46)
2FITV	**87.9** (56.8 to 100)	**0.54** (0.23 to 0.73)
2FPTV	**98.9** (65.8 to 100)	**0.36** (0.21 to 0.49)
3FITV	**88.5** (53 to 99.9)	**0.58** (0.26 to 0.77)
3FPTV	**99.1** (70.9 to 100)	**0.4** (0.26 to 0.52)

Results of the six combinations for all patients (median and range)

Conclusion

- Best results obtained with large focus and short GW in terms of target dose coverage, similar CN values for both configurations
- Better target dose coverage and conformity number using 2 or 3 fields compared to single field simulations
- But increased risk of using a range sensitive entry channel ⟶ dose delivery errors: possible lower V95 values despite more fields
- Better target dose coverage for single and multiple fields calculations using additional ITV-PTV margins
- But decreasing CN ⟶ irradiation of more healthy tissue

Possible solutions as next steps:

- Rescanning only and combined with gating to explicitly address intrafraction motion
- Plan adaptation or replanning as options to address interfractional motion components

[1] van't Riet *et al*, 1997, *Int. J. Radiat. Oncol. Biol. Phys.* **37** 731–6
[2] Britton et al, 2007, *Int. J. Radiat. Oncol. Biol. Phys.* **68** (4) 1036-46
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[4] Lujan et al, 1999, *Med. Phys.* **26**, 715-720
[5] Richter et al, 2013, *Med. Phys.* **40** (5) 051722

* *funded as an ESR within the EU-FP-7 ENTERVISION framework, Grant Agreement no. 264552. Further funds received by DFG KFO 214.*