Photons, protons or carbon ions for stage I NSCLC - results of the multicentric ROCOCO *in silico* study

Krista C.J. Wink[1], Erik Roelofs[1], Charles B. Simone[2], Urszula Jelen[3], Nicolas Jansen[4], Wim Dries[5], Stephen Avery[2], Alina Santiago[3], Judith van der Stoep[1], Esther G.C. Troost[1], Philippe Lambin[1].
krista.wink@maastro.nl

Disclosures

- **None**

What is ROCOCO?

- International collaboration network
- *In silico* planning study
- Currently 16 partners

- MAASTRO: data host & coordinator
- Photons *vs* protons *vs* C-ions
- Non-small cell lung cancer, head and neck cancer (*Eekers, PTCOG 22-05*), prostate cancer

http://www.mistir.info/ROCOCO

Stage I NSCLC ROCOCO study

- 25 consecutive patiënts
- Stage I NSCLC (max tumor size 3cm)
- Treated with SBRT @ MAASTRO clinic
- **Rapid Arc**: Maastricht (NL)
- **IMRT**: Eindhoven (NL)
- **Cyberknife**: Liège (FR)
- **DSP**: Pennsylvania (USA)
- **IMIT**: Marburg (GER)

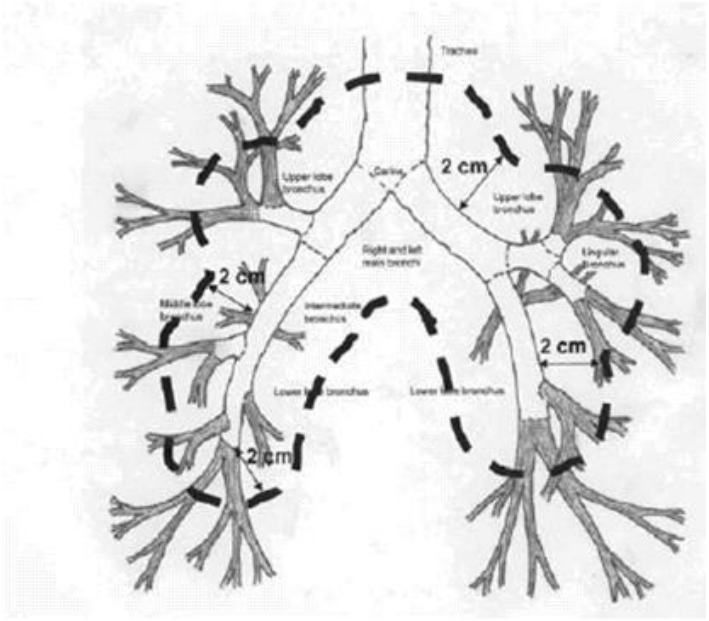
Methods (1)

- Contouring/delineation @ MAASTRO on 4DCT (50% exhale phase)

- CTV = GTV + 5mm
- PTV = CTV + 5mm
- No ITV

- Prescribed dose: **8x7.5Gy**

  (TD 60Gy, BED 105Gy, EQD2 87.5Gy))



Timmerman et al, J Clin Oncol 24, 2006

Methods (2)

- Radiobiology: RBE 1.1 used for protons, LEM1 used for c-ions

- Comparison of dose-volume metrics, IMRT serving as 'golden standard'
  - Iso-effective tumor control (NTCP)
  - Dose-escalation probability (MTD)

Dose:

- 95% of the PTV should receive at least 100% of the prescribed dose
- D_{max} <140%

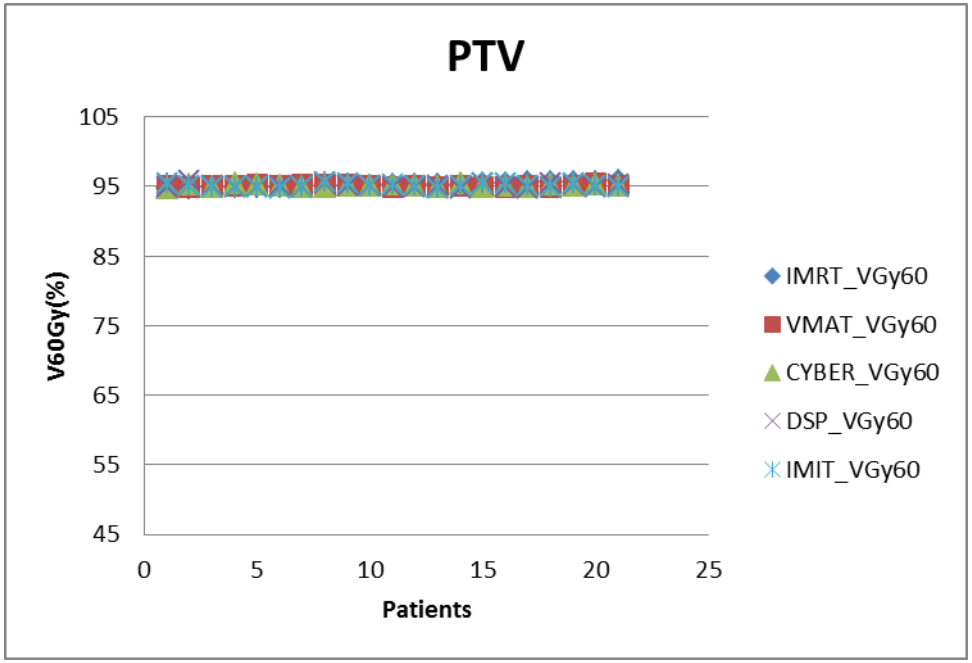
OAR:

- Objectives equal to clinical practice (with added priorities)
- Additional objectives for chest wall and ribs

PTV – re-scaling

n=21	Measure	IMRT	VMAT	Cyberknife	DSP	IMIT
PTV	V60Gy	95.2 (0.33)	95.1 (0.13)	95.1 (0.19)	95.1 (0.29)	95.1 (0.26)
	D_{mean}	65.0 (1.2)	67.6 (1.4)*	65.9 (0.6)*	63.6 (1.5)*	63.2 (0.59)*
	$D_{2\%}$	72.7 (2.8)	76.6 (2.7)*	72.6 (0.68)	68.1 (3.2)*	67.3 (1.2)*

* = significant (p<0.01); two-sided pairwise Wilcoxon test against IMRT



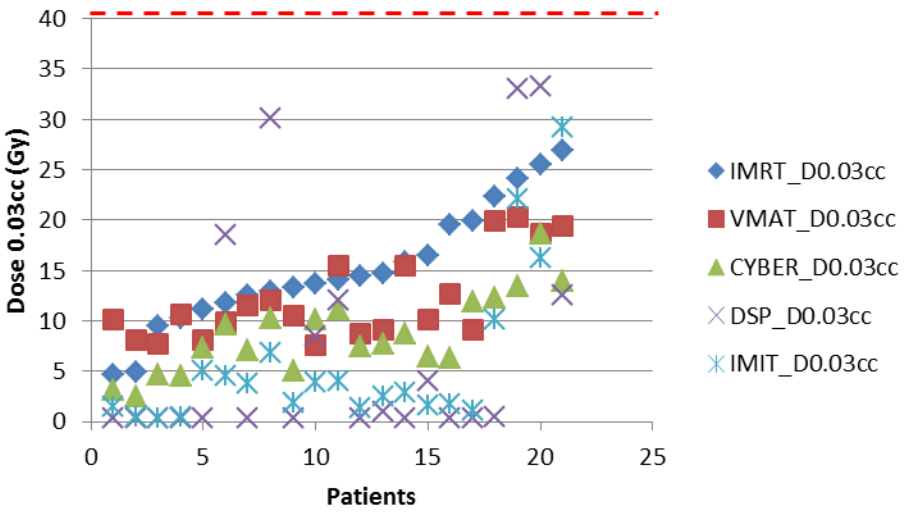
OAR comparison

	Measure	IMRT	VMAT	Cyberknife	DSP	IMIT
Healthy lungs	Dmean	4.9 (1.7)	4.5 (1.7)*	4.5 (2.2)	4.3 (1.7)*	2.4 (1.1)*
	V20Gy (<15%)	7.3 (2.9)	6.1 (2.8)*	4.4 (2.8)*	8.8 (3.4)*	4.4 (2.1)*
Esophagus	Dmean	3.2 (1.4)	2.4 (1.0)*	2.6 (1.5)	0.43 (1.0)*	0.46 (0.6)*
	D0.03cc	15.2 (6.1)	12.2 (4.3)*	8.7 (4.0)*	7.5 (11.6)*	5.8 (7.6)*
Heart	D0.03cc	12.7 (13.7)	9.9 (9.7)*	12.9 (7.1)	14.2 (19.1)	7.4 (10.6)*
Mediastinal structures	Dmean	2.8 (1.1)	2.3 (0.8)*	3.0 (1.5)	0.75 (0.7)*	0.41 (0.3)*
	D0.03cc	34.6 (13.3)	31.9 (12.1)	29.3 (13.9)*	48.7 (18.9)	36.0 (14.6)
Spinal cord	D0.03cc	9.8 (2.9)	14.0 (6.8)*	7.1 (3.5)*	2.5 (6.1)*	3.2 (3.9)*
Ribs	D2%	62.1 (5.5)	63.6 (7.6)	61.5 (9.0)	64.2 (2.6)	60.7 (6.6)
Chest_wall	$D_{2\%}$	42.3 (10.9)	39.6 (10.5)*	34.9 (16.5)*	54.1 (8.3)	34.5 (12.9)*

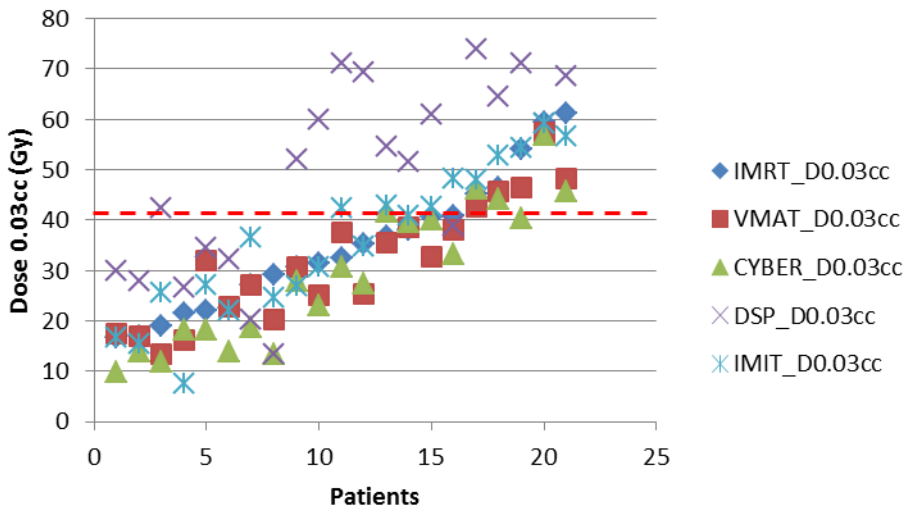
* = significant (p<0.01); two-sided pairwise Wilcoxon test against IMRT

Constraint not reached.

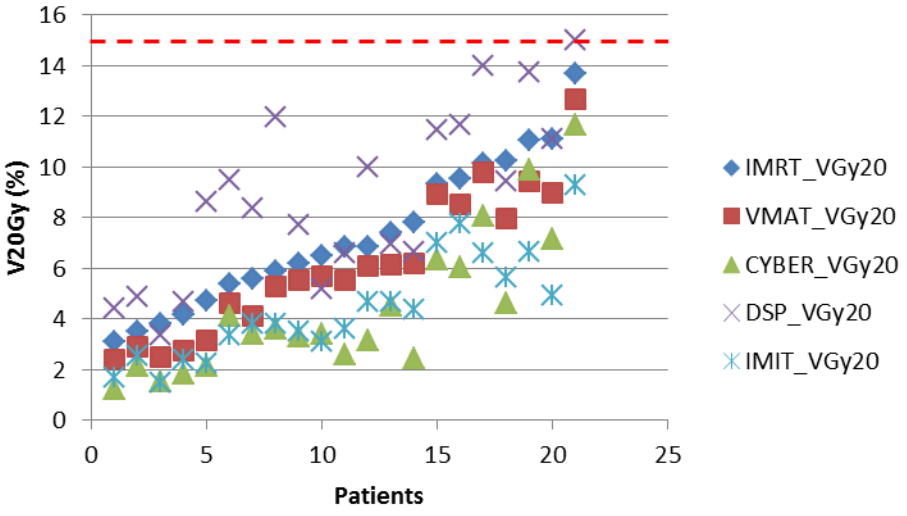
Esophagus



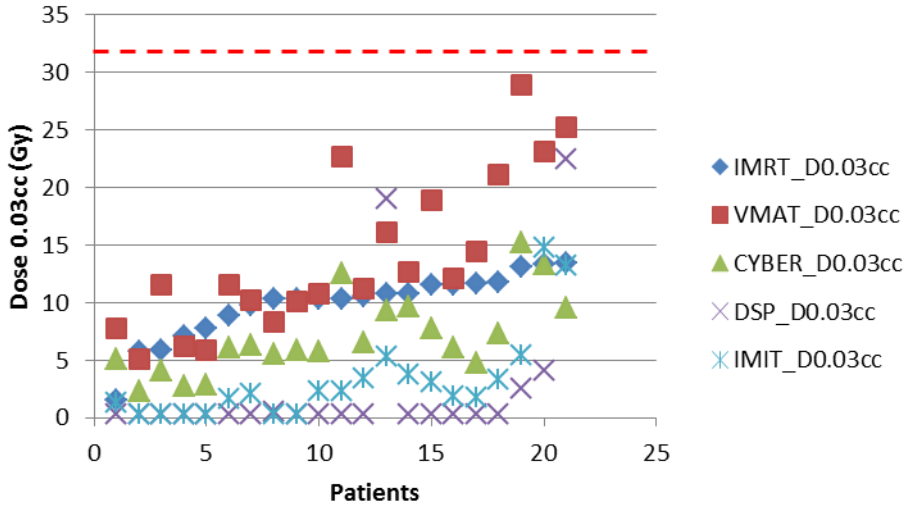
PRV mediastinal structures



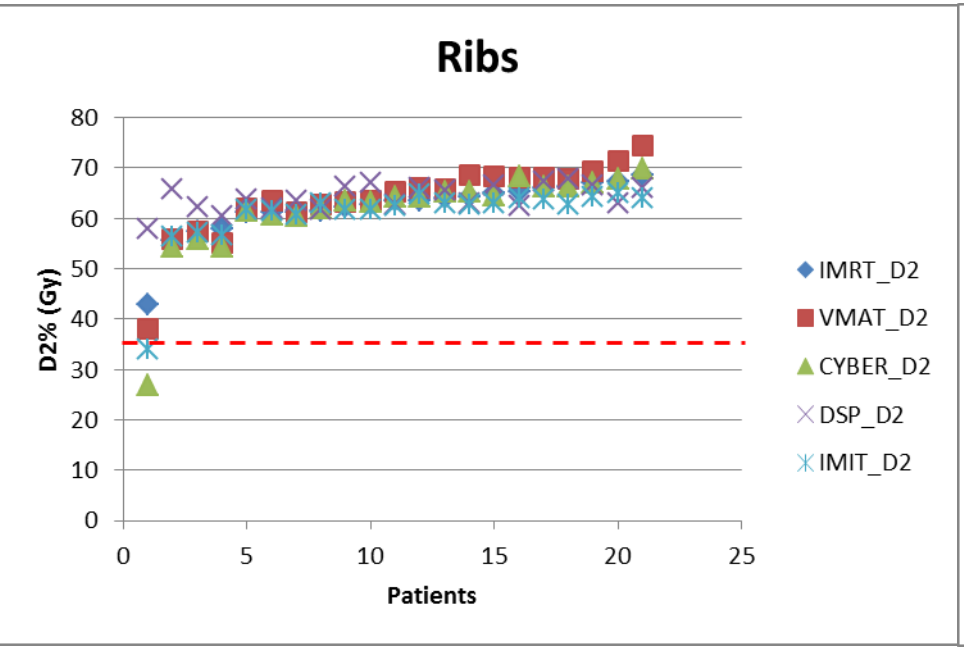
Lungs

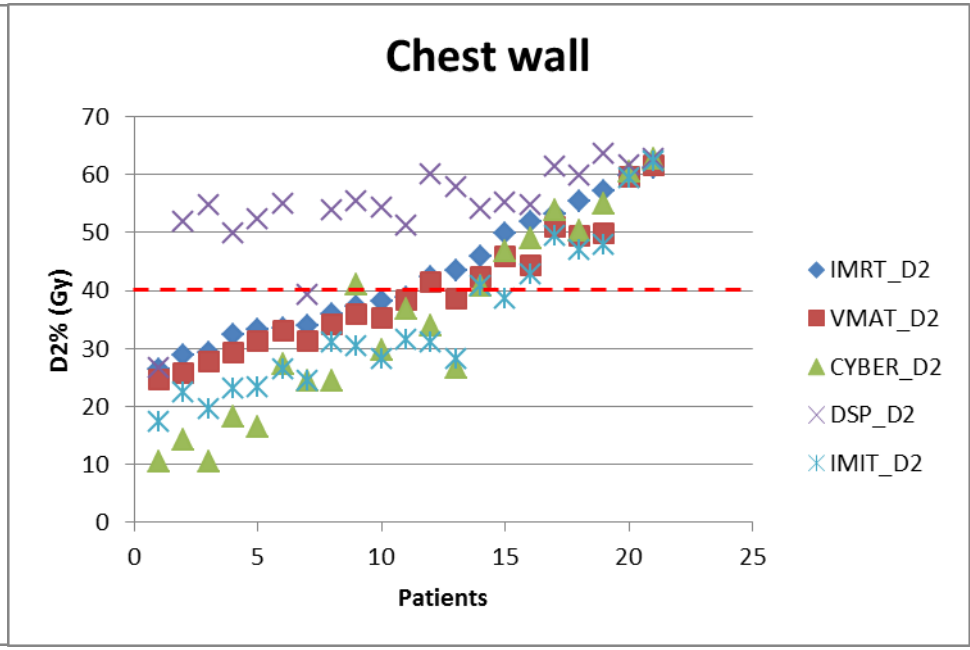


Spinal cord

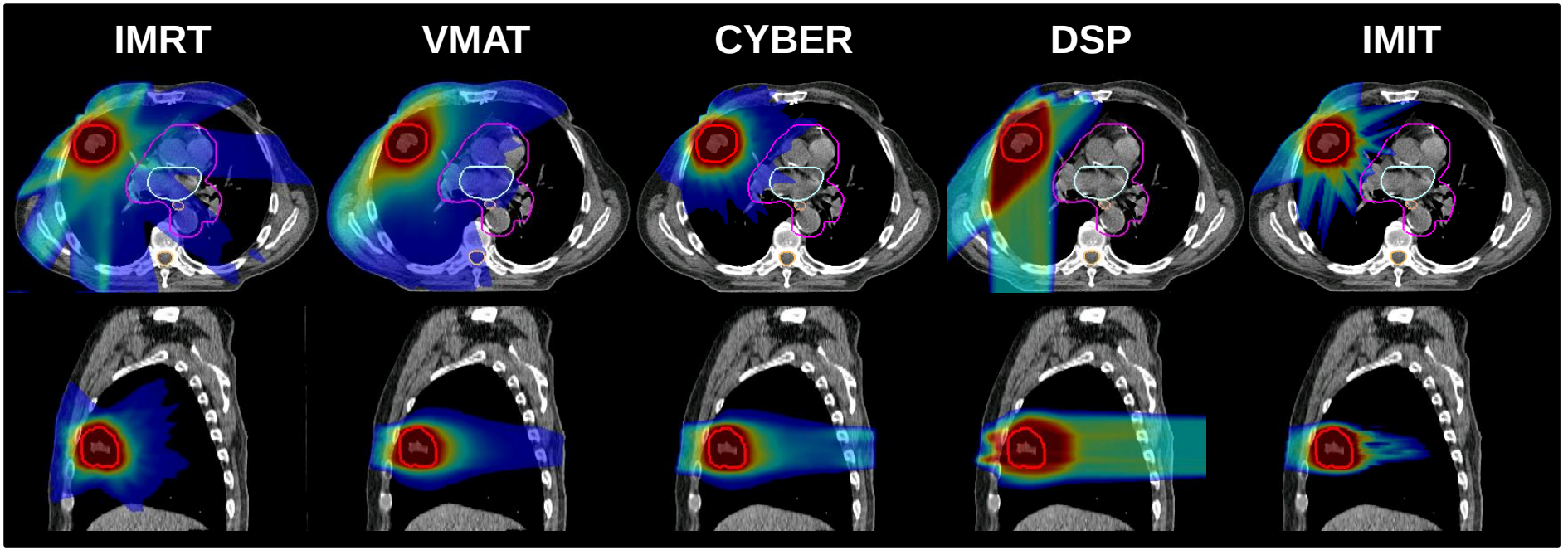


Chest wall challenge…





Patient example



Conclusions

PTV:

- Both protons and carbon-ions deliver more homogenous doses to the PTVs with lower hot spots

OAR:

- Doses to the lungs, heart, and mediastinal structures lowest with IMIT
- Doses to the spinal cord lowest with DSP
- Mean doses to the OARs lowest using particle therapy, but dose to small volume within OAR may be higher
- RapidArc and CyberKnife allowed for reduced doses to most OARs compared with IMRT, therefore:

The additional benefit of particle therapy irradiation for stage I NSCLC may not be the most relevant indication for DSP or IMIT

Future work

- Continue analysis: dose escalation
- Further hypofractionation (and central tumors)
- Lung re-irradiation study

- Develop tools to distinguish patients who would benefit from protons/c-ions

- Cost-effectiveness

- Clinical relevance

Proton Decision Support System

Acknowledgements

MAASTRO clinic

- Erik Roelofs
- Esther Troost
- Esther Bloemen-vanGurp
- Judith van der Stoep
- Philippe Lambin

Penn Medicine

- Charles B. Simone II
- Stephen Avery
- Timothy Solberg

CZ Eindhoven

- Wim Dries
- Mieke Verhoeven
- Julia Smits

Marburg

- Urszula Jelen
- Andrea Wittig
- Alina Santiago
- Filippo Ammazzalorso

Liege

- Nicolas Jansen
- David Dechambre
- Paul Nguyen
- Veronique Baart