Studying inter- and intrafraction motion mitigation with sequential 4D CTs of lung tumor patients

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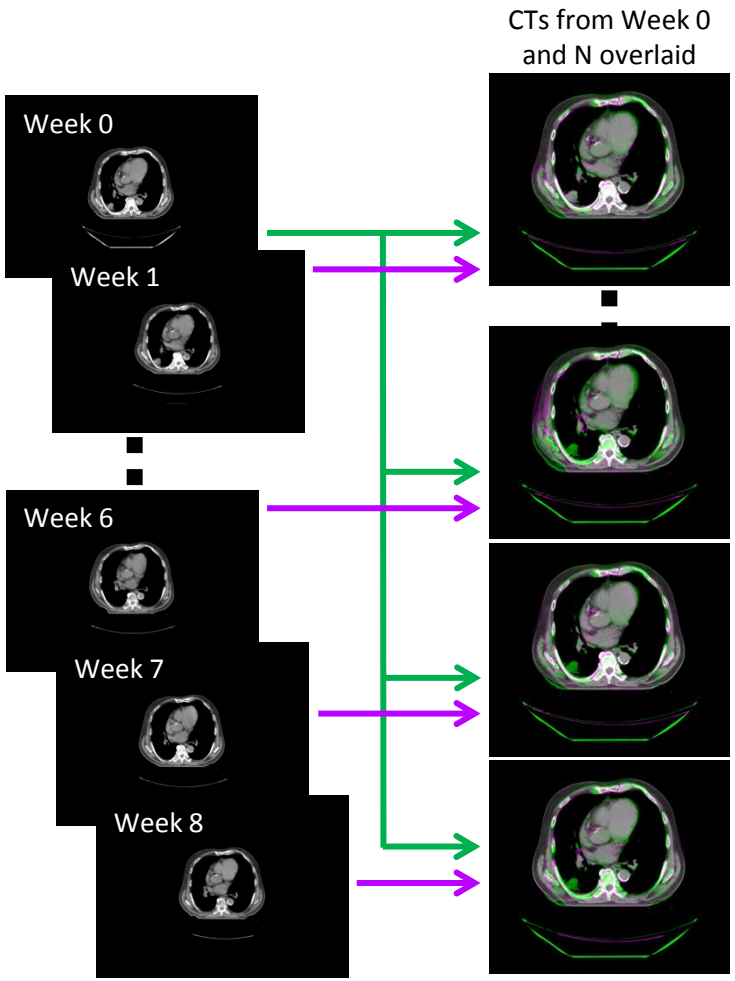
Introduction



Intrafraction motion +

Interfraction motion: visible anatomic changes in subsequent weeks:

- Patient misalignments
- Organ/tissue drifts
- Rigid registration errors

Consequences on the treatment:

- Dose inhomogeneity: under- and/or overdosage
- Dose on organs at risk (OAR)

Problem to be solved for active beam scanning with carbon ions:

➔ What parameters could optimize dose homogeneity and target coverage?

beam focus, gating window, margins?

Materials & Methods

Study overview:

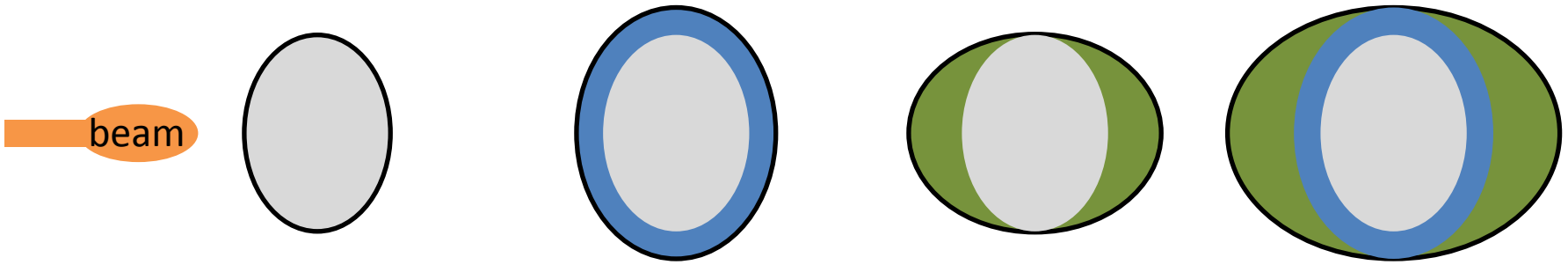
- Weekly 4DCT datasets from 5 NSCLC lung tumor patients from MDACC [1] (The University of Texas MD Anderson Cancer Center)
- Weekly CTs aligned using rigid registration
- Motion phases of each week registered non-rigidly using Plastimatch [2]
- Gating plans simulated using the GSI treatment planning system TRiP4D [3]:
  - active scanning (raster scanning)
  - carbon ions
  - optimized with first week of each patient, then used for all weeks 4D calculations
- Motion surrogate defined according to Lujan [5], one starting phase (0 degree) and one period (3.6 seconds)
- Range corrected ITVs [4] (5 motion phases, 25% of the amplitude)

[1] Britton et al, 2007, *Int. J. Radiat. Oncol. Biol. Phys.* **68** (4) 1036-46
[2] Shackleford *et al*, 2010, *Phys. Med. Biol.* **55**, 6329-6351
[3] Richter et al, 2013, *Med. Phys.* **40** (5) 051722
[4] Graeff *et al*, 2012, *Med. Phys.* **39**, 6004-6014
[5] Lujan et al, 1999, *Med. Phys.* **26**, 715-720

Materials & Methods

Studied parameters:

- 3 different beam foci: 6, 10 and 15 mm (FWHM)
- 3 different gating windows: 11.9, 30 and 50% of motion amplitude
- 4 different cases of margins:



ITV

ITV + isotropic 3mm

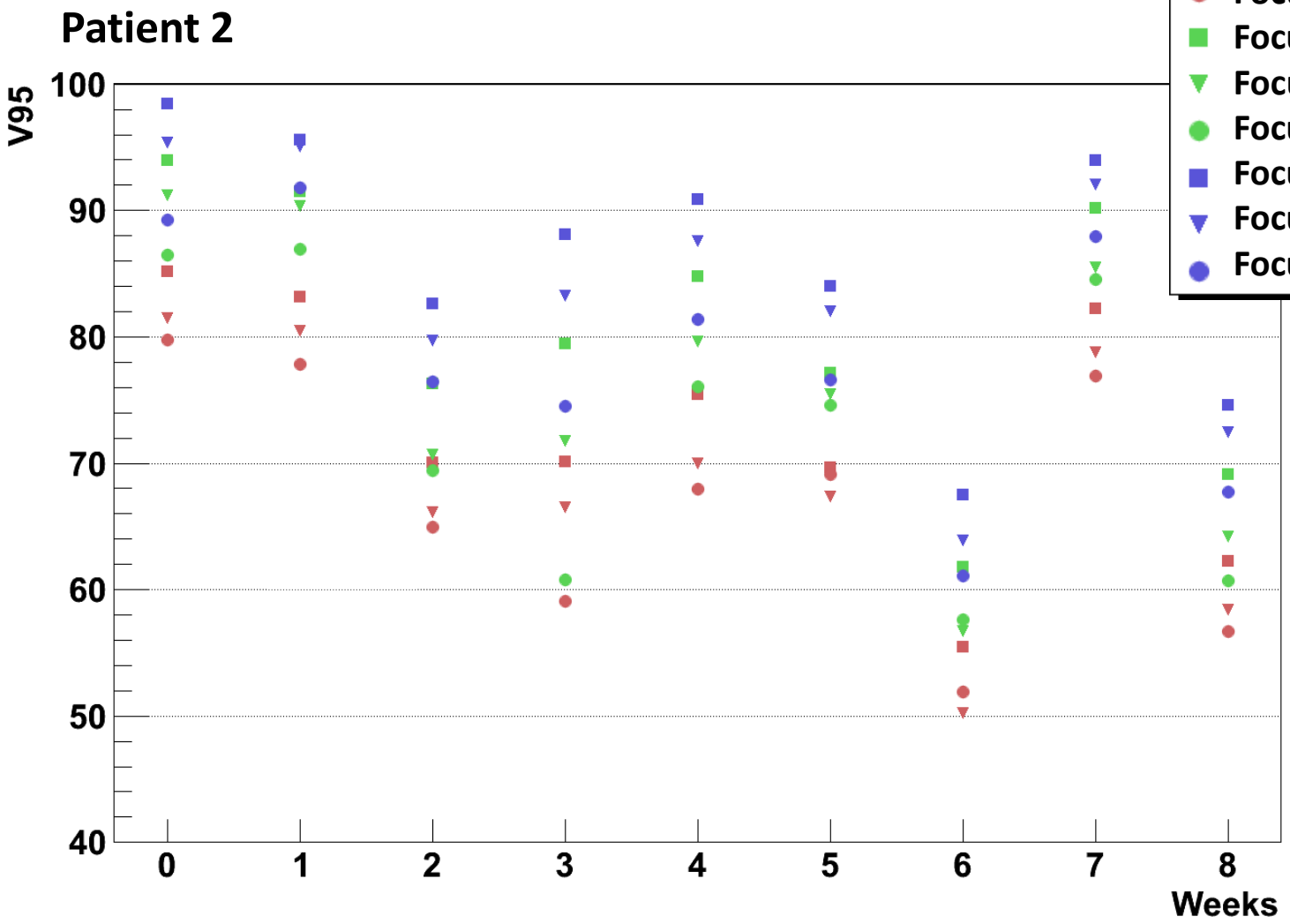
ITV + range 3%+3mm

ITV + isotropic 3mm + range 3%+3mm

- Looking at V95 and conformity number [1]: $$CN = \frac{V_{CTV,95\%}}{V_{CTV}} \times \frac{V_{CTV,95\%}}{V_{95\%}}$$

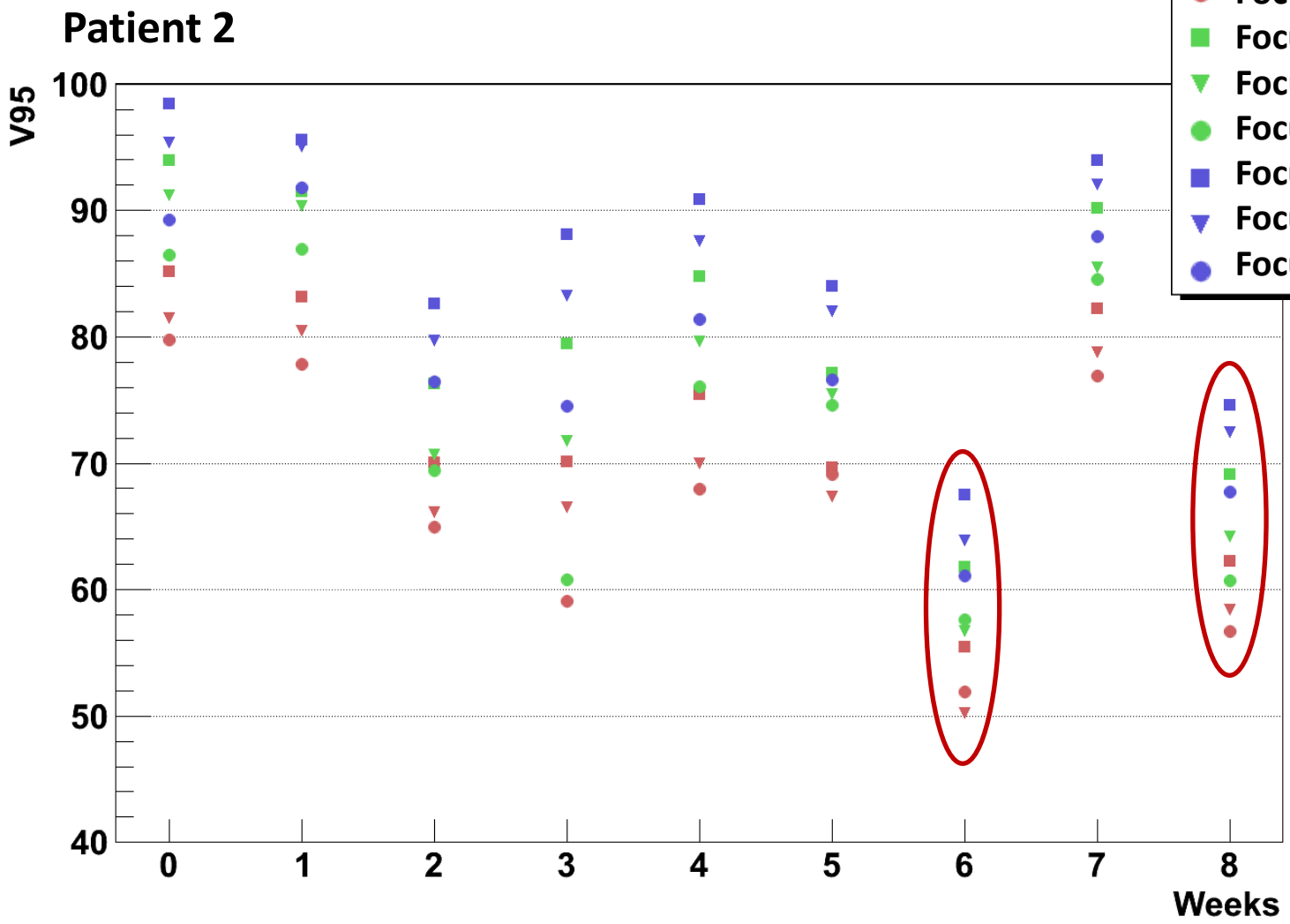
[1] van't Riet *et al*, 1997, *Int. J. Radiat. Oncol. Biol. Phys.* **37** 731–6

Results



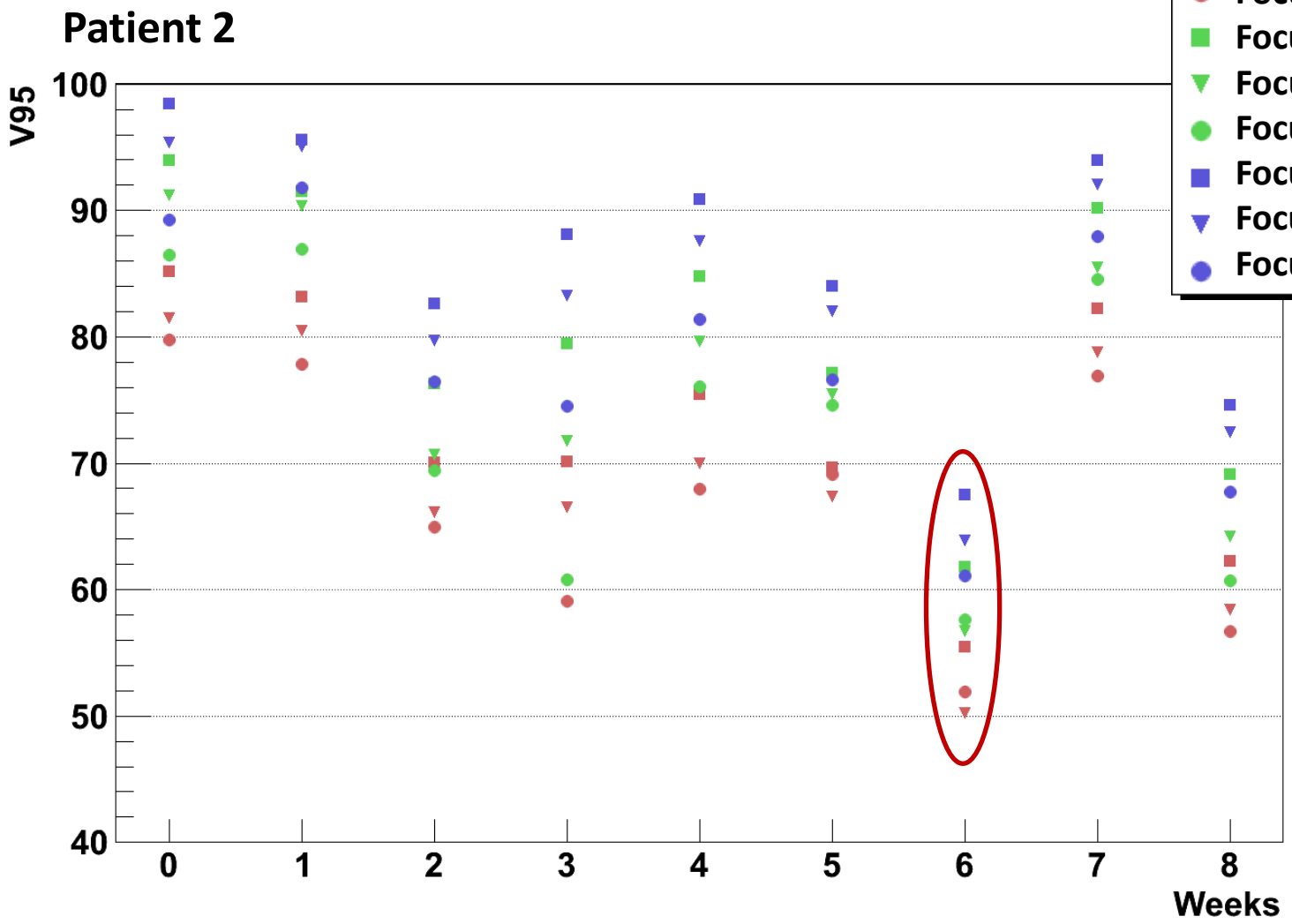
GW = gating window

Results



GW = gating window

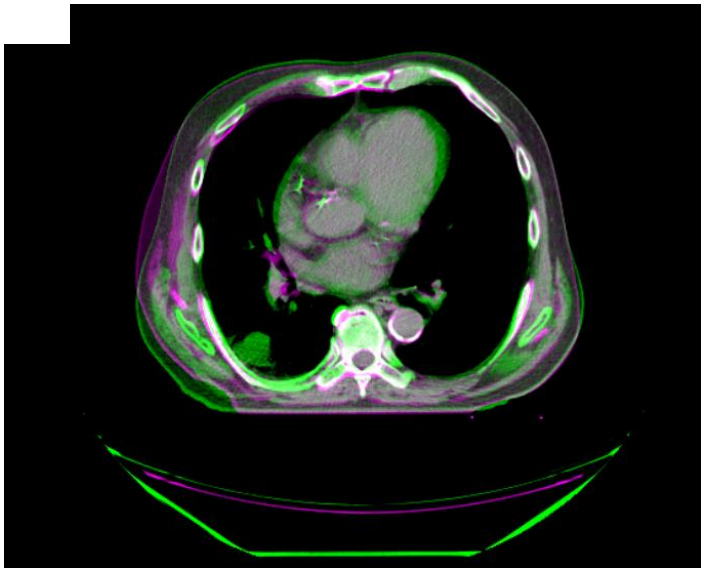
Results

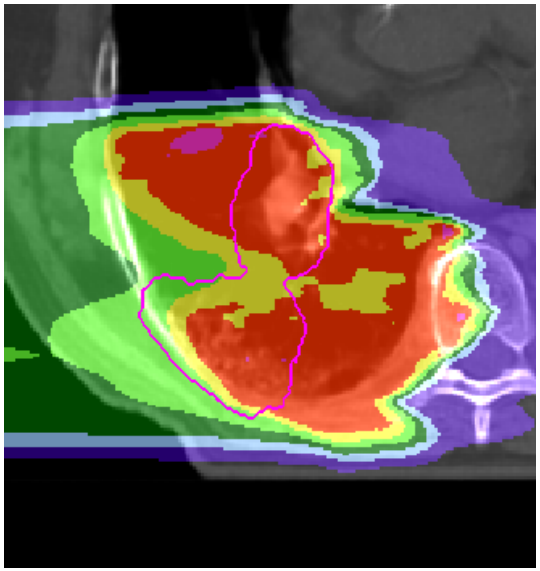


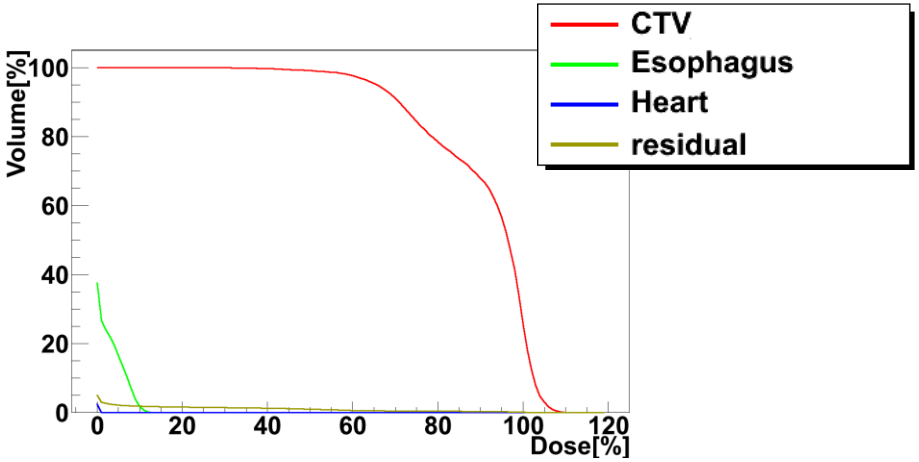
GW = gating window

Results

Patient 2

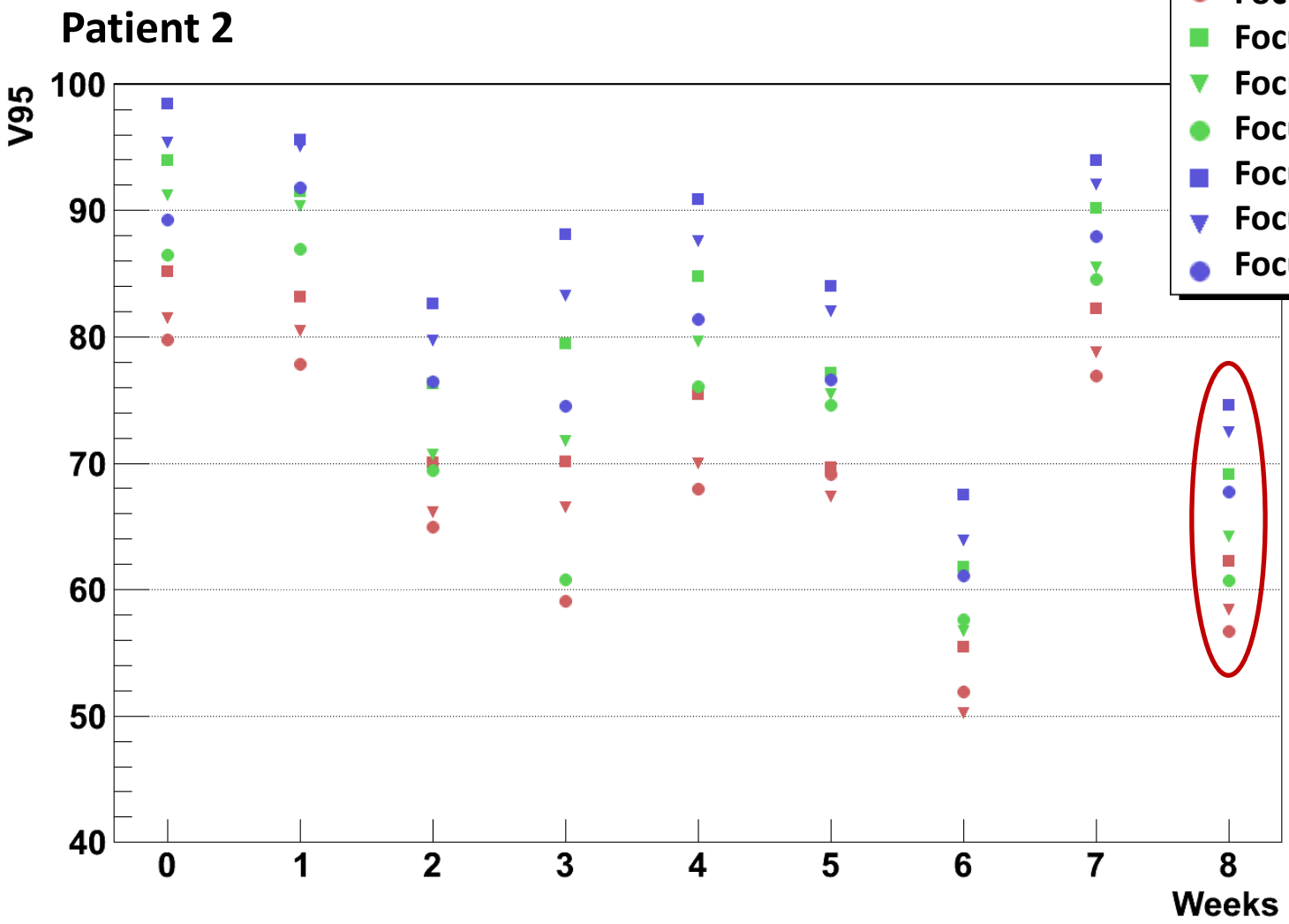






GW = gating window

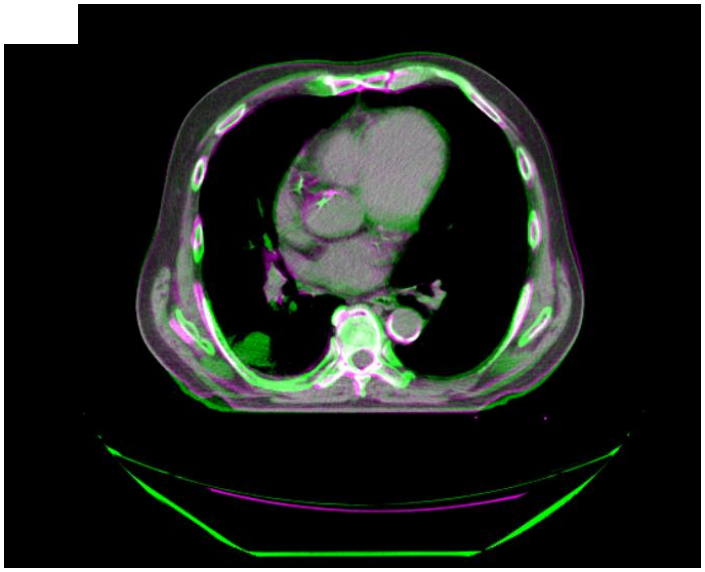
Results

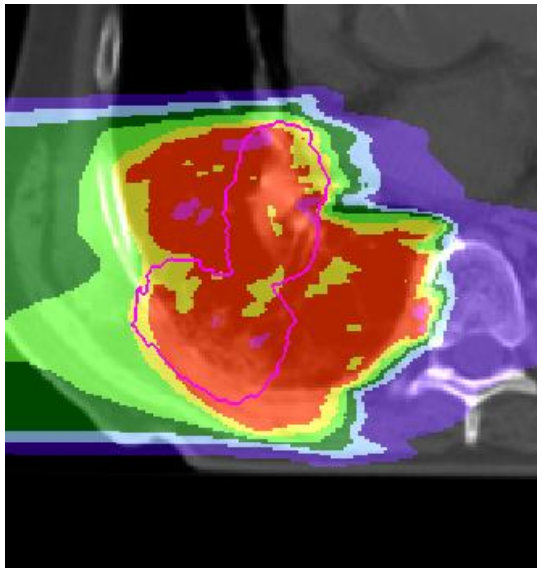


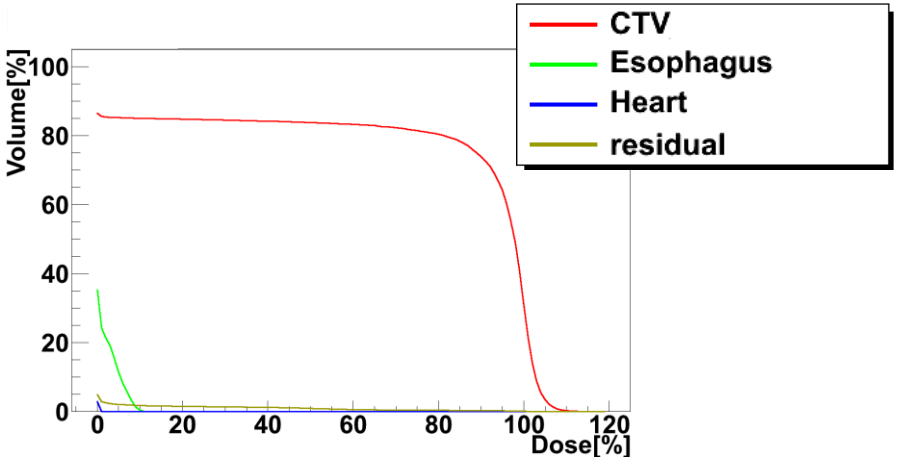
GW = gating window

Results

Patient 2

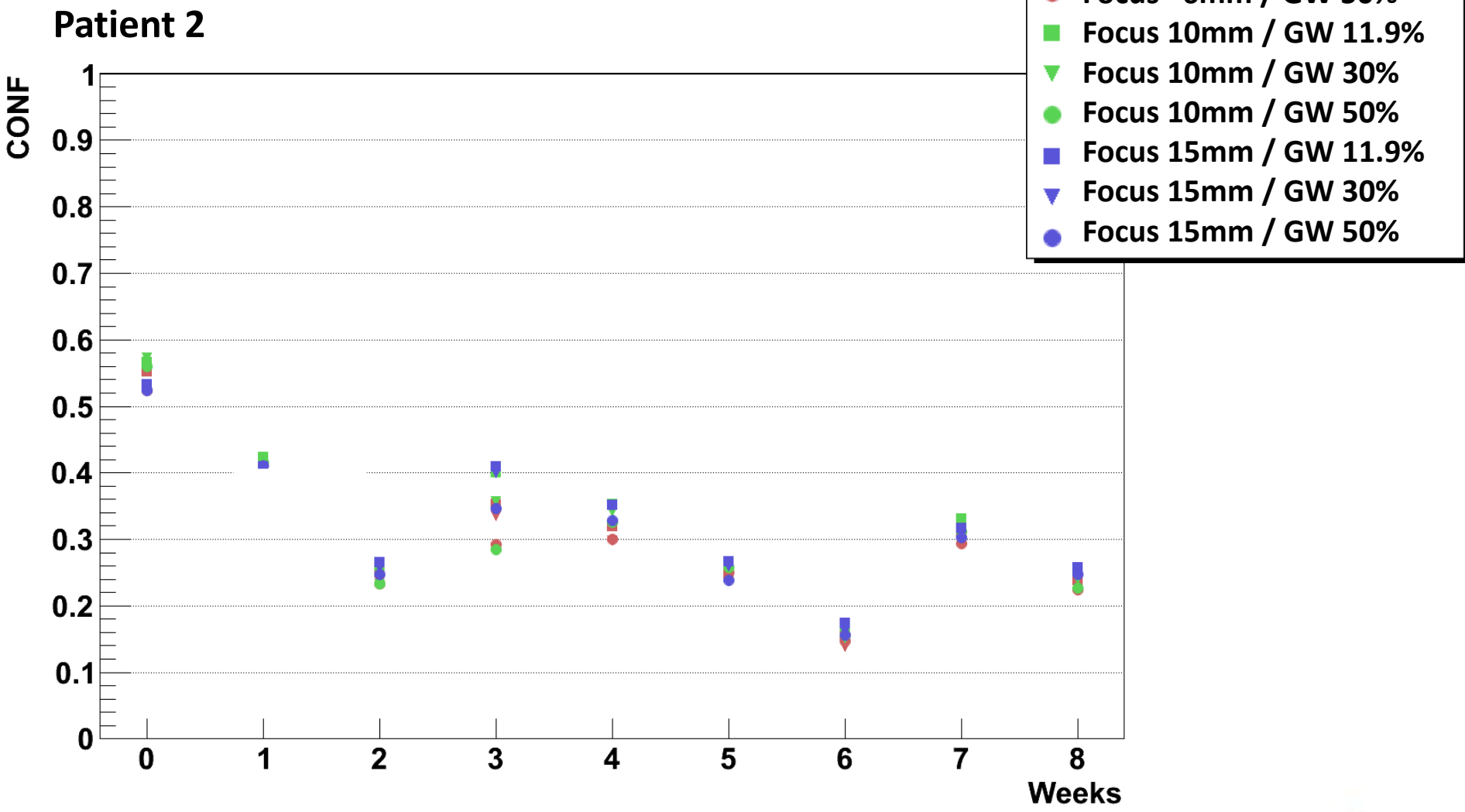






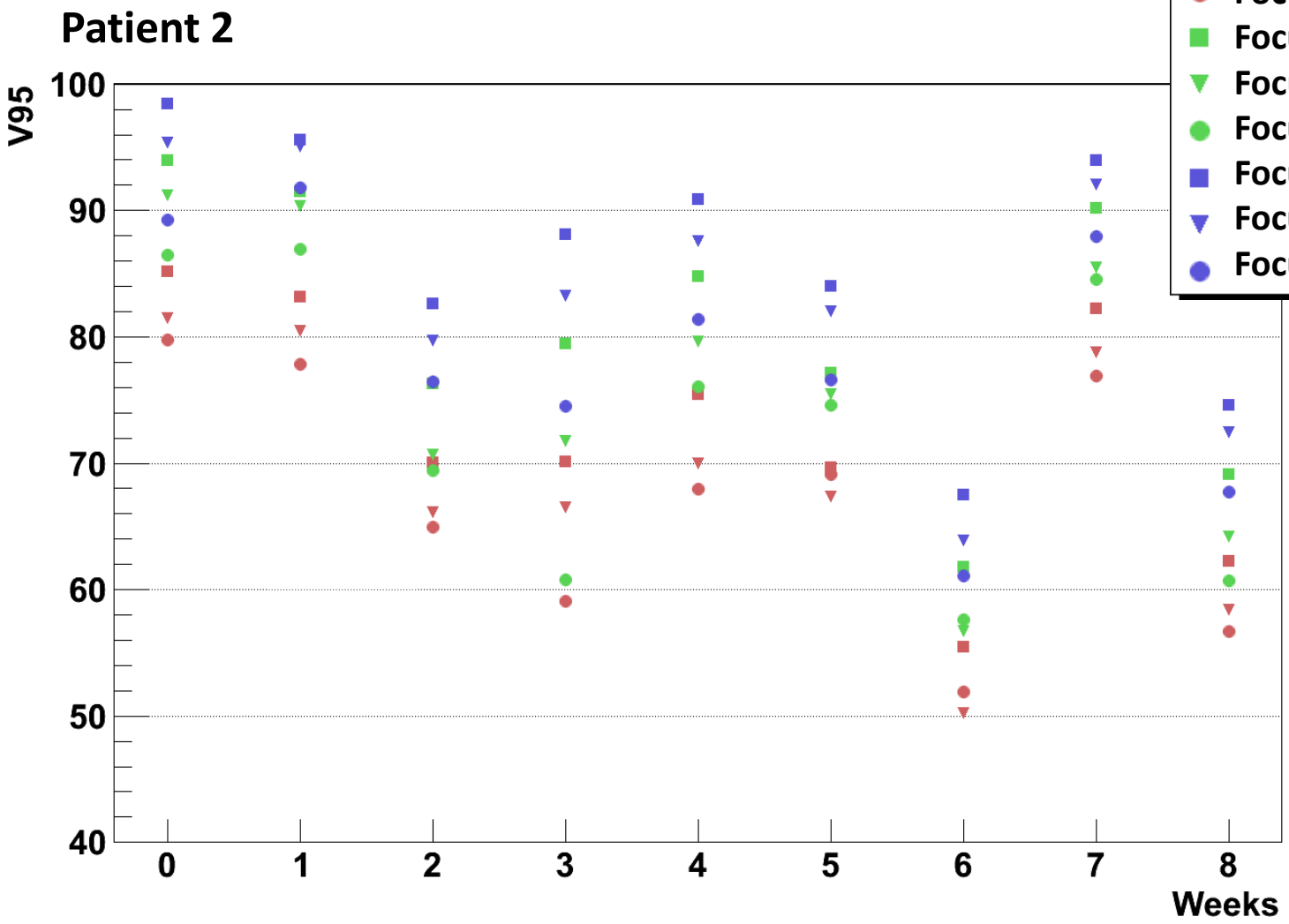
GW = gating window

Results



GW = gating window

Results

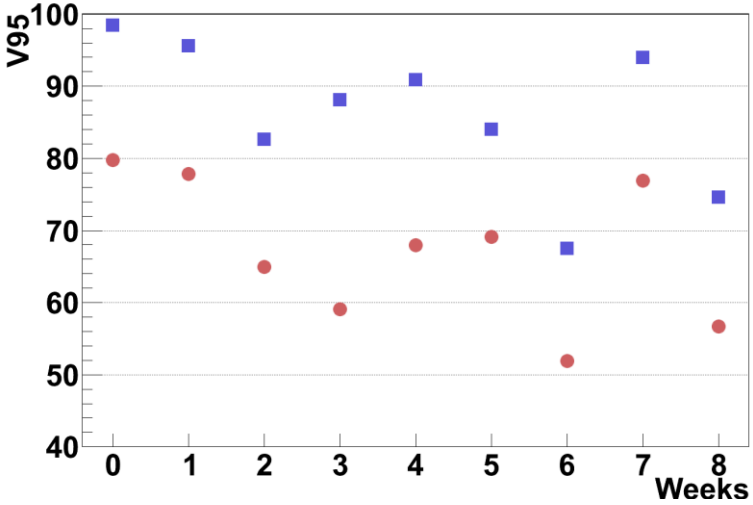


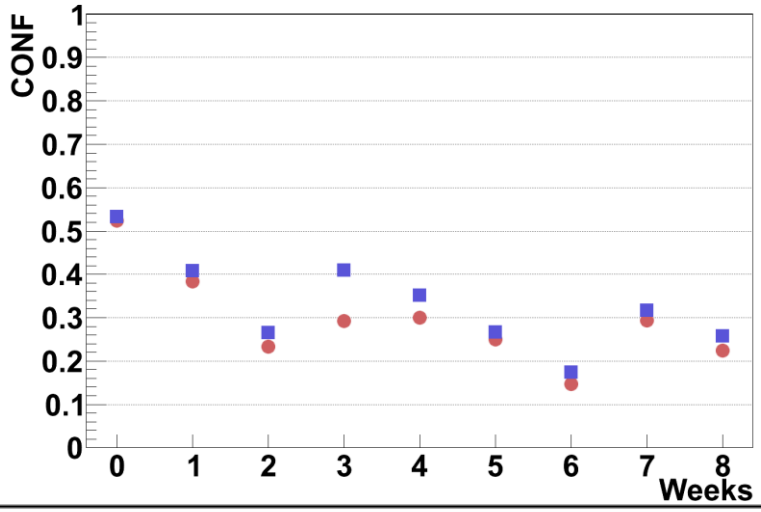
GW = gating window

Results

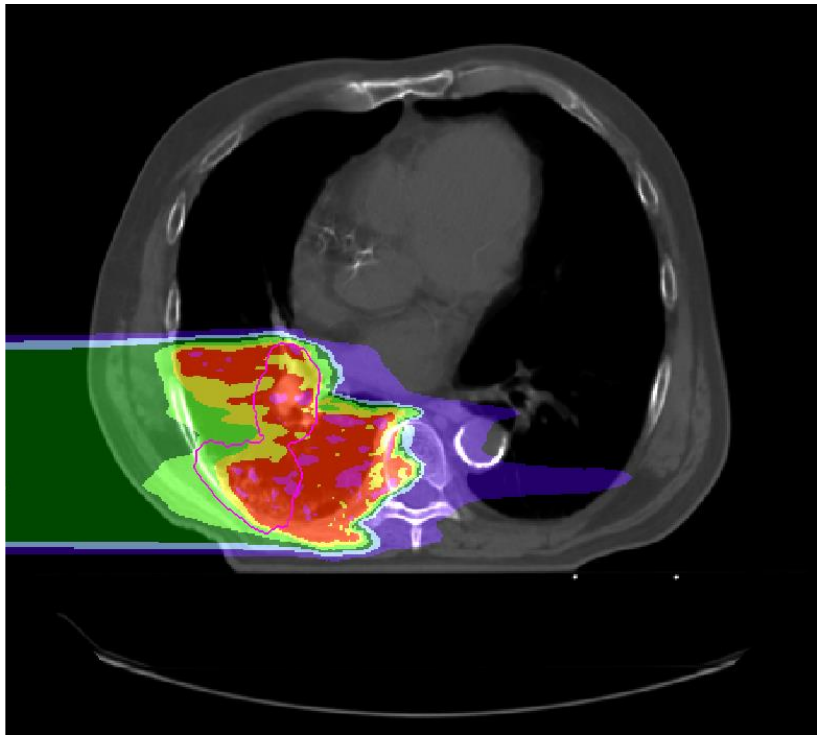
ITV margins

Patient 2





- Focus 6mm / GW 50%
- Focus 15mm / GW 11.9%

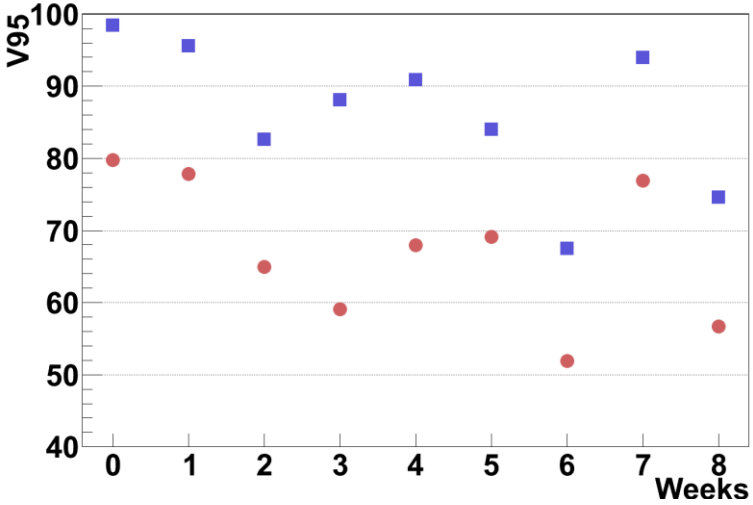


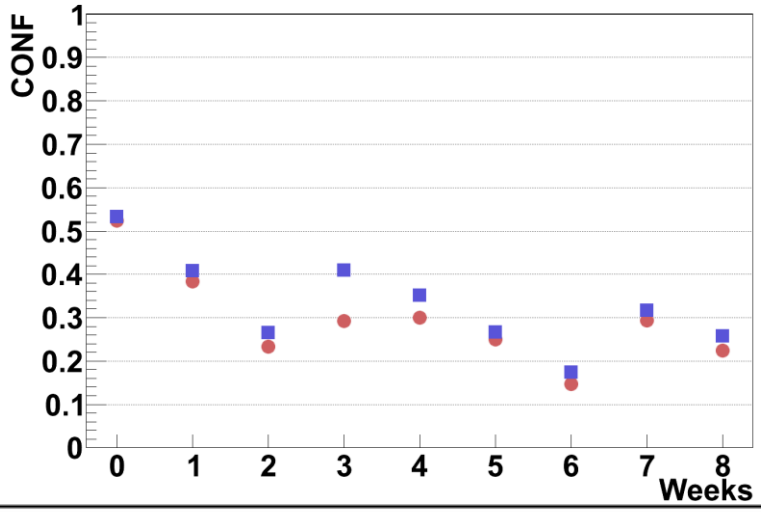
GW = gating window

Results

ITV margins

Patient 2





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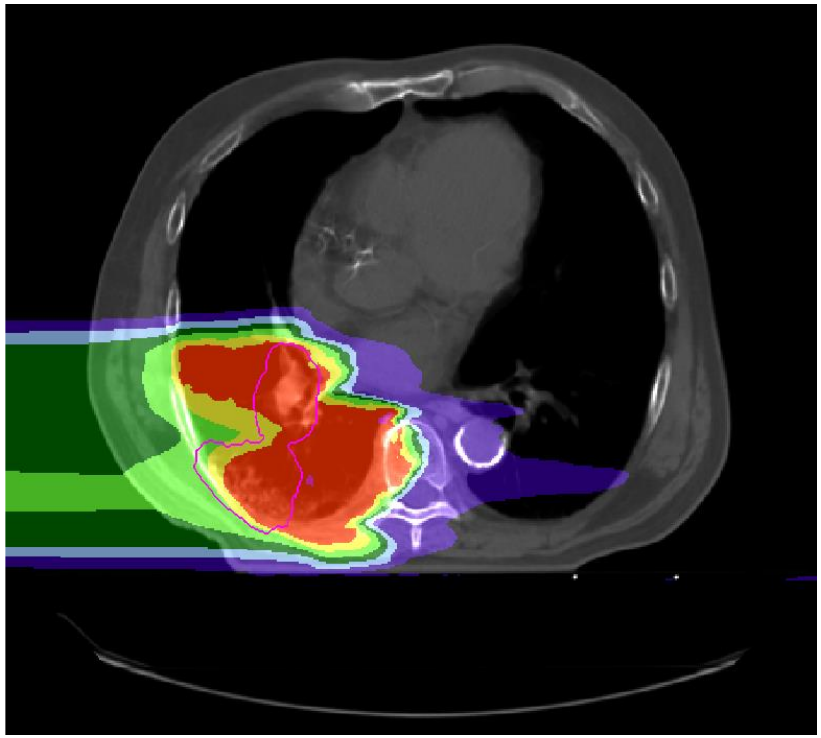
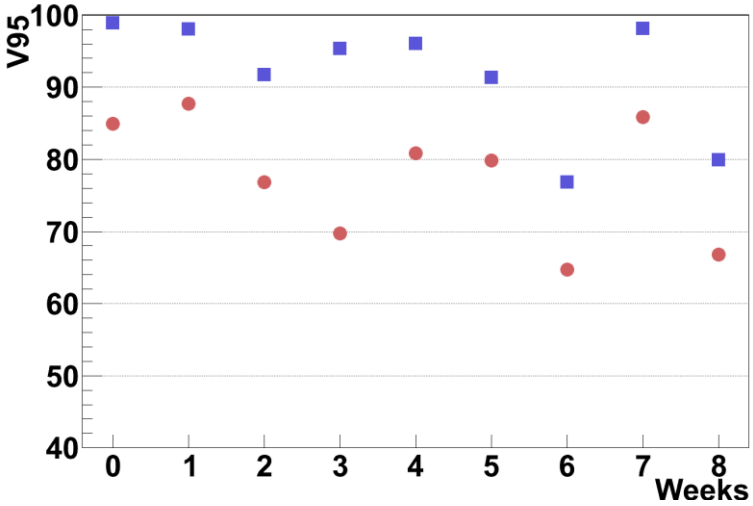


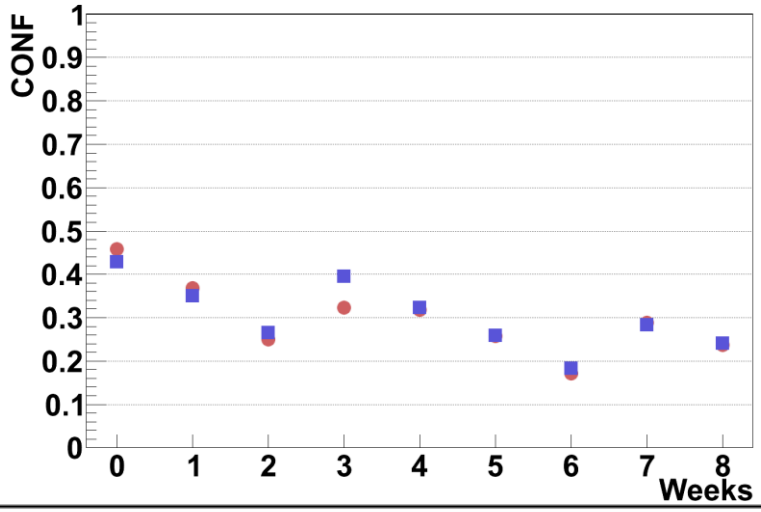
GW = gating window

Results

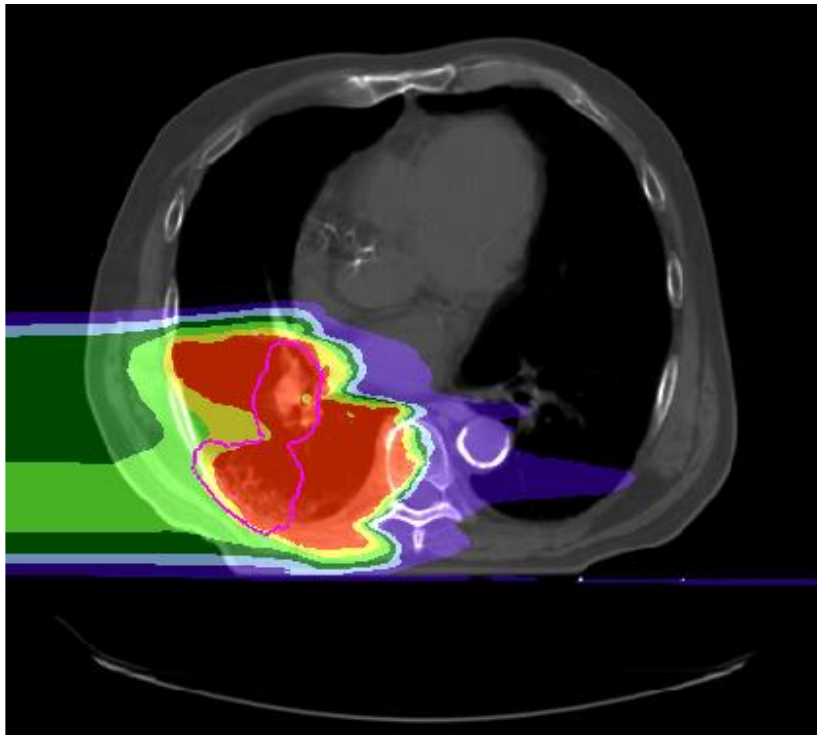
ITV + 3mm isotropic margins

Patient 2





- Focus 6mm / GW 50%
- Focus 15mm / GW 11.9%

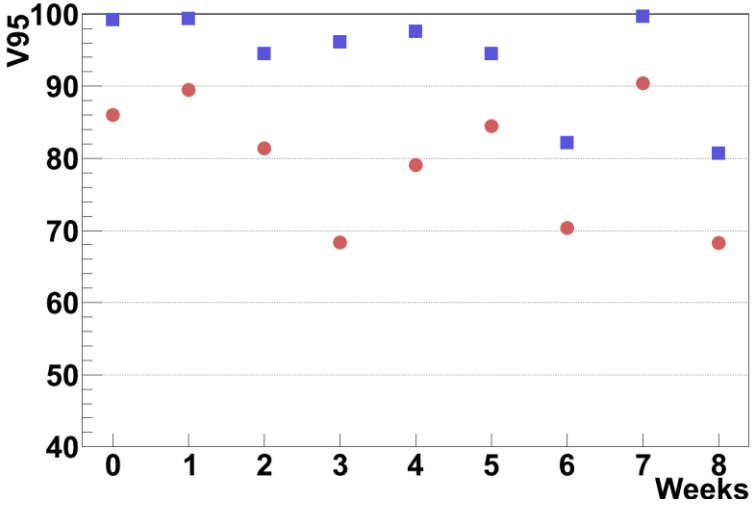


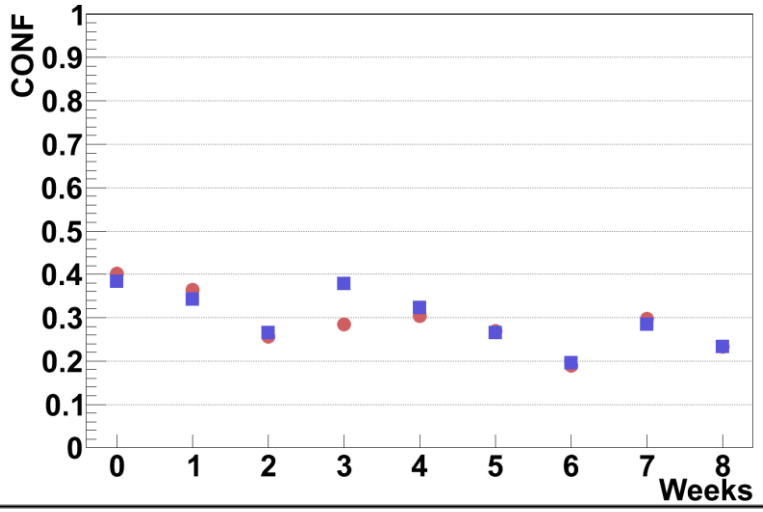
GW = gating window

Results

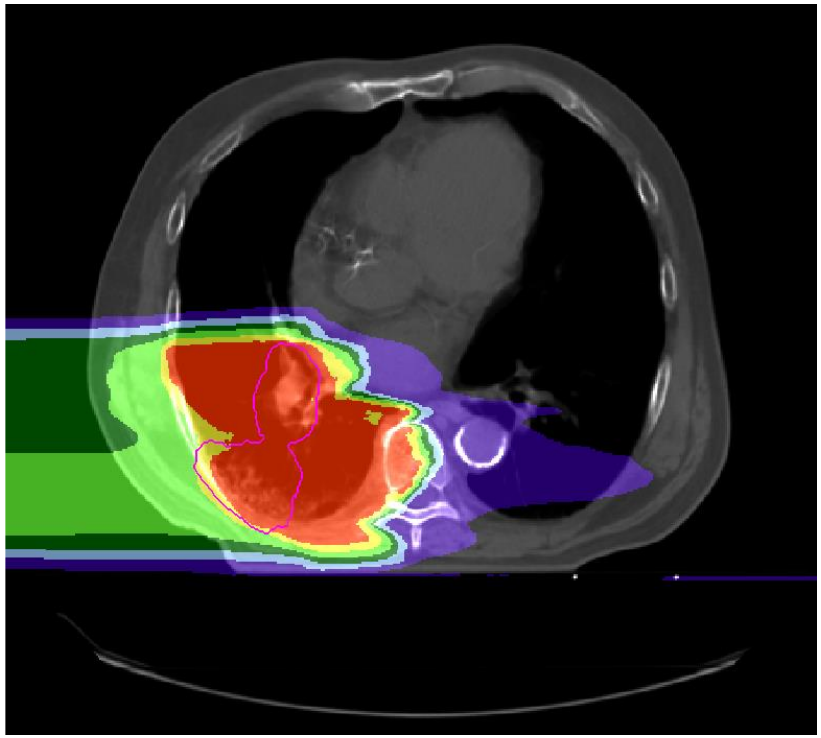
ITV + 3mm+3% range margins

Patient 2





- Focus 6mm / GW 50%
- Focus 15mm / GW 11.9%

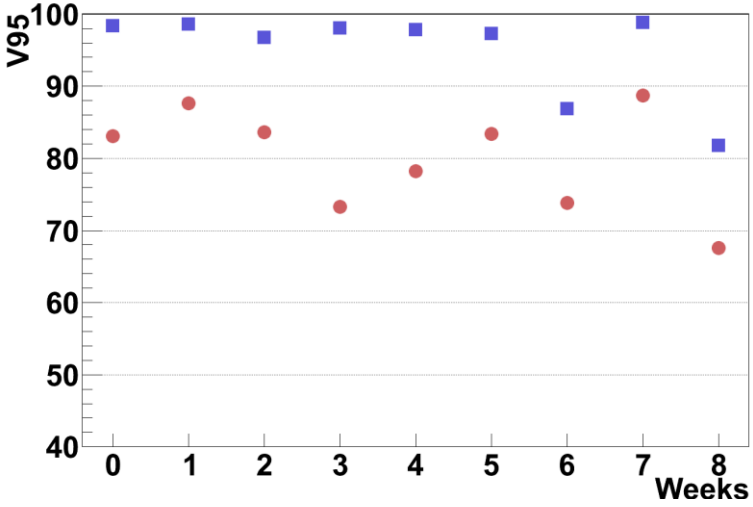


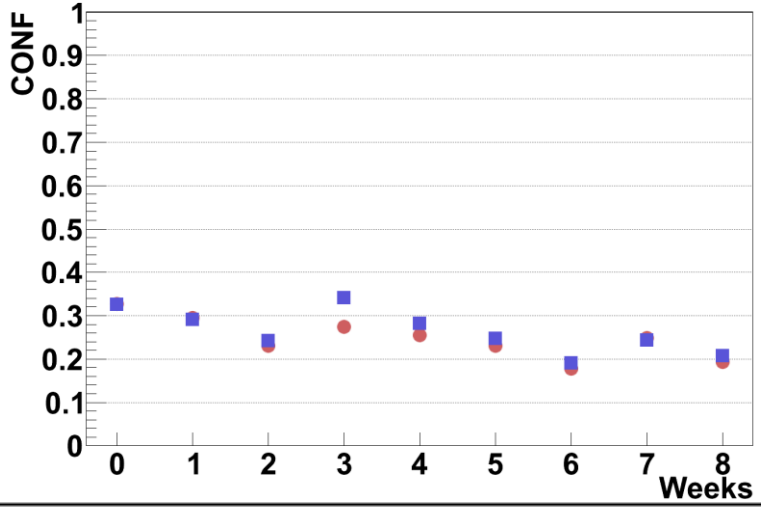
GW = gating window

Results

ITV + 3mm isotropic margins + 3mm+3% range margins

Patient 2





- Focus 6mm / GW 50%
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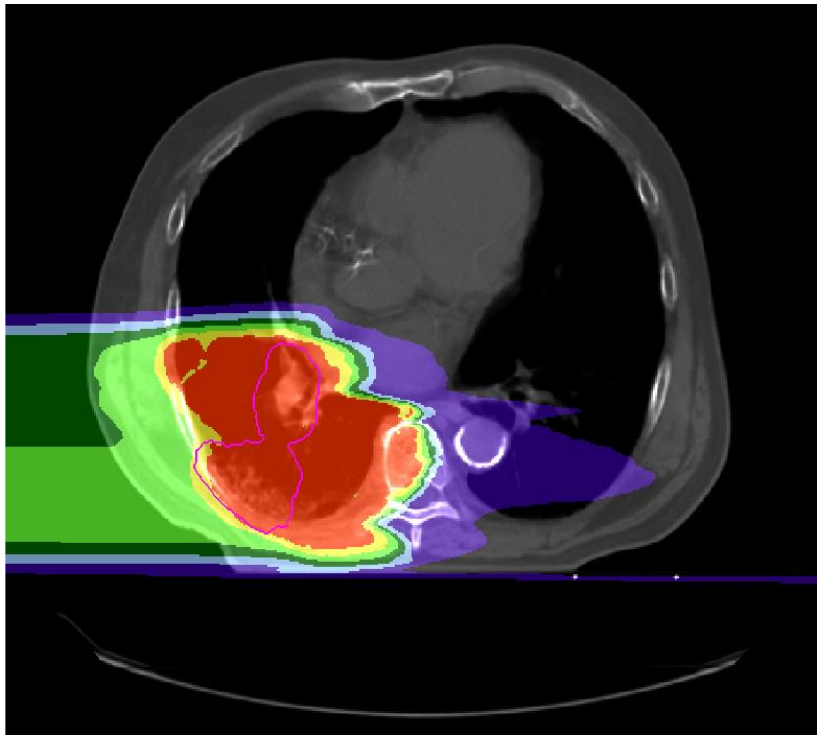
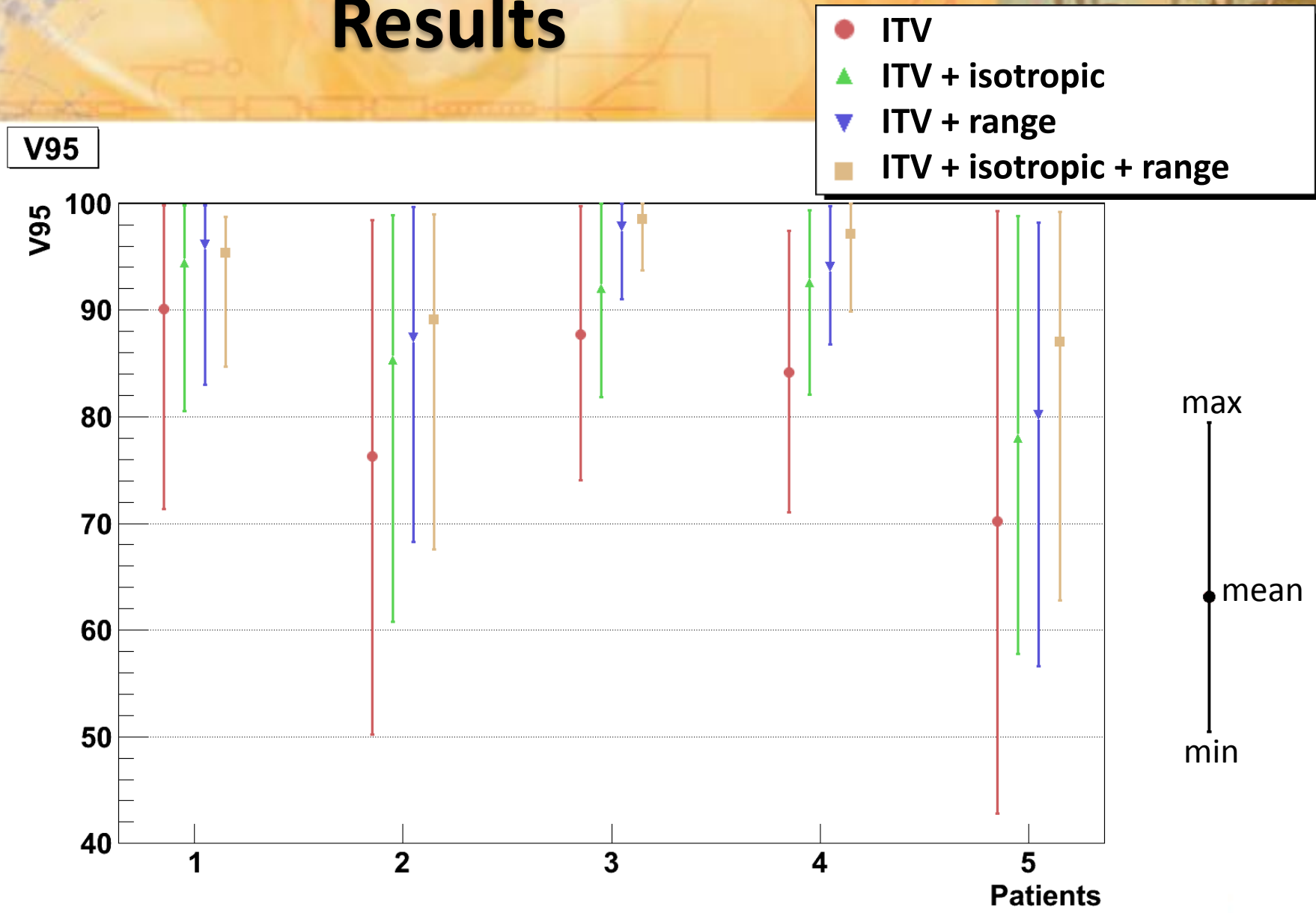
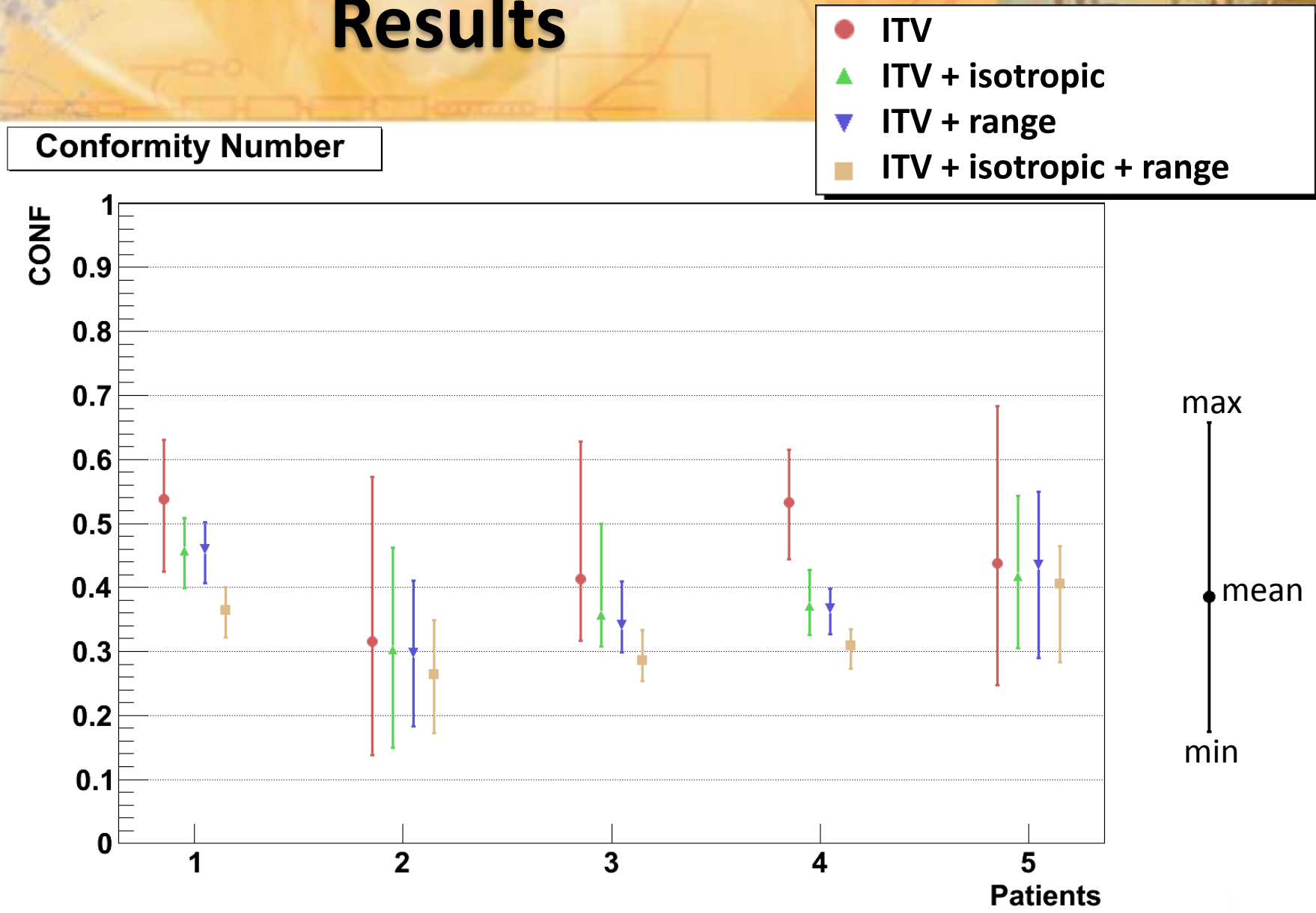


GW = gating window

Results


ITV
ITV + isotropic
ITV + range
ITV + isotropic + range
V95
V95
100
90
80
70
60
50
40
1
2
3
4
5
Patients
max
mean
min

Results


ITV
ITV + isotropic
ITV + range
ITV + isotropic + range
Conformity Number
CONF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
Patients
max
mean
min

Summary

Margins	Focus (mm)	GW* (% of amplitude)	V95 (range)	CN (range)
ITV	6	50	72.7 (42.8 to 94.5)	0.39 (0.15 to 0.62)
ITV	15	11.9	89.2 (67.5 to 99.8)	0.45 (0.17 to 0.66)
ITV + 3mm isotropic	15	11.9	94.2 (76.8 to 100)	0.38 (0.18 to 0.52)
ITV + 3mm+3% range	15	11.9	96.4 (80.7 to 100)	0.38 (0.2 to 0.53)
ITV + 3mm isotropic + 3mm+3% range	15	11.9	97.6 (81.8 to 100)	0.33 (0.19 to 0.45)

- Dose homogeneity deteriorated due to anatomic changes
- Partial recovery of target coverage using large focus and small gating window
- More important impact of focus
- Better recovery of target coverage using margins but more irradiated tissue

*GW = gating window

Conclusion

- Best target coverage obtained with combination of isotropic and range margins but more irradiated tissue
- Multiple fields and rescanning as a next step to further improve target coverage
- Adaptive treatment planning strategy:
  - Correctable positionning errors
  - Real anatomic changes ⟶ replanning

Thank you for your attention!