

Introduction

We evaluate three commercially available treatment planning systems (TPS) for intensity modulated arc therapy (IMAT) with regard to the optimization and dose calculation algorithm and the plan outcome.

Methods and Materials

Patient Cases

- * re-optimization and re-planning of 25 clinical accepted RA plans (cRA)
- * prostate/prostatic fossa, up to 2 levels (n=9), head and neck (HnN), up to 3 levels (n=8, lung (n=4)/upper abdominal PTVs (n=4))
- * transfer of PTV(s) / OAR / normalization method = physician's intent

Re-Optimization Method

- * independence from plan outcome of cRA
- * change of collimator rotation (45°(cRA) -> 20°(rRA, SA, MoV) or 0 (MoV))
- * adaptation of arc length, if necessary
- * additional helping structures to model e.g. conformity, if necessary

LINAC

- * VARIAN Trilogy
- * 6MV photons, only
- * 120 MLC

Investigated TPS

- * ECLIPSE RapidArc (RA) Version ____
- * PINNACLE SmartArc (SA) Version ____
- * MONACO VMAT (MoV) Version 2.4

evaluation method

- * PTV: $PTV\text{-coverage} = D_{\text{mean(TPS)}}/D_{\text{prescribed}}$
 $HI = D_{1\%}/D_{99\%}$
 $CI = (V_{PTV} \cap V_{\text{prescr.dose}})^2 / (V_{PTV} * V_{\text{prescr.dose}})$ ¹
- * OAR: DVH with respect to physician's intent and QUANTEC criteria
 $\rightarrow OAR\text{-exposure} = D_{x(TPS)}/D_{x(\text{phys.intent})}$ and $D_{x(TPS)}/D_{x(QUANTEC)}$
- * physical plan parameters: total arc length monitor units (MU) calculation time

Results

Apart from four HnN and one lung case, for which MoV yield no competitive plan, all three investigated TPS are capable to calculate reasonable IMAT plans with comparable learning curves (2 to 6 trials) and reasonable calculation times (6 to 225 min., fig. 5).

The largest arc length is found for MoV (886°±191°), as here the arc length is calculated by the TPS itself instead of a user defined and preset plan parameter (cRA: 725°±137°, rRA: 731°±85°, SA: 726°±66°). Accordingly, the number of MU is the highest for MoV (table 1).

Evaluating the PTV coverage (fig. 3), CI (fig. 1) and HI (fig. 2), we see the best PTV coverage for MoV, the best CI for RA and the highest homogeneity for rRA. The OAR exposure depends on the treatment site, but has also high standard deviations as some criteria are uncritical to achieve and some are discarded by the physician in favor of a better PTV coverage.

Discussion and Conclusion

All three investigated IMAT planning tools calculate reasonable IMAT plans with comparable learning curves. Calculation times differ due to adjustment of optimization parameter, calculation volume and case complexity. Differences in the DVH drop offs for serial OAR, skin dose and segment shapes were seen due to different optimization and dose calculation algorithms.

Non-competitive MoV plans can have their origin in either MONACO's segmentation algorithm or RA and SA might predict non-realistic dose distribution – as here dose algorithms are used that model lateral scattering in case of tissue heterogeneities not as properly as the Monte Carlo dose engine in MONACO does. Future calculations using a later version of MONCAO, dose measurements at the linac and separate Monte Carlo calculations will prove the reliability of the calculated dose distributions.

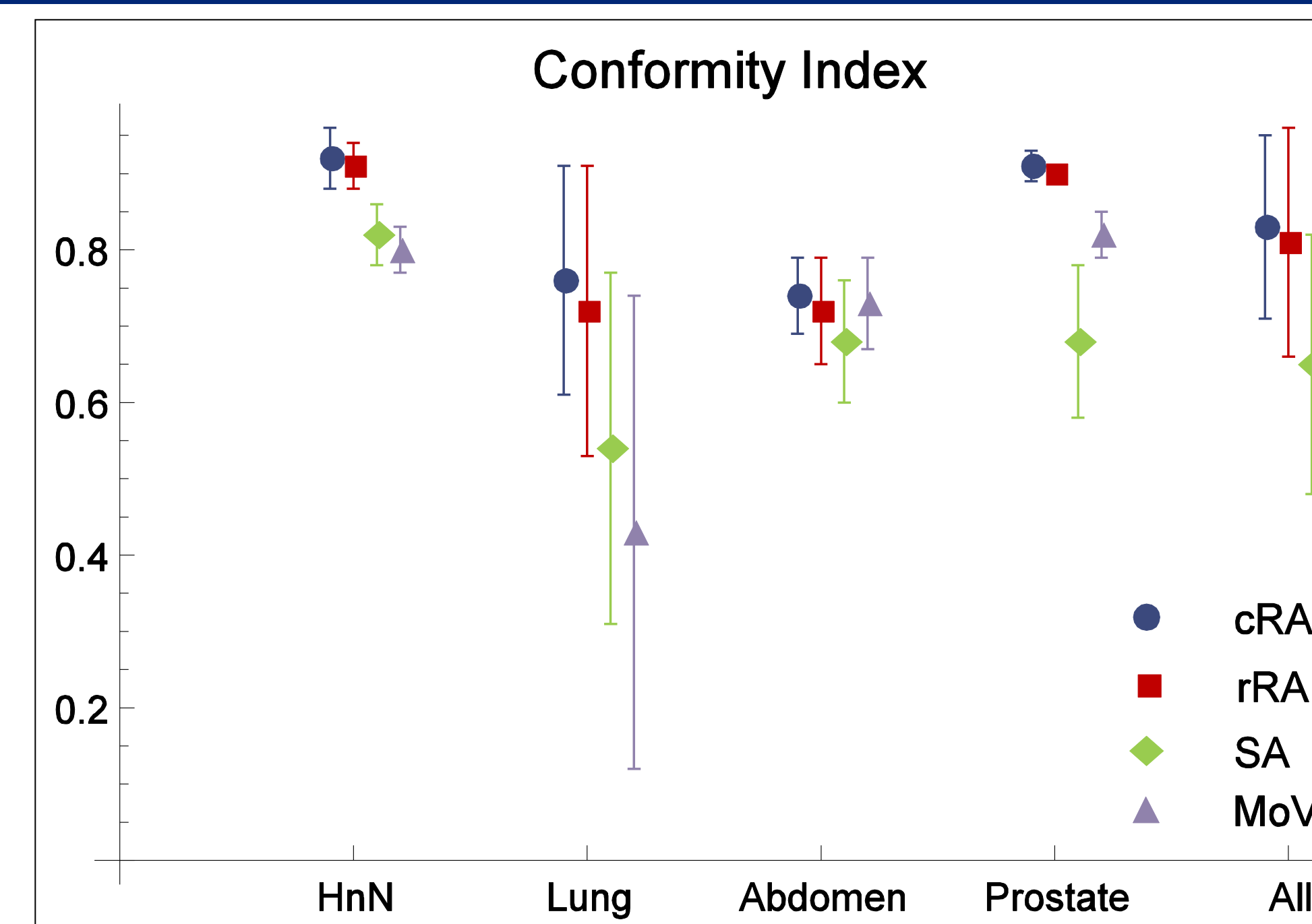


fig. 1: Conformity Index (average and standard deviation), according to Paddick (2000)¹

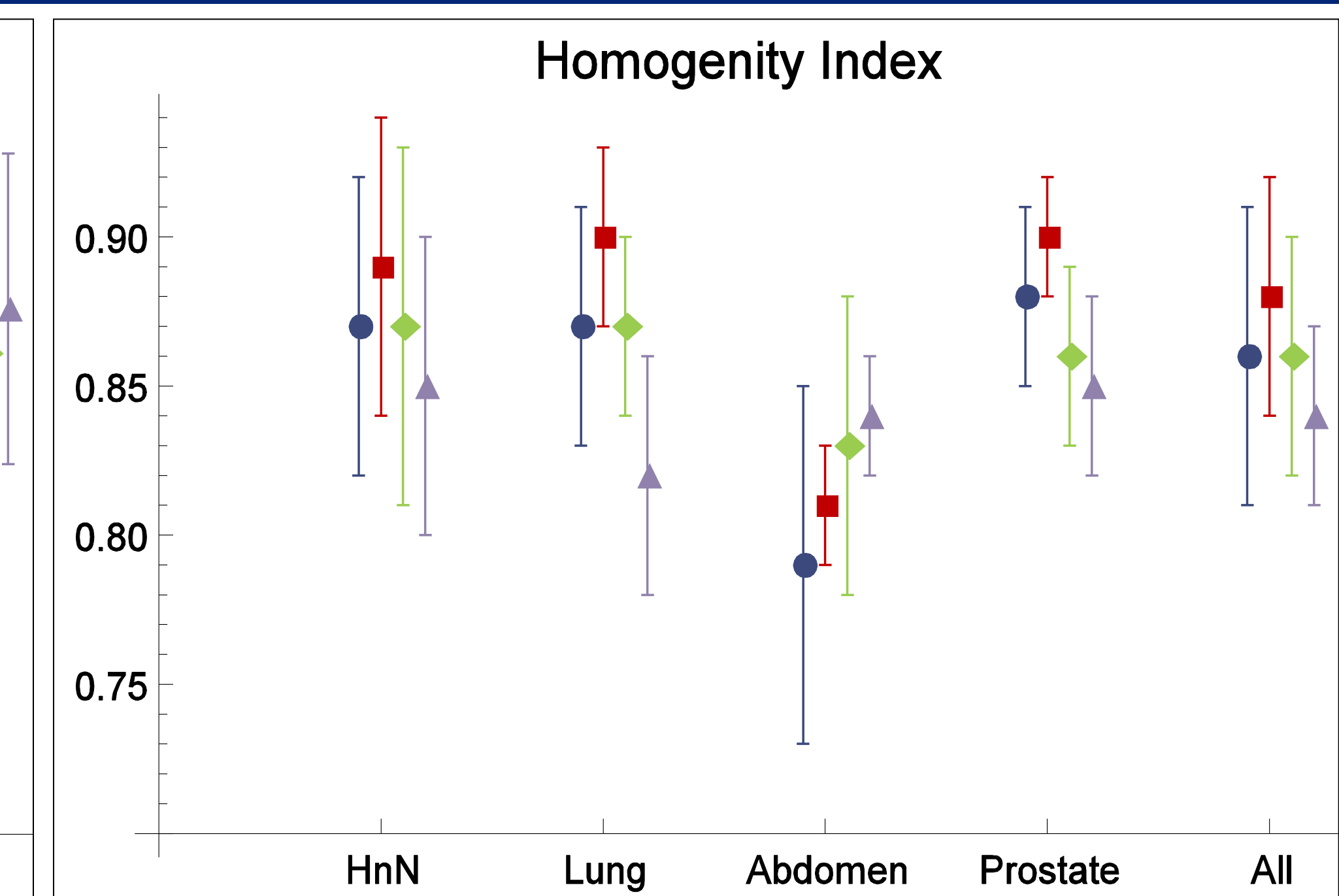


fig. 2: Homogeneity Index (average and standard deviation)

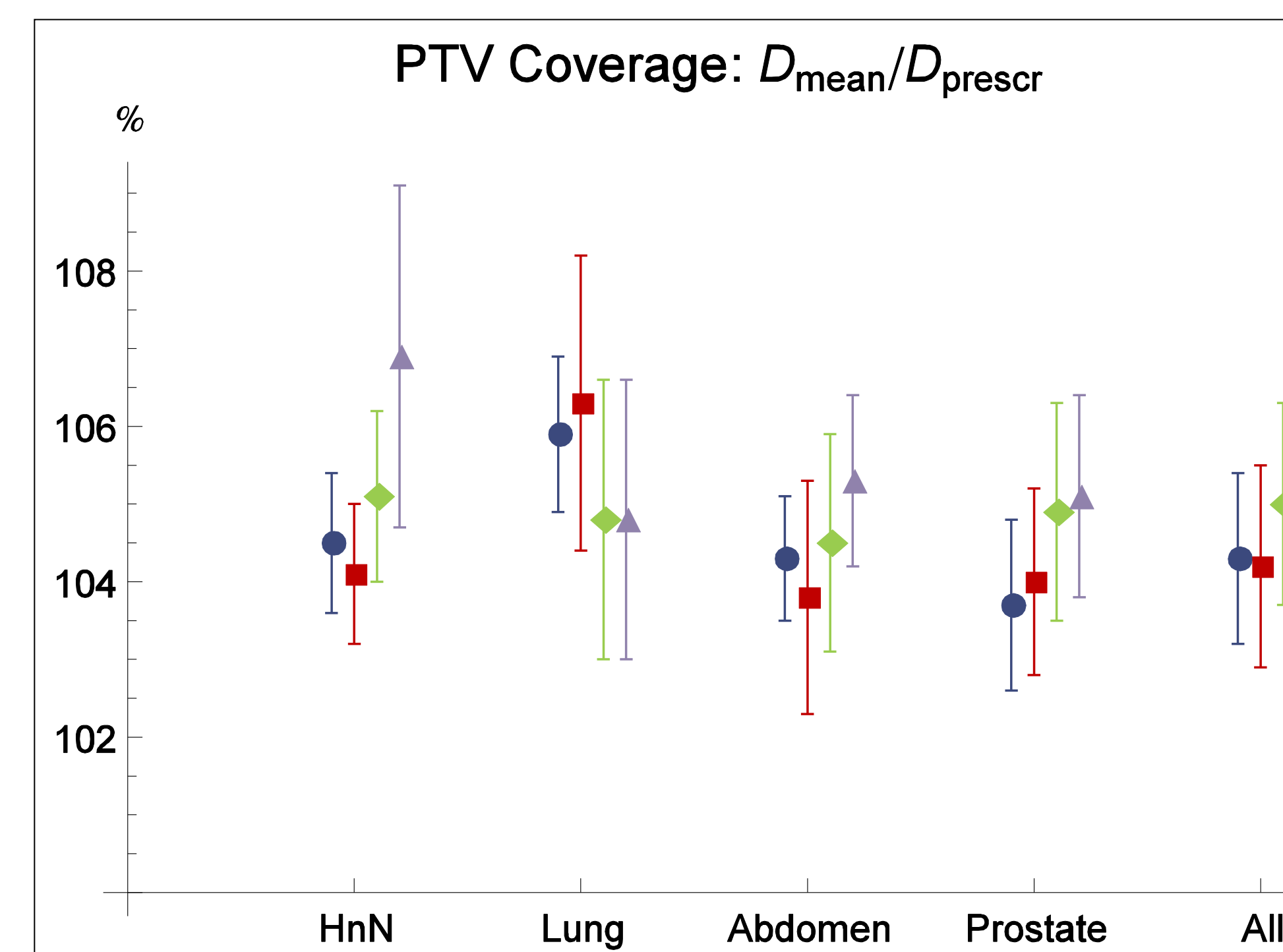


fig. 3: PTV coverage (average and standard deviation), for HnN and Prostate PTV 1 (receiving the highest dose) is shown.

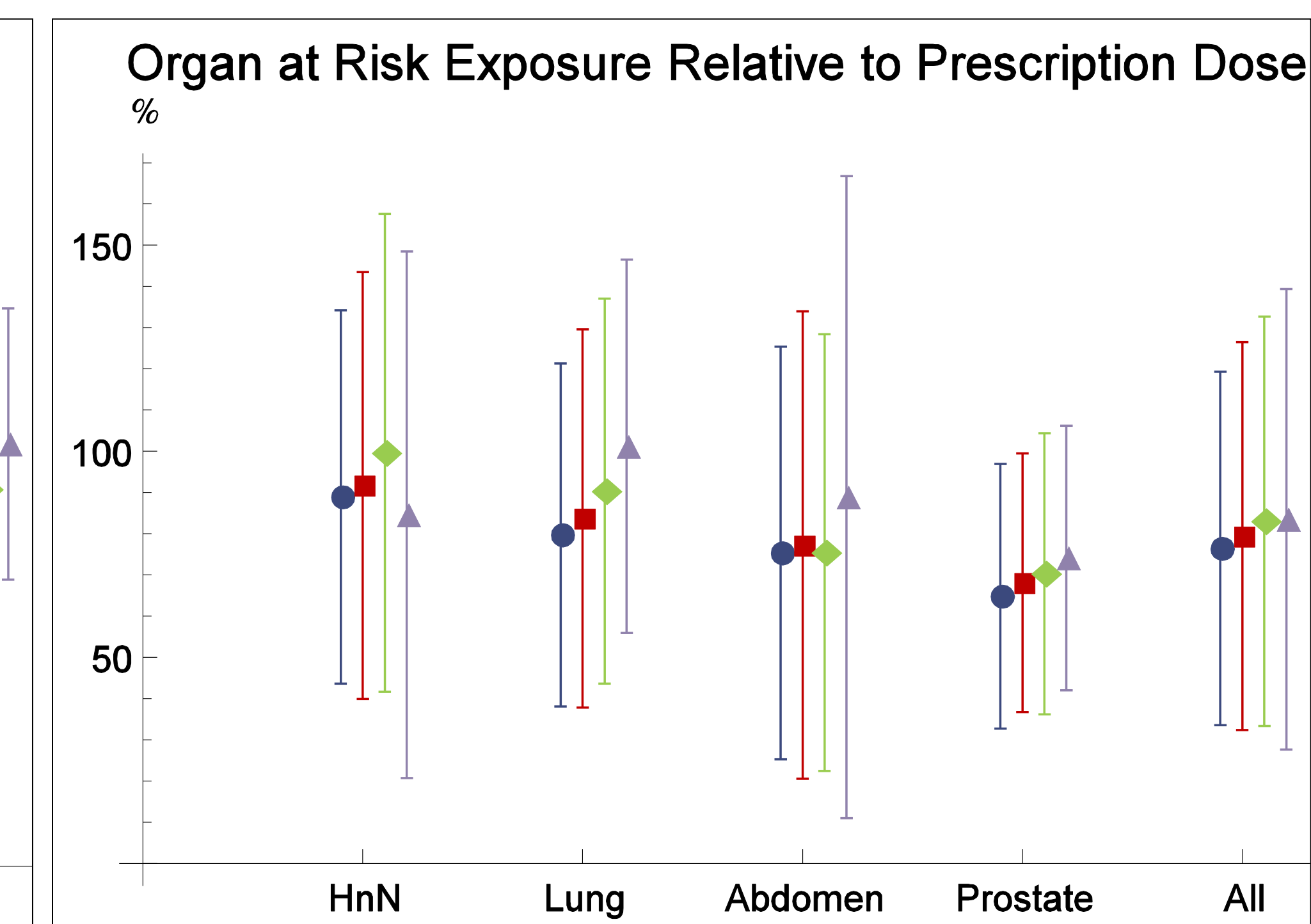


fig. 4: OAR exposure (average and standard deviation)

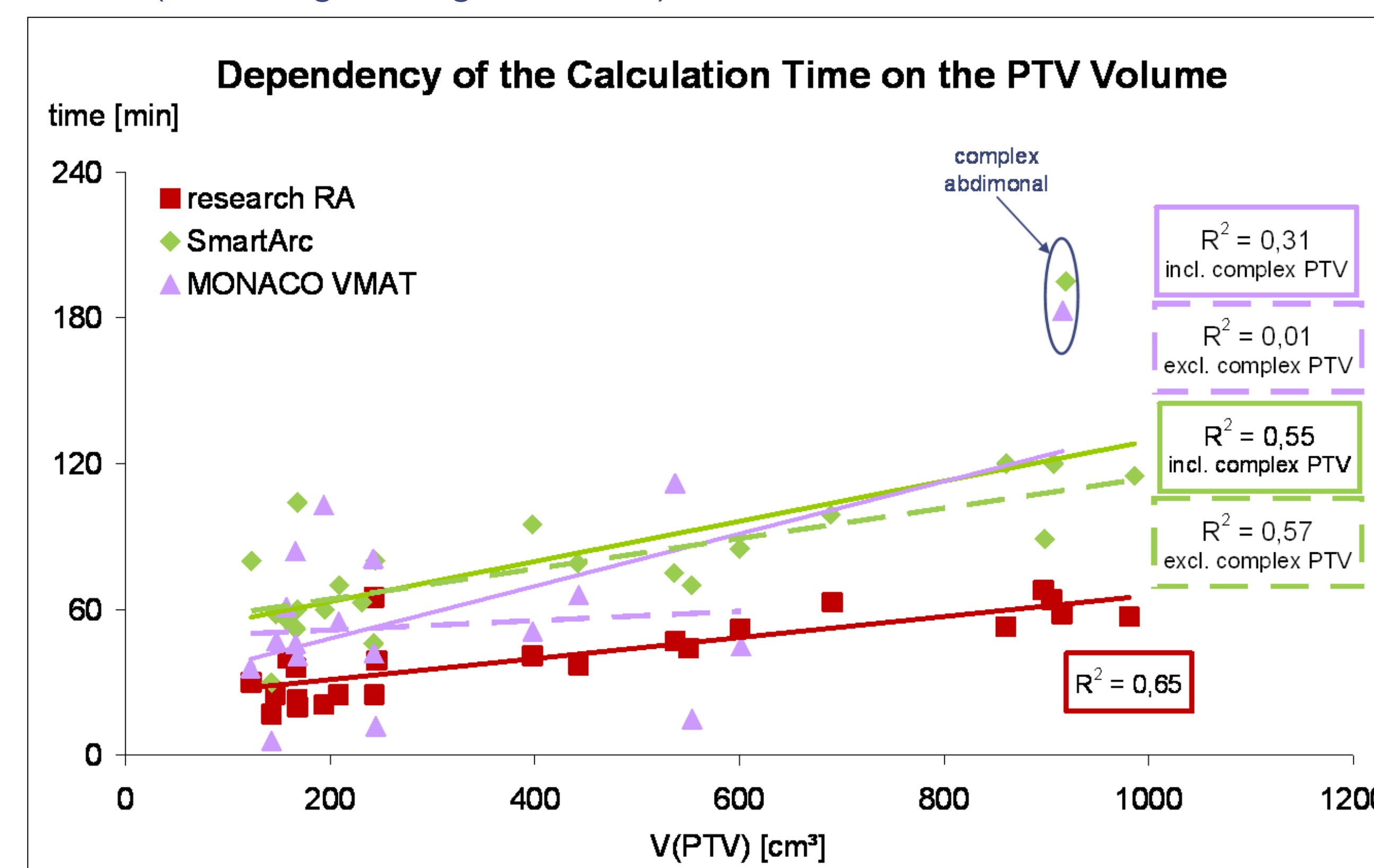


fig. 5: Influence of the PTV volume to the calculation time— including (solid lines) and excluding (dashed lines) one extreme complex abdominal case (blue circle).

tab. 1: average MU and standard deviation for all investigated TPS and treatment sites

MU	clinical RA average ± σ	research RA average ± σ	SmartArc average ± σ	MONACO VMAT average ± σ
HnN	463 ± 125	443 ± 80	502 ± 149	817 ± 235
lung	368 ± 67	367 ± 43	494 ± 76	757 ± 209
abdomen	480 ± 92	440 ± 41	491 ± 60	779 ± 207
prostate	905 ± 138	830 ± 100	944 ± 193	1110 ± 125
all	610 ± 255	570 ± 214	658 ± 261	932 ± 233

¹ Paddick I. (2000). A simple scoring ratio to index the conformity of radiosurgical treatment plans. J Neurosurg, 93, pp. 219-222