Automation on RaySearch

ICTP School of Medical Physics for Radiation Therapy: Dosimetry and Treatment Planning for Basic and Advanced Applications
12 September 2025
Trieste

Christian Fiandra, PhD

AZIENDA OSPEDALIERO - UNIVERSITARIA Città della Salute e della Scienza di Torino

Department of Oncology, University of Turin

RayStation infrastructure
Citta della Salute e della Scienza, Turin, Italy
Three hospitals

Molinette

S. Giovanni

S. Anna

5 Versa HD

RayStation server

Radixact

First automation step:
Images loading e contouring

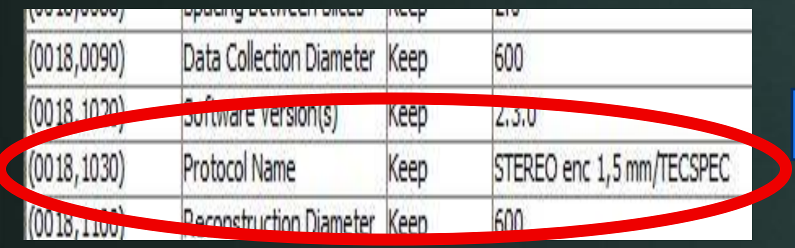
Create patient in the database with images and structures

Philips CT Big Bore

Tag Dicom (0018,1030)	Structure template RayStation
STANDARD/TECSPEC	
STEREO ENC 1,5 mm/TECSPEC	Brain_Template and Couch SRS_Template
ENC 3 mm Vol/TECSPEC	Brain_Template
TESTACOLL 2 mm Vol./TECSPEC	HN_Template
Pulm Gating 4D PRO/TECSPEC	Lung_Template
LIVER Gating 4D PRO/TECSPEC	Liver_Template
FEGATO 4D SEMI 2 mm/TECSPEC	Liver_Template
FEGATO / SURRENE NO 4D/TECSPEC	Liver_Template
TORACE 3 mm/TECSPEC	Lung_Template
SBRT VERTEBRATORACICHE/TECSPEC	Lung_Template
TORACE 3 mm ESOFAGO/TECSPEC	Esoph_Template
TORACE 3 mm LINFOMA/TECSPEC	LIMP_Template
ABLAZIONE CARDIACA/TECSPEC	Lung_Template
MAMMELLA 3 mm/TECSPEC	BREAST_Template
MAMMELLA 3 mm C-PAP/TECSPEC	BREAST_Template
PELVI 3 mm PROSTATA/TECSPEC	PROSTATE_Template
PROSTATA IPO TOMO 2mm/TECSPEC	PROSTATE_Template
PELVI 3 mm/TECSPEC	Rectum_Template
SBRT VERTEBRALOMBARE/TECSPEC	Rectum_Template
T.M.I. 5mm/TECSPEC	TMI/TMLI_Template
T.M.L.I. 5mm/TECSPEC	TMI/TMLI_Template
MEDULLO 3 mm/TECSPEC	TMI/TMLI_Template
T.B.I. 5 mm/TECSPEC	TBI_Template

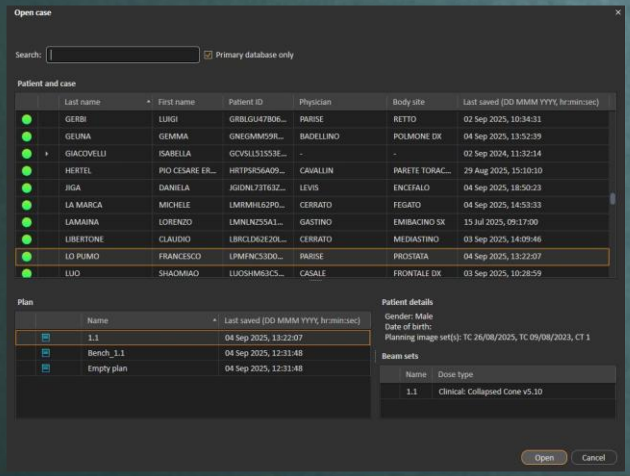
First automation step
Images loading e contouring

Dicom

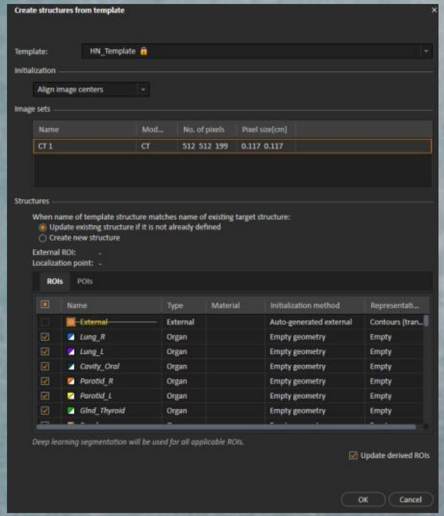


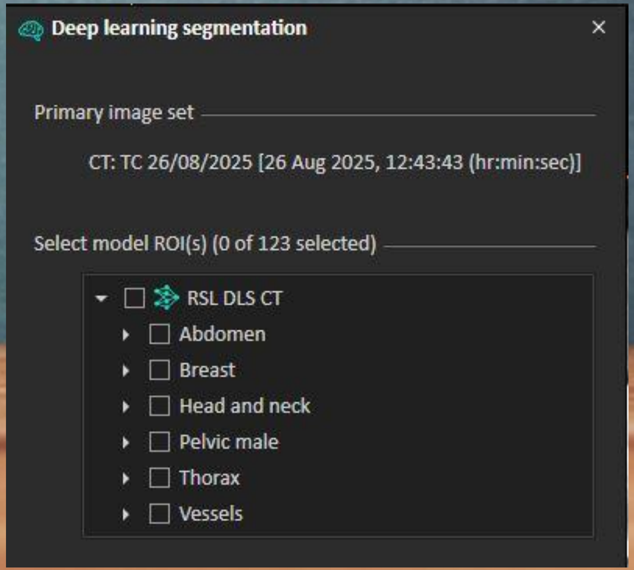
(0018,0090)	Data Collection Diameter	Keep	600
(0018,1020)	Software version(s)	Keep	2.3.0
(0018,1030)	Protocol Name	Keep	STEREO enc 1,5 mm/TECSPEC
(0018,1100)	Reconstruction Diameter	Keep	600

Database creation



Structures template





Second automation step
Planning

RayStation

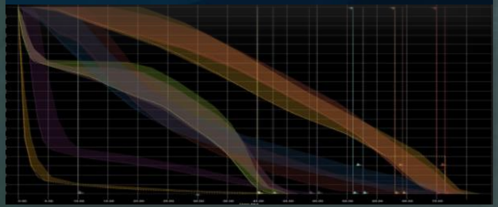
MCO

RayStation Plan Explorer

VARIAN medical systems

THE SOLUTION

RapidPlan™



Elekta ONE® Planning

M-cycle

Guided Planning Solution

AAPM REPORT NO. 263

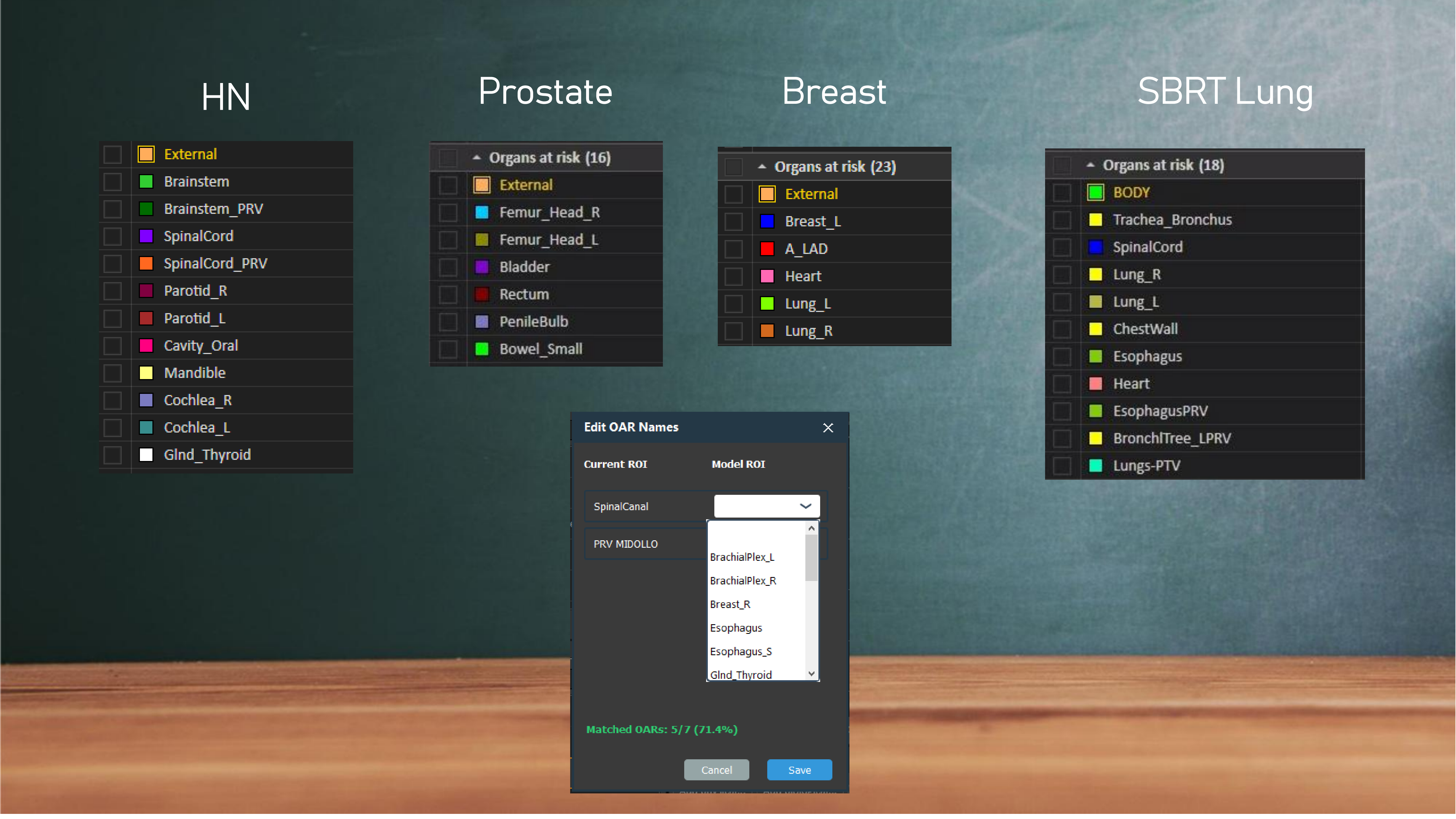
Standardizing Nomenclatures in Radiation Oncology

The Report of AAPM
Task Group 263

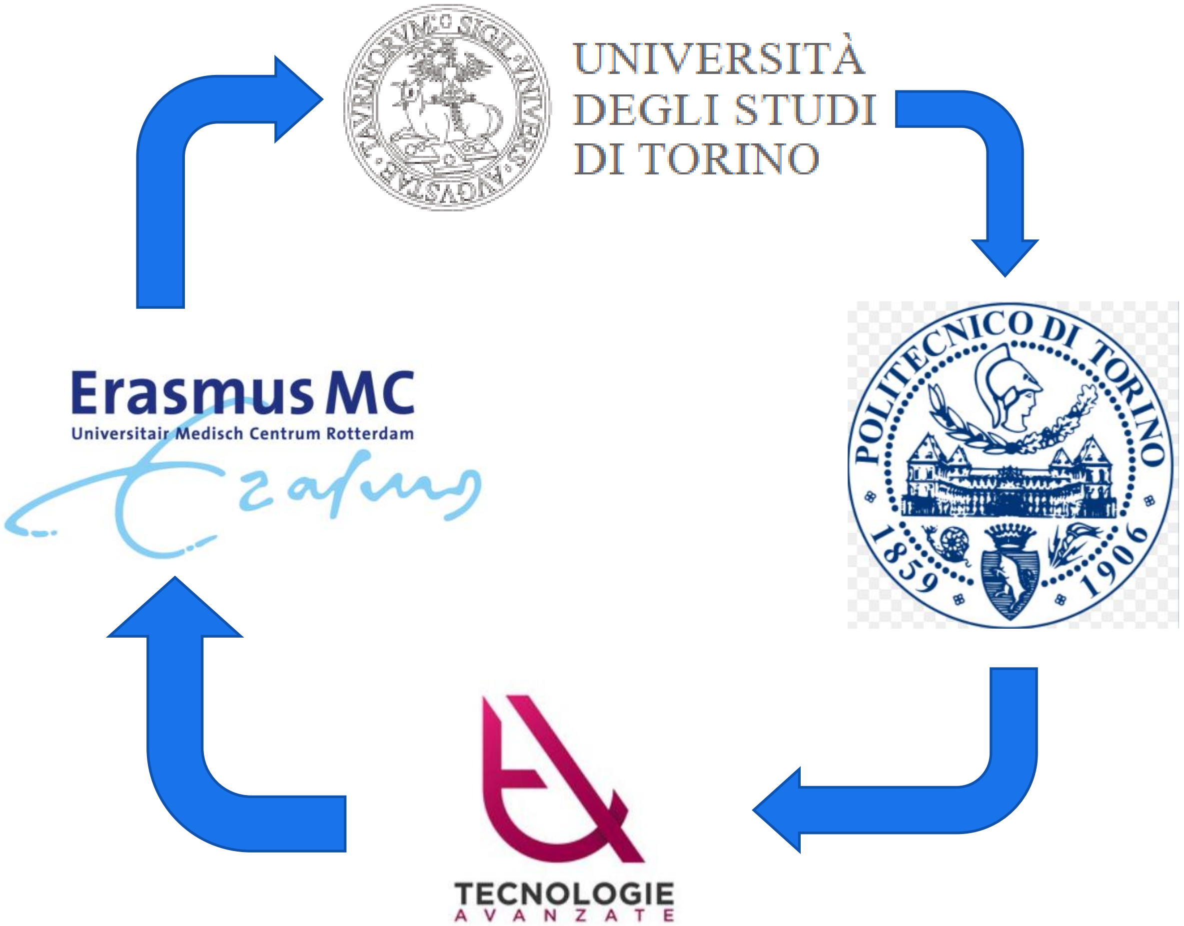
January 2018

Standardization is key to improve script-based plan evaluation

Reduce variability and inconsistencies


HN
External
Brainstem
Brainstem_PRV
SpinalCord
SpinalCord_PRV
Parotid_R
Parotid_L
Cavity_Oral
Mandible
Cochlea_R
Cochlea_L
Glnd_Thyroid
Prostate
Organs at risk (16)
External
Femur_Head_R
Femur_Head_L
Bladder
Rectum
PenileBulb
Bowel_Small
Breast
Organs at risk (23)
External
Breast_L
A_LAD
Heart
Lung_L
Lung_R
SBRT Lung
Organs at risk (18)
BODY
Trachea_Bronchus
SpinalCord
Lung_R
Lung_L
ChestWall
Esophagus
Heart
EsophagusPRV
BronchlTree_LPRV
Lungs-PTV
Edit OAR Names
Current ROI
Model ROI
SpinalCanal
PRV MIDOLLO
BrachialPlex_L
BrachialPlex_R
Breast_R
Esophagus
Esophagus_S
Glnd_Thyroid
Matched OARs: 5/7 (71.4%)
Cancel
Save

Genetic Planning Solution – GPS



GPS

OARs

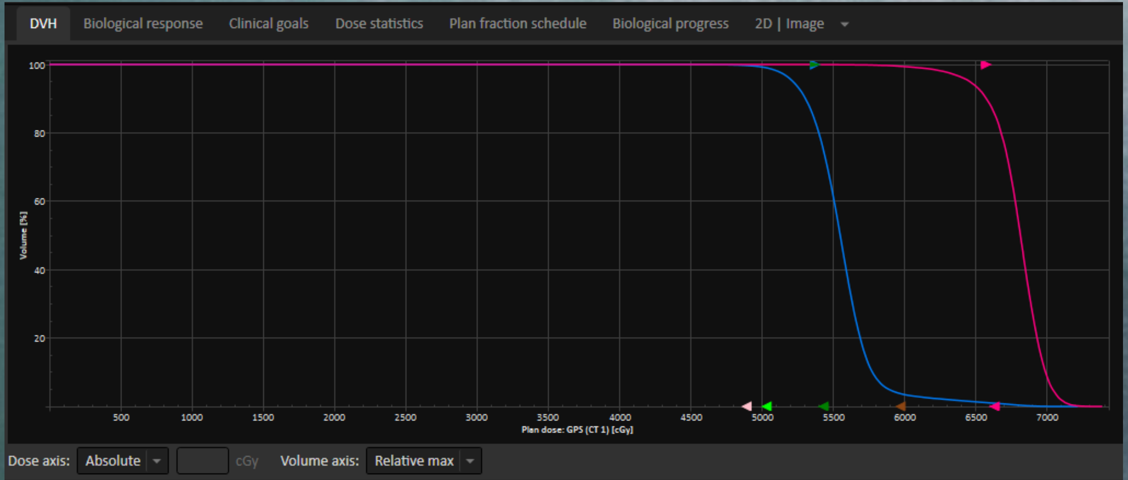
$$EUD = \left(\frac{1}{N} \sum_{i=1}^{N} d_i^a \right)^{\frac{1}{a}}$$

where:

- N = number of voxels (or dose bins) in the structure
- d_i = dose in voxel i
- a = tissue-specific parameter
  - **Negative** a → makes the calculation tumor-control–oriented (focuses on underdosed regions)
  - **Positive** a → makes the calculation normal-tissue–oriented (focuses on hotspots)
  - $a \to \infty$ → EUD approaches the maximum dose
  - $a = 1$ → EUD becomes the mean dose

Max EUD		Plan	Femur_Head_R	Max EUD 685 cGy, Parameter A 1
Max EUD		Plan	Femur_Head_L	Max EUD 765 cGy, Parameter A 1
Max EUD		Plan	Bladder1	Max EUD 1611 cGy, Parameter A 1
Max EUD		Plan	Rectum1	Max EUD 1464 cGy, Parameter A 1
Max dose		Plan	Bowel_Small	Max dose 5000 cGy
Max EUD		Plan	Bowel_Small	Max EUD 4000 cGy, Parameter A 10
Max EUD		Plan	Bowel_Small1	Max EUD 477 cGy, Parameter A 1
Max EUD		Plan	PenileBulb1	Max EUD 1946 cGy, Parameter A 20

PTV



Objectives/constraints | Beams | Control points | Protect | Treat | Beam optimization settings | Beam weighting | Beam dose specification points | Prescription

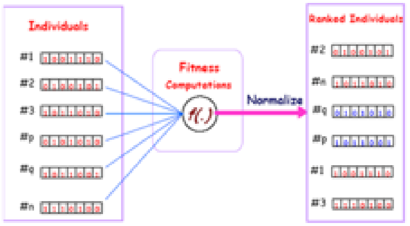
Add physical... | Add biological... | Edit... | Delete | Load template... | Save as template... | Add MCO function | Compute values

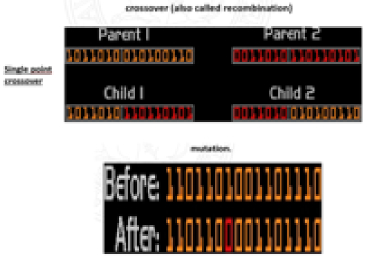
Function	Constraint	Dose	ROI	Description	Robust	Weight	Value	EUD
Physical composite objective							6.9735	
Min dose		Plan	PTV 66	Min dose 6600 cGy		500.00	0.0957	
Max dose		Plan	PTV 66	Max dose 6600 cGy		500.00	0.7177	
Max dose		Plan	ring1.1	Max dose 5940 cGy		25.00	0.0561	
Min dose		Plan	PTV 54	Min dose 5400 cGy		500.00	0.1079	
Max dose		Plan	newringbis1.2	Max dose 4860 cGy		500.00	0.9409	
Uniform dose		Plan	PTV 66	Uniform dose 6600 cGy		500.00	0.8135	
Max dose		Plan	RealPTV 54	Max dose 5400 cGy		500.00	0.7347	
Uniform dose		Plan	RealPTV 54	Uniform dose 5400 cGy		500.00	0.8467	

Genetic Planning Solution 2.2

Genetic algorithm

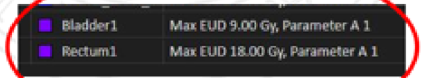
RayStation





A genetic algorithm was implemented in the RayStation treatment planning system (Version 8A) using Python code inside a platform called Genetic Planning Solution

Same fitness function for all centers no center-specific tuning is applied!!



Heuristic Optimization - Genetic Algorithm

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Automated Heuristic Optimization of Prostate VMAT Treatment Planning

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GAs are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination)

Abstract

Purpose: To investigate a genetic algorithm approach to automatic treatment planning. **Methods:** A Python script based on genetic algorithm (GA) was implemented for VMAT treatment planning of prostate tumor. The script was implemented in RayStation treatment planning system using Python code. Two different clinical prescriptions were considered: 78 Gy prescribed to planning target volume in 39 fractions (GROUP 1) and simultaneous integrated boost (70.2 Gy to prostate bed and 61.1 Gy to seminal vesicles) in 26 fractions (GROUP 2). The script automatically optimizes doses to PTV and OARs according to GA. A comparison with corresponding plans created with Monaco TPS (M) and Auto-Planning module of Pinnacle³ (AP) was carried out. The plans were evaluated with a total score (TS) of PlanIQ software in terms of target coverage and sparing of OARs as well as clinical score (CS) performed by a Radiation Oncologist. **Results:** In GROUP 1, mean value of TS were 150.6 ± 30.7, 146.3 ± 36.1 and 137.4 ± 35.7 for AP, GA and M respectively. For GROUP 2, mean value for TS were 163.5 ± 16.8, 163.4 ± 24.7 and 162.9 ± 16.6 for AP, GA and M respectively with no significance differences. In terms of CS, the highest value has been attributed to GA in four patients out of five for both GROUP 1 and 2. **Conclusions:** Genetic approach is practicable for prostate VMAT plan generation and studies are underway in other anatomical sites such as Head and Neck and Rectum.

AAPM REPORT NO. 263

Standardizing Nomenclatures in Radiation Oncology

The Report of AAPM Task Group 263

January 2018

VMAT Prostate radiotherapy treatment planning

10 participating Italian centers

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10 prostate patients

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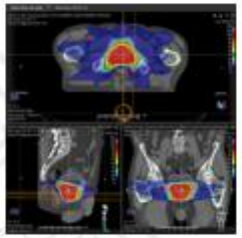
manually generated Vs AutoGPS

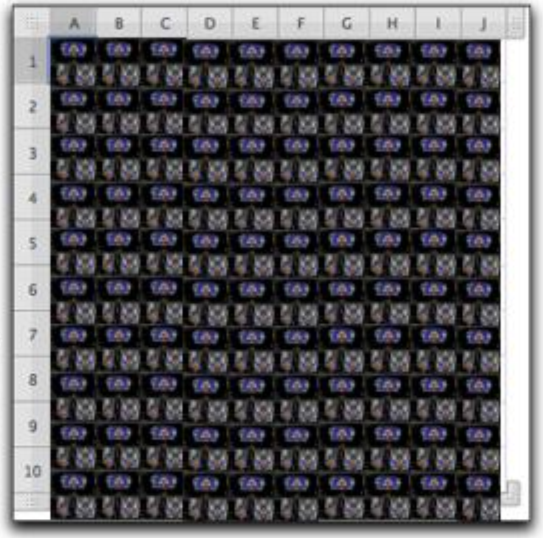
100 Manual plans



100 AutoGPS plans

centers

patients

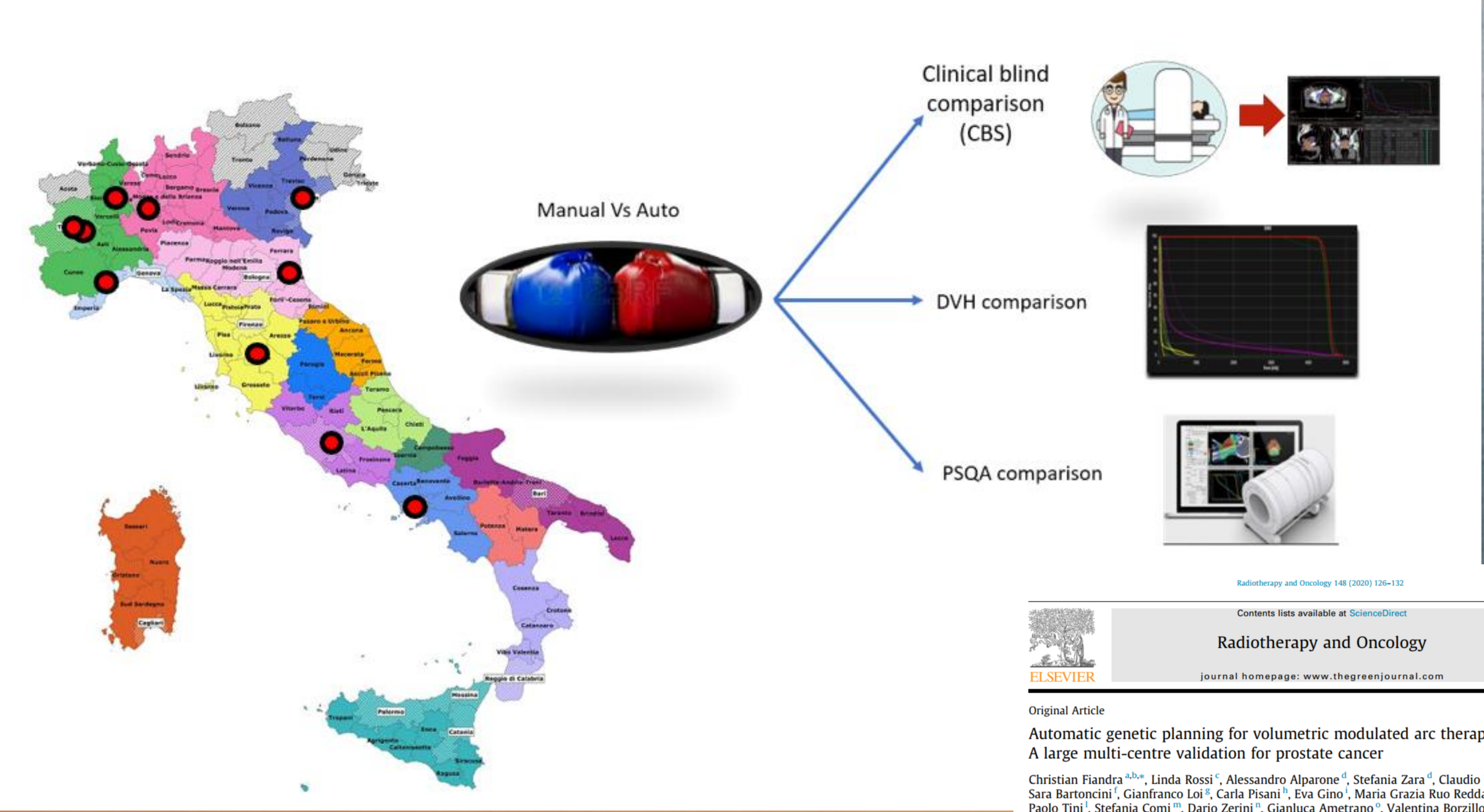


Vs

centers

patients

GPS in clinical practice – prostate



Radiotherapy and Oncology 148 (2020) 126–132

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Original Article

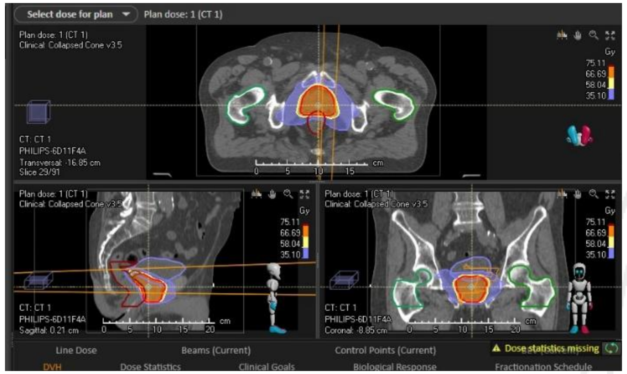
Automatic genetic planning for volumetric modulated arc therapy: A large multi-centre validation for prostate cancer

Christian Fiandra [a,b,*], Linda Rossi [c], Alessandro Alparone [d], Stefania Zara [d], Claudio Vecchi [d], Anna Sardo [e], Sara Bartoncini [f], Gianfranco Loi [g], Carla Pisani [h], Eva Gino [i], Maria Grazia Ruo Redda [j], Gian Marco Deotto [k], Paolo Tini [l], Stefania Comi [m], Dario Zerini [n], Gianluca Ametrano [o], Valentina Borzillo [o], Lidia Strigari [p,1], Silvia Strolin [p,1], Alessandro Savini [q], Antonino Romeo [r], Sonia Reccanello [s], Imad Abu Rumeileh [t], Nunzia Ciscognetti [u], Flavia Guerrisi [v], Gabriella Balestra [w], Umberto Ricardi [x], Ben Heijmen [c]

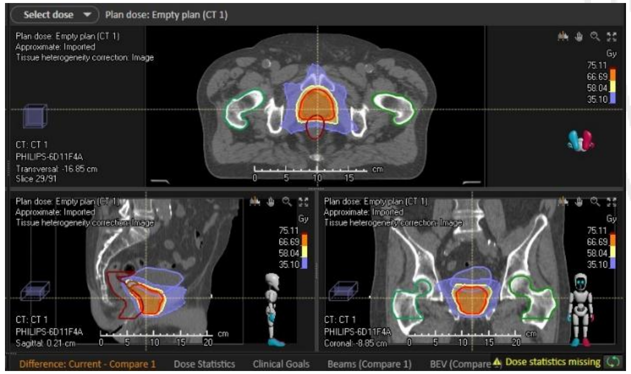
Validation

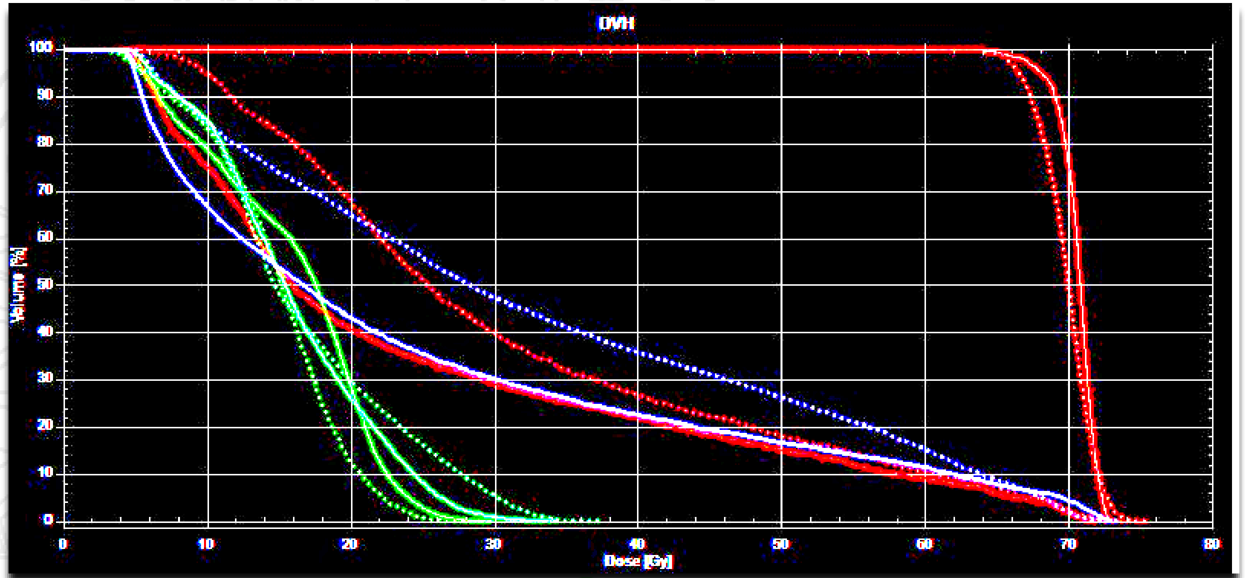
Which is the better plan?

1



2





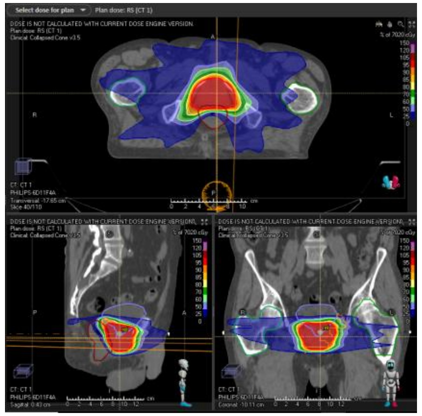
1 —
2 .....

or

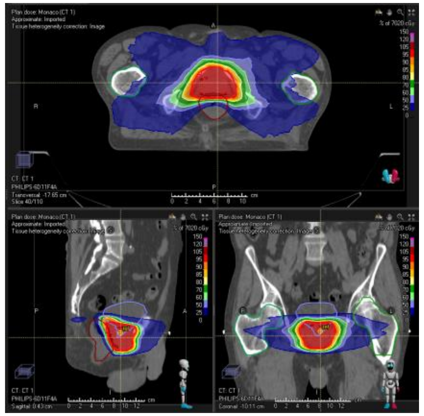
Validation

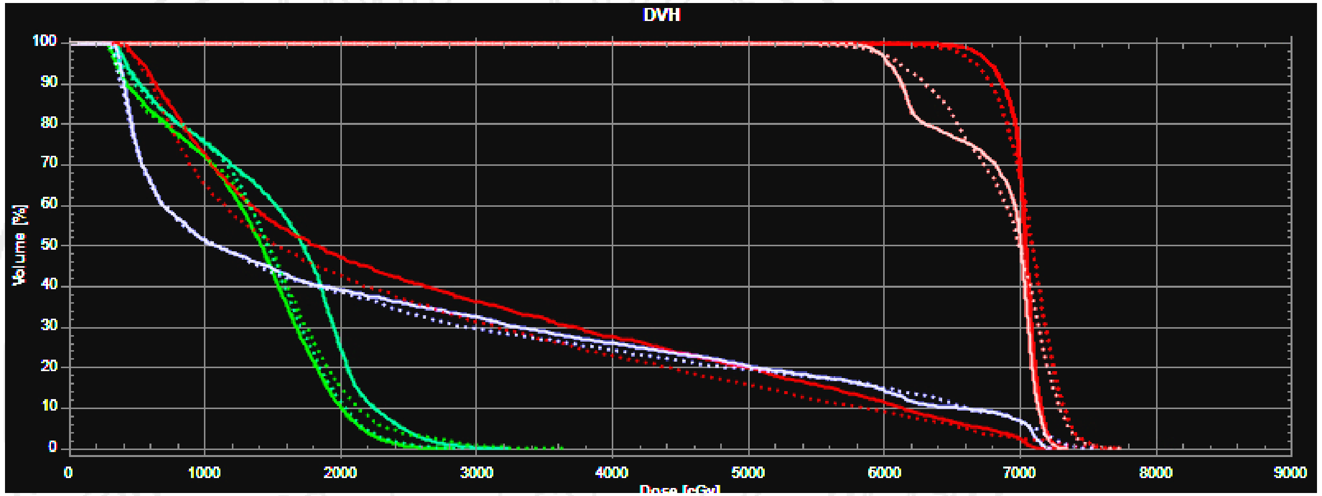
Which is the better plan?

1



2





1 ——

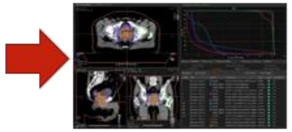
2 ·····

1 *or* 2

Multi-centre prostate

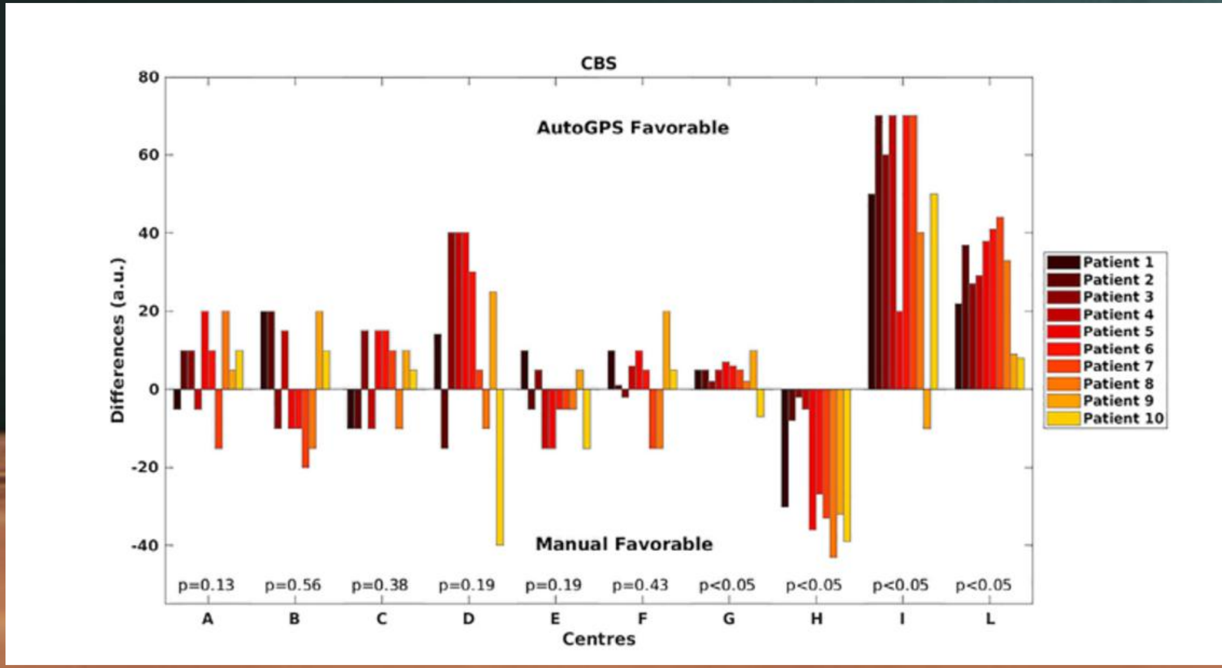
Manual Vs Auto

Clinical blind comparison (CBS)

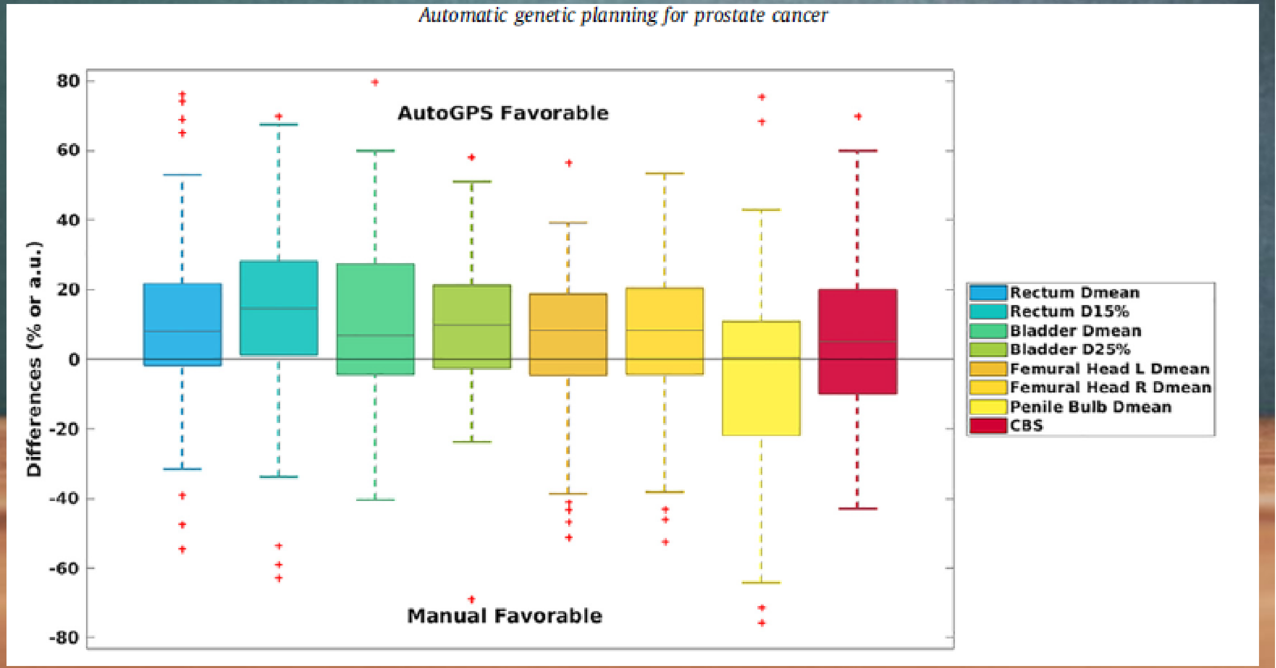


GPS in clinical practice – Prostate

Clinical Blind Score



Dosimetric OAR parameters



GPS in clinical practice – prostate

- **Goal:** Validate a single-configuration genetic autoplanning system (GPS) for prostate VMAT across 10 centres.

- **Key results:**
  - 91% of autoGPS plans were clinically acceptable.
  - 69% of acceptable plans were preferred over manual ones.
  - Better rectum/bladder sparing with similar PTV coverage.

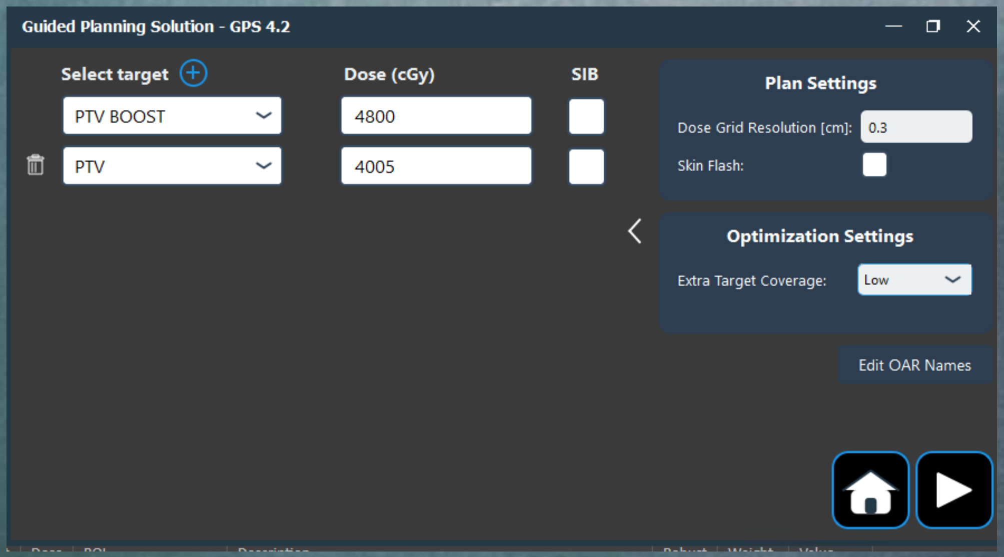
- **Variability:**
  - Inter-centre differences linked to protocol mismatch and manual plan quality.
  - GPS could help standardize plan quality across centres.
- **Centre H issue:** Solved by minor configuration adjustment to match local coverage criteria.

- **Strengths & implications:**
  - Largest multi-centre autoplanning validation to date.
  - Shows potential to reduce workload, improve quality, and avoid centre-specific tuning.

- **Limitations:** Small sample per centre and QA checks done only in one centre

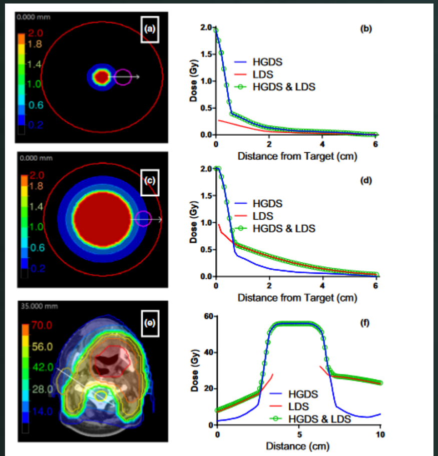
GPS 4.2

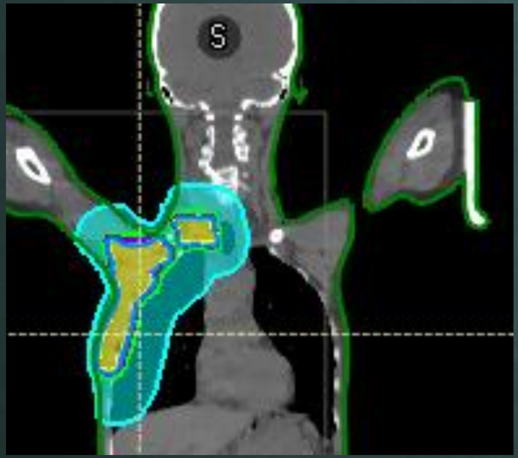

Body Site Selection
Prostate
Head & Neck
Breast
SRS-SBRT
Abdomen
Thorax
Brain
CSI
Target Volume
TECNOLOGIE AVANZATE


Guided Planning Solution - GPS 4.2
Select target
Dose (cGy)
SIB
PTV BOOST
4800
PTV
4005
Plan Settings
Dose Grid Resolution [cm]:
0.3
Skin Flash:
Optimization Settings
Extra Target Coverage:
Low
Edit OAR Names

GPS 4.2

Benchmark dose





A method for *a priori* estimation of best feasible DVH for organs-at-risk: Validation for head and neck VMAT planning

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(Received 27 March 2017; revised 24 July 2017; accepted for publication 24 July 2017; published 31 August 2017)

Patient specific optimization function

...tion	Constraint	Dose	ROI	Description
Physical composite objective				
Min DVH		Plan	PTV_Breast	Min DVH 4005 cGy to 100% volume
Max DVH		Plan	PTV_Breast	Max DVH 4285 cGy to 2% volume
Max dose		Plan	PTV_Breast	Max dose 4406 cGy
Max EUD		Plan	ring1.PTV somma	Max EUD 2804 cGy, Parameter A 20
Dose fall-off		Plan	ring1.PTV somma	Dose fall-off [H]4005 cGy [L]1602 cGy,
Uniform dose		Plan	PTV_Breast	Uniform dose 4005 cGy
Dose fall-off		Plan	Ext1	Dose fall-off [H]4005 cGy [L]801 cGy, L
Dose fall-off		Plan	Ext2	Dose fall-off [H]401 cGy [L]80 cGy, Low
Max EUD		Plan	Glnd_Thyroid	Max EUD 4830 cGy, Parameter A 20
Max EUD		Plan	Liver	Max EUD 463 cGy, Parameter A 20
Max EUD		Plan	Breast_L	Max EUD 168 cGy, Parameter A 20
Max EUD		Plan	Lung_L	Max EUD 100 cGy, Parameter A 1
Max EUD		Plan	Medial_Region	Max EUD 1602 cGy, Parameter A 20
Max EUD		Plan	Dummy1	Max EUD 1602 cGy, Parameter A 20
Max EUD		Plan	Lung_R1	Max EUD 296 cGy, Parameter A 1
Max EUD		Plan	Heart	Max EUD 50 cGy, Parameter A 1

Benchmark dose

DVH | Biological respo... | Clinical goals | Dose statistics | Plan fraction sc... | Biological progr... | 2D | Image

ROI statistics | POI statistics

Name	ROI	ROI vol. [cm³]	Dose [Gy] D99	D98	D95	Average	D50	D2	D1
Plan dose: Bench_1 (T...	Bladder	314.26	0.00	0.21	0.51	7.79	2.62	42.70	42.70
Plan dose: Bench_1 (T...	Bowel_Small	453.95	0.00	0.00	0.00	0.70	0.00	6.34	7.77
Plan dose: Bench_1 (T...	CTV1.1	77.76	42.70	42.70	42.70	42.70	42.70	42.70	42.70
Plan dose: Bench_1 (T...	Femur_Head_L	209.30	0.00	0.00	0.00	0.35	0.05	2.38	2.77
Plan dose: Bench_1 (T...	Femur_Head_R	206.46	0.00	0.00	0.00	0.43	0.03	3.06	3.60
Plan dose: Bench_1 (T...	Genitals	321.13	0.00	0.00	0.00	2.54	0.93	33.76	42.70
Plan dose: Bench_1 (T...	PenileBulb	4.03	15.16	16.64	24.71	38.44	40.07	42.70	42.70
Plan dose: Bench_1 (T...	PTV1.1	180.24	42.70	42.70	42.70	42.68	42.70	42.70	42.70
Plan dose: Bench_1 (T...	Rectum	66.71	1.23	1.31	1.54	16.92	10.09	42.70	42.70

1. Generation of a $\mathbf{D_0}$ dose grid of the required resolution, the values are given by the **dose prescribed** to the target(s) within the target(s) and zero outside.

2. Generation of a **D1** dose grid, the DO dose is evolved applying to each axial plane a series of convolutions through symmetrical kernels that take into account the Low-Gradient Dose Spread component both at mid-range and far-range.

$$\mathbf{D1[y][x,z] = (D_0[y][x,z] * LGDS\text{-}Mid_E[x,z]) * LGDS\text{-}Far_E[x,z]}$$

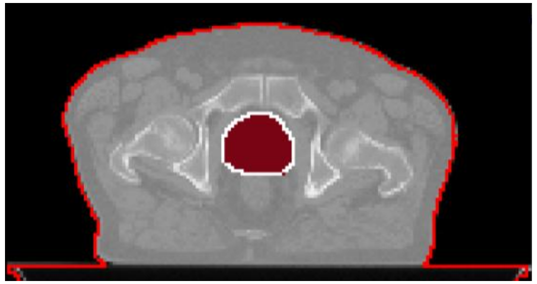
3. Generation of a **D2** dose grid, the DO dose is evolved outside the target(s) assigning to each voxel external to the target(s) the value given by the maximum diffuse value searched among all the nearby target voxels:

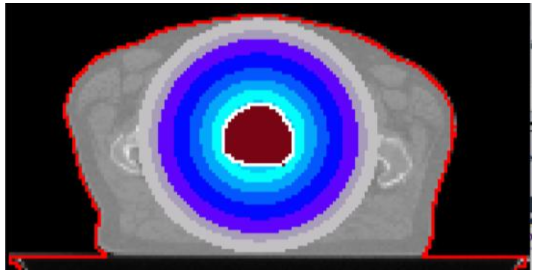
$$\mathbf{D2[x,y,x] = max(x_T,y_T,z_T) \{ D0[x_T,y_T,z_T] \times HGDS_E[r,r_{rad}]\}}$$

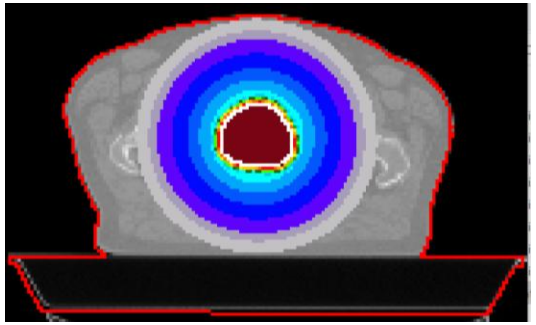
*Where $HGDS_E[\mathbf{r},\mathbf{r}_{rad}]$ is the High-Gradient Dose Spread function for a given beam energy E, **r** is the physical distance between the voxel to be filled [x,y,z] and the target voxel $[x_T,y_T,z_T]$, and $\mathbf{r}_{rad}$ is the corresponding radiological distance calculated as the line integral of the density extracted from the CT associated with the study.*

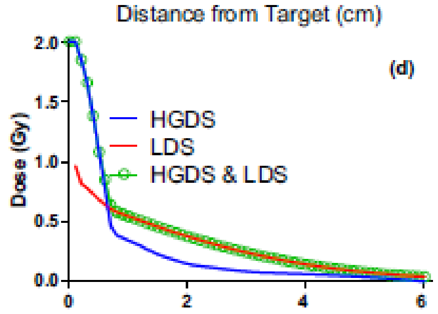
4. Combination of doses D0, D1 e D2 into a dose D defined as:

$$\mathbf{D[x,y,z] = max\ (D1\ [x,y,z],\ D2\ [x,y,z],\ D3\ [x,y,z])}$$





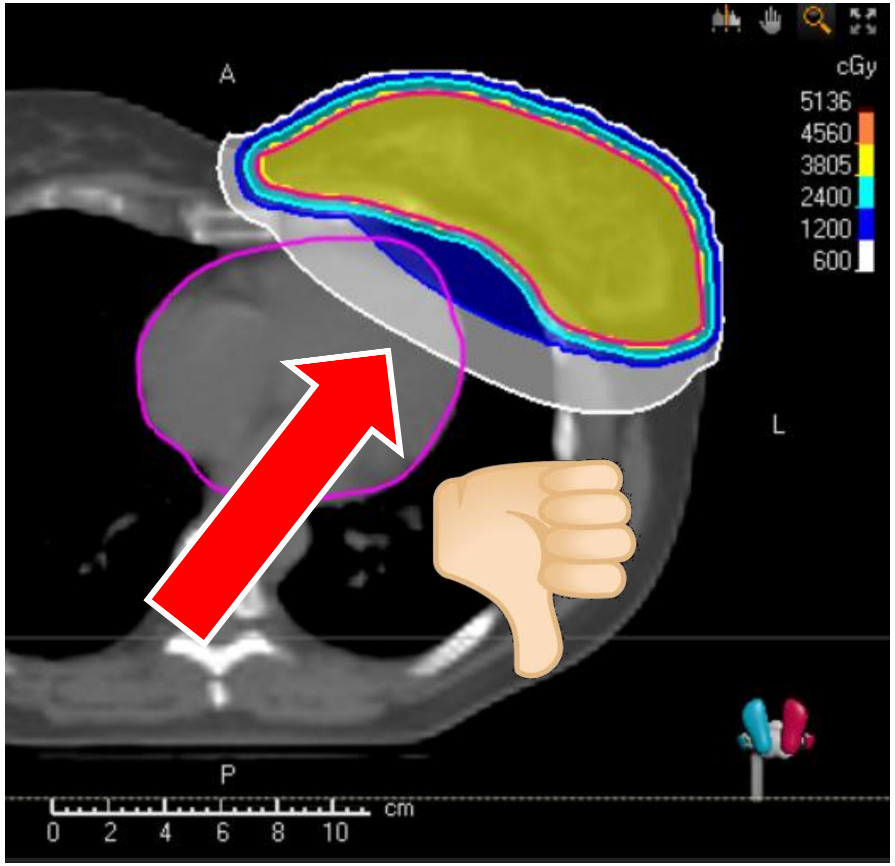


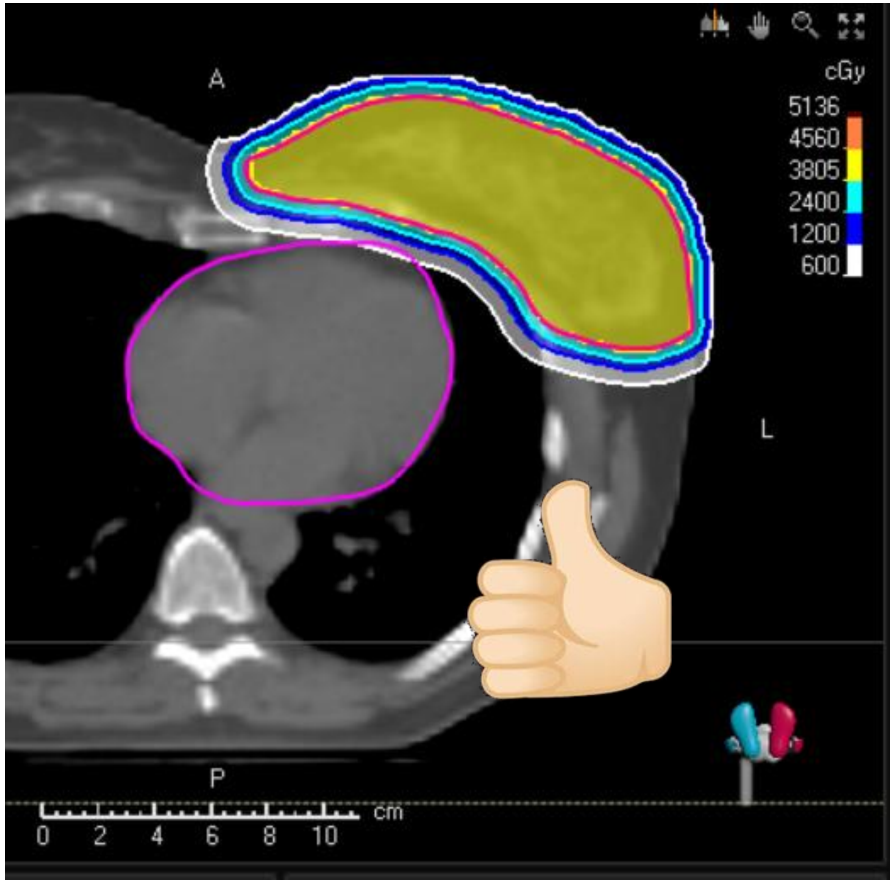


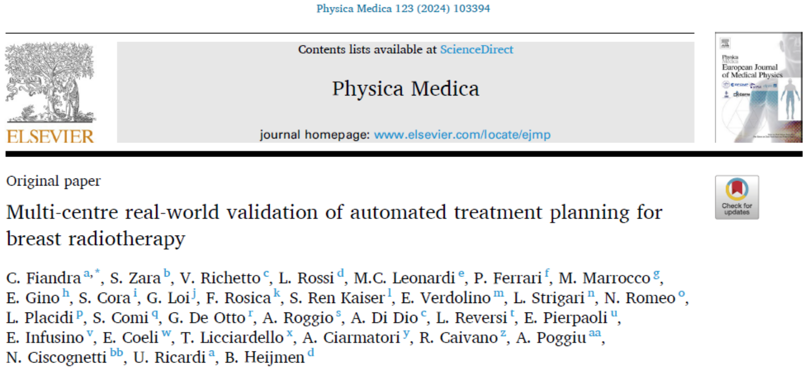
Benchmark dose

Standard parameters

Optimized parameters







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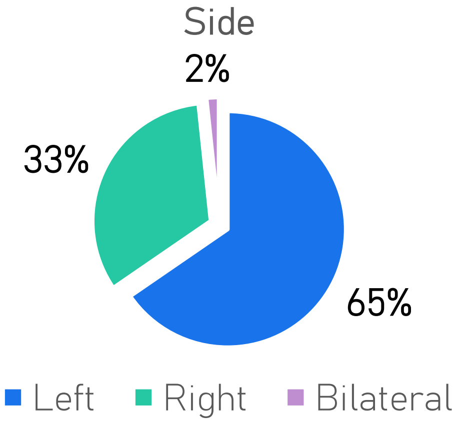
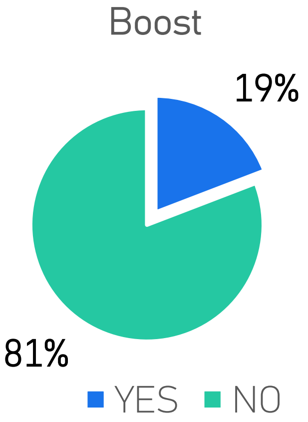
Original paper

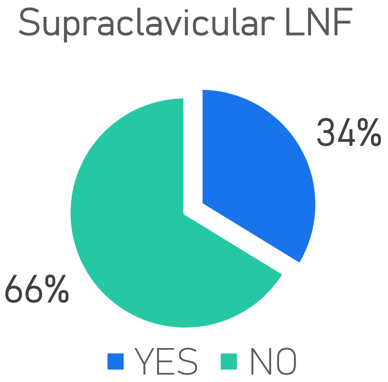
Multi-centre real-world validation of automated treatment planning for breast radiotherapy

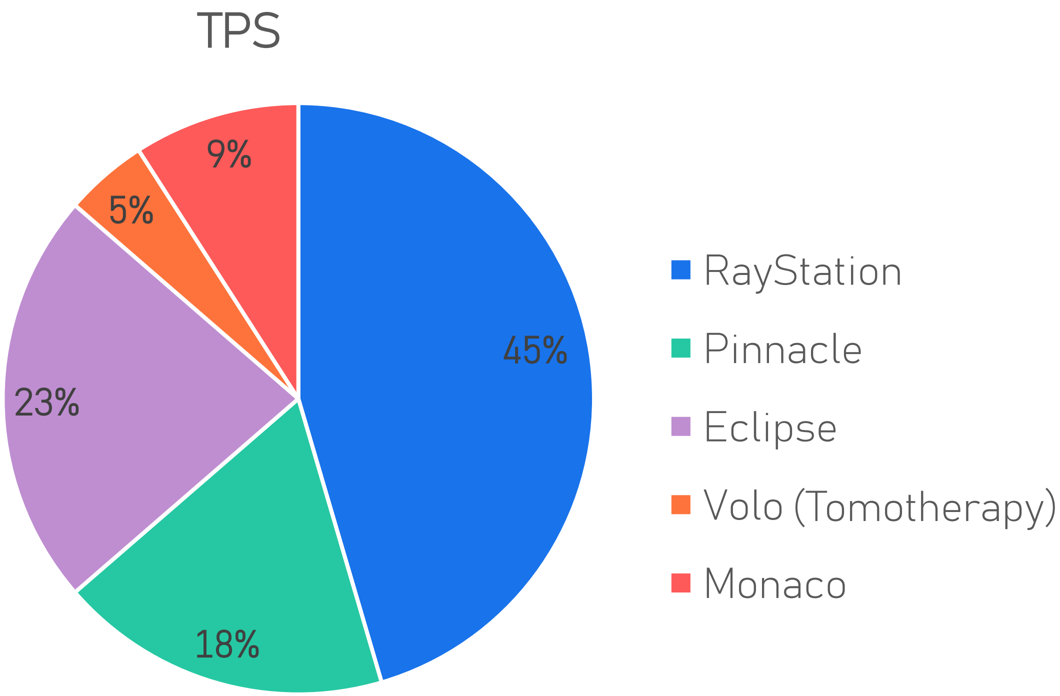
C. Fiandra[a,*], S. Zara[b], V. Richetto[c], L. Rossi[d], M.C. Leonardi[e], P. Ferrari[f], M. Marrocco[g], E. Gino[h], S. Cora[i], G. Loi[j], F. Rosica[k], S. Ren Kaiser[l], E. Verdolino[m], L. Strigari[n], N. Romeo[o], L. Placidi[p], S. Comi[q], G. De Otto[r], A. Roggio[s], A. Di Dio[c], L. Reversi[t], E. Pierpaoli[u], E. Infusino[v], E. Coeli[w], T. Licciardello[x], A. Ciarmatori[y], R. Caivano[z], A. Poggiu[aa], N. Ciscognetti[bb], U. Ricardi[a], B. Heijmen[d]

- 24 centres
- 10 patients / centre
- 240 patients

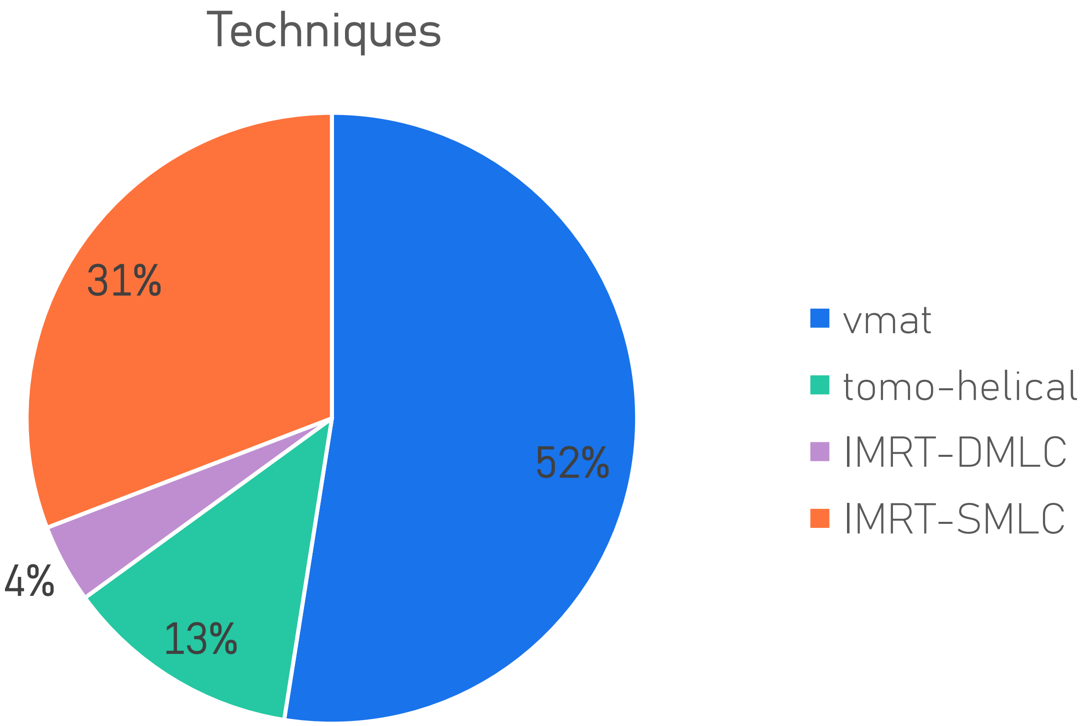








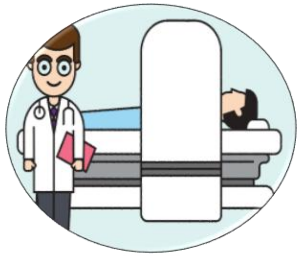
- 24 centres
- 10 patients / centre
- 240 patients

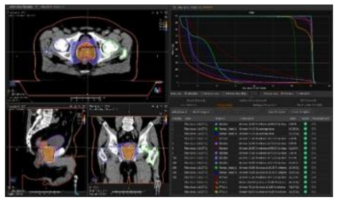


Study design

Manual Vs Auto

Clinical blind comparison (CBS)





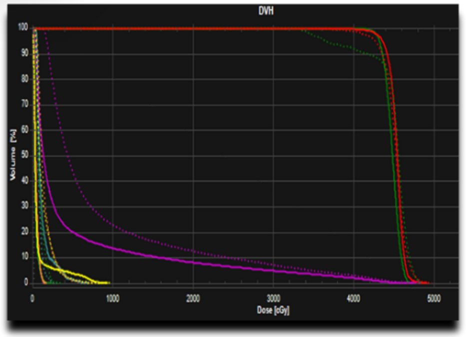
CBS1

GPS
Parity
Manual

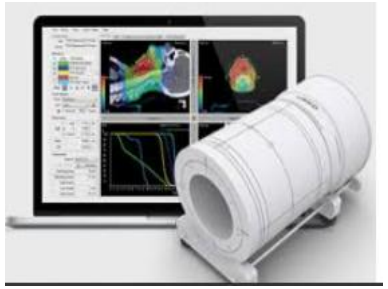
CBS2

GPS-High
GPS-Medium
GPS-Low
Parity
Manual-High
Manual-Medium
Manual-Low

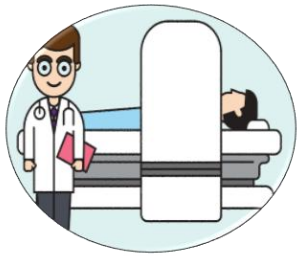
DVH comparison

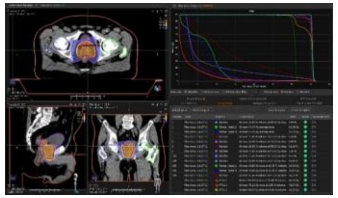


PSQA comparison



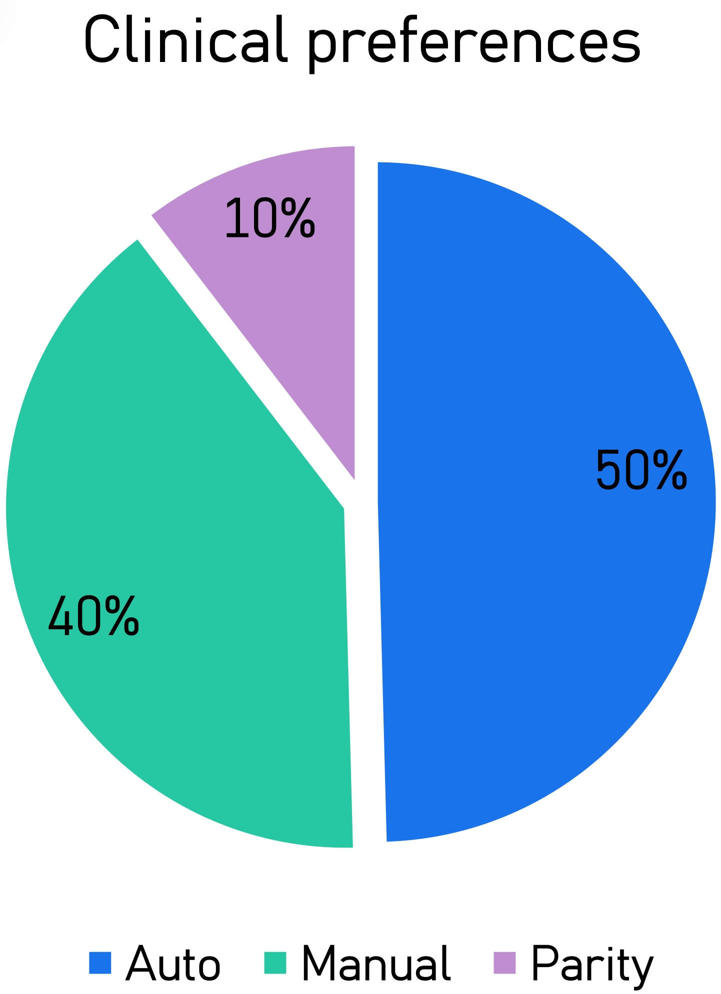
Results: CBS1



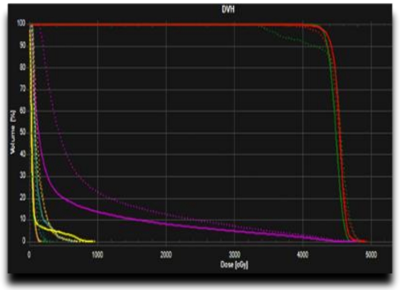


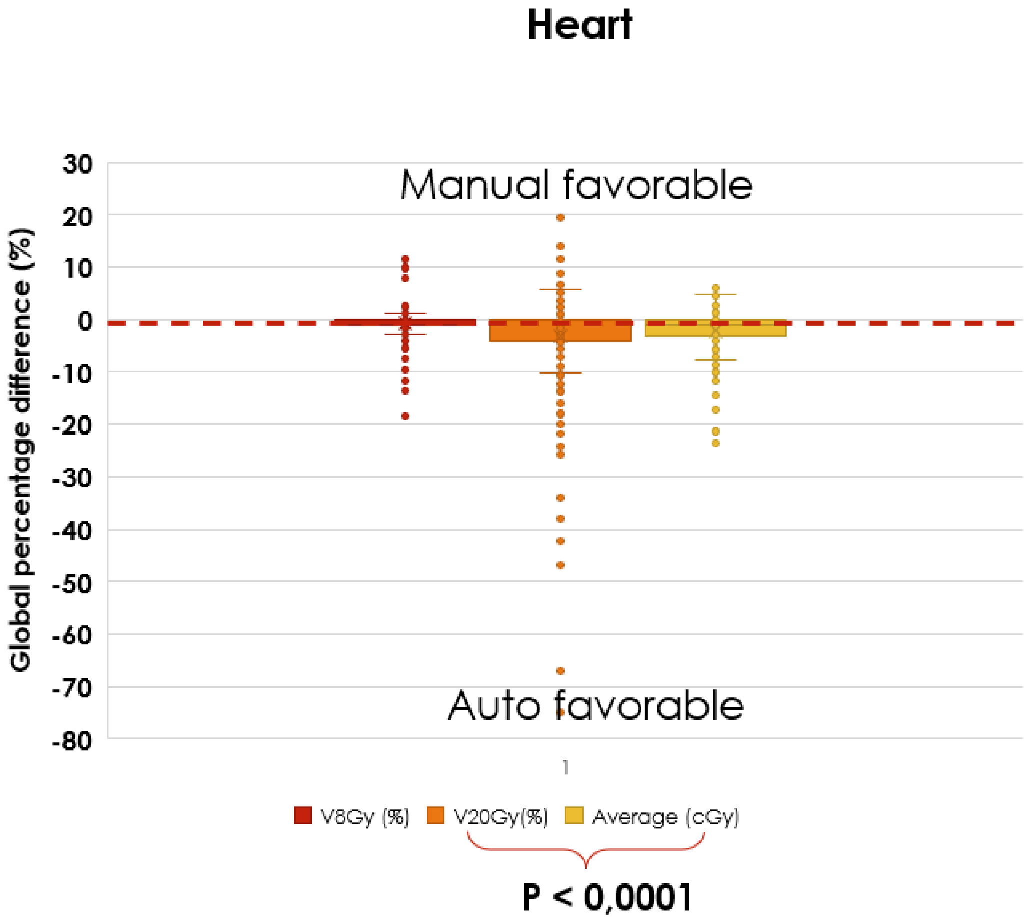
All plans were clinically acceptable

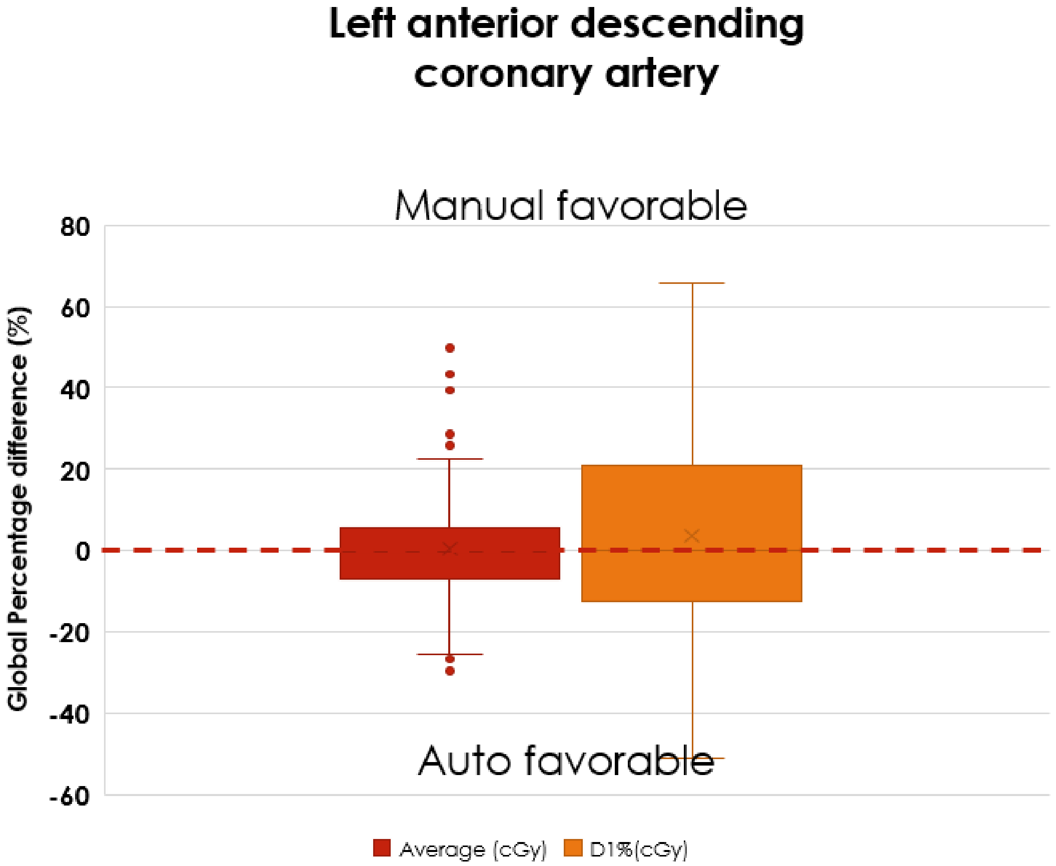
No centre specific configuration



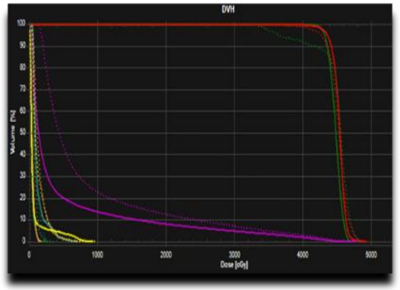
Results: DVH comparison OARs



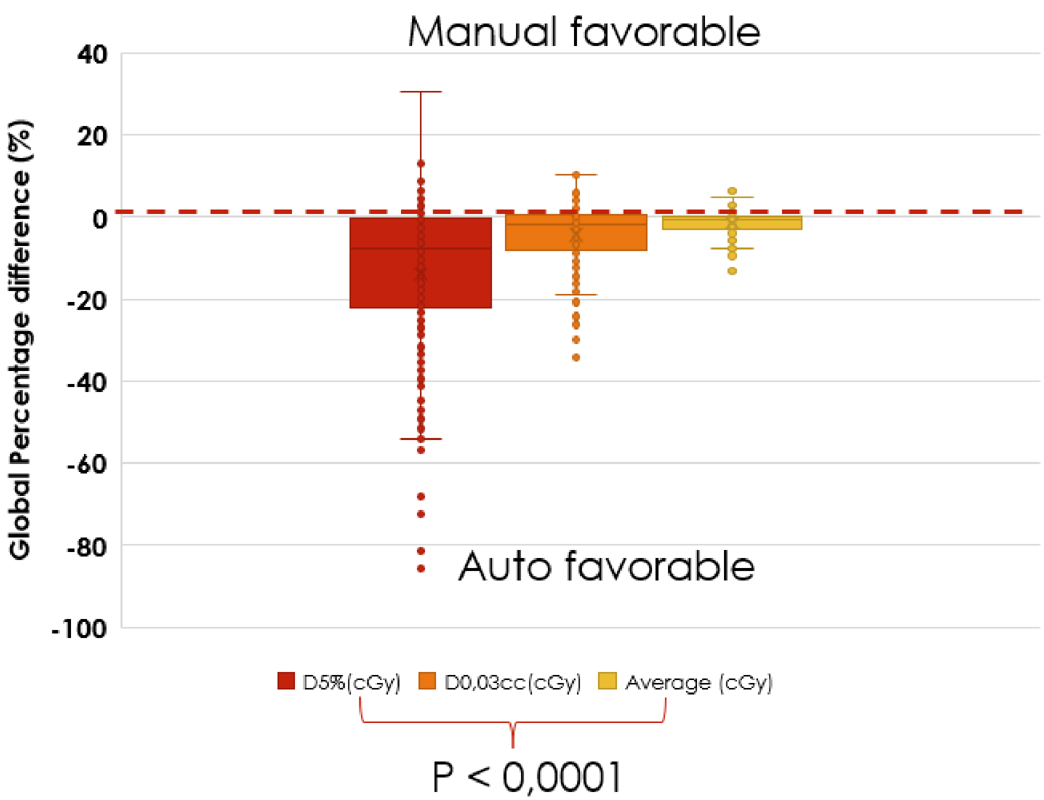




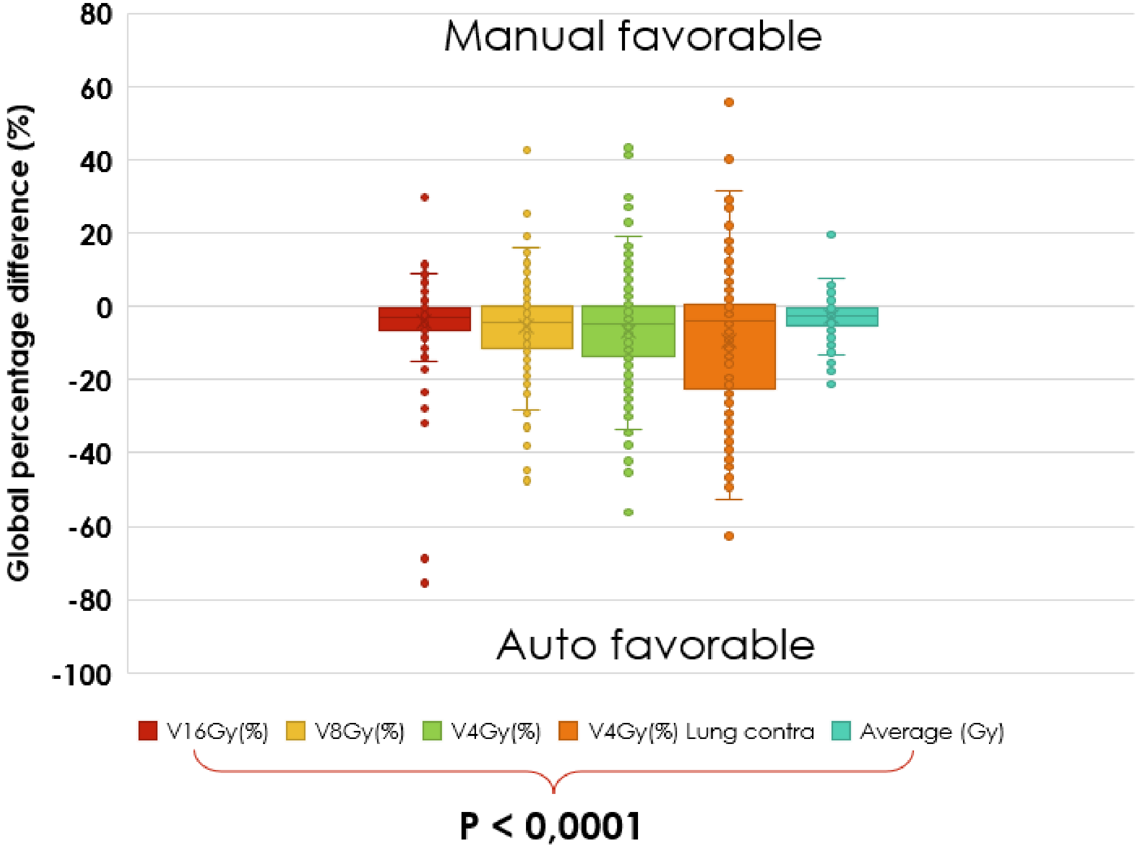
Results: DVH comparison OARs



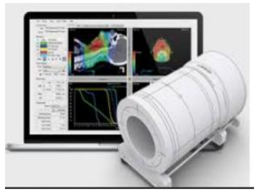
Contralateral breast

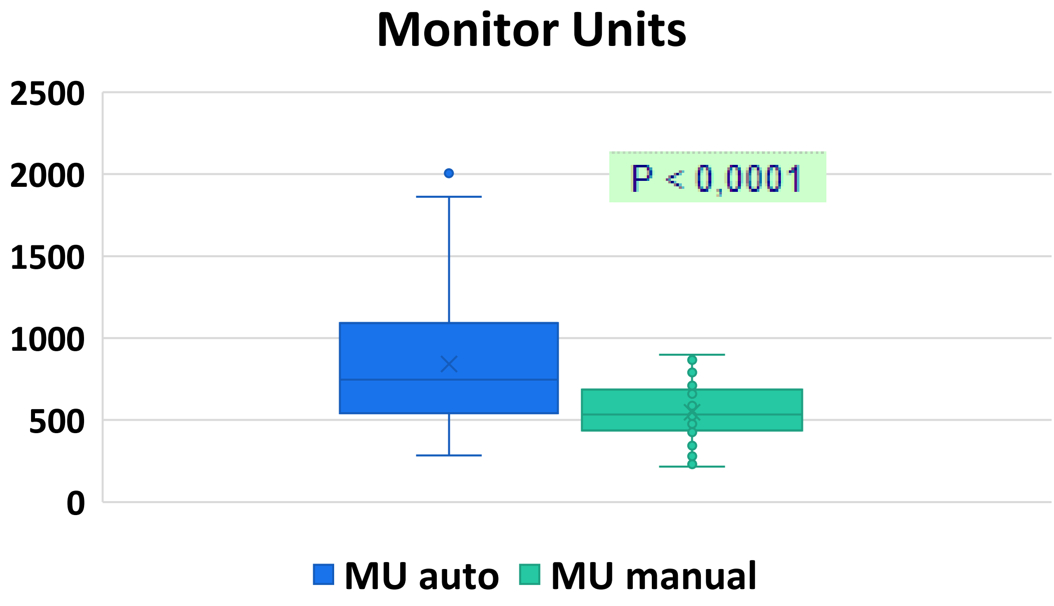


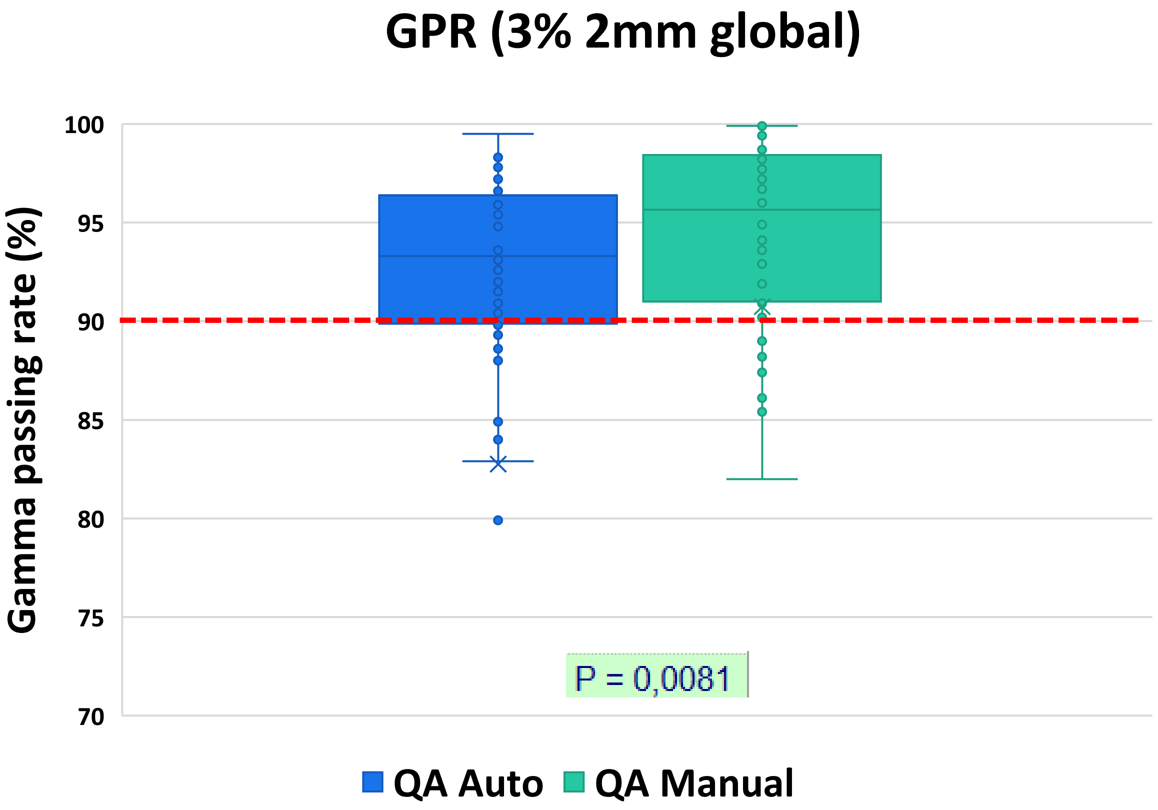
Lungs



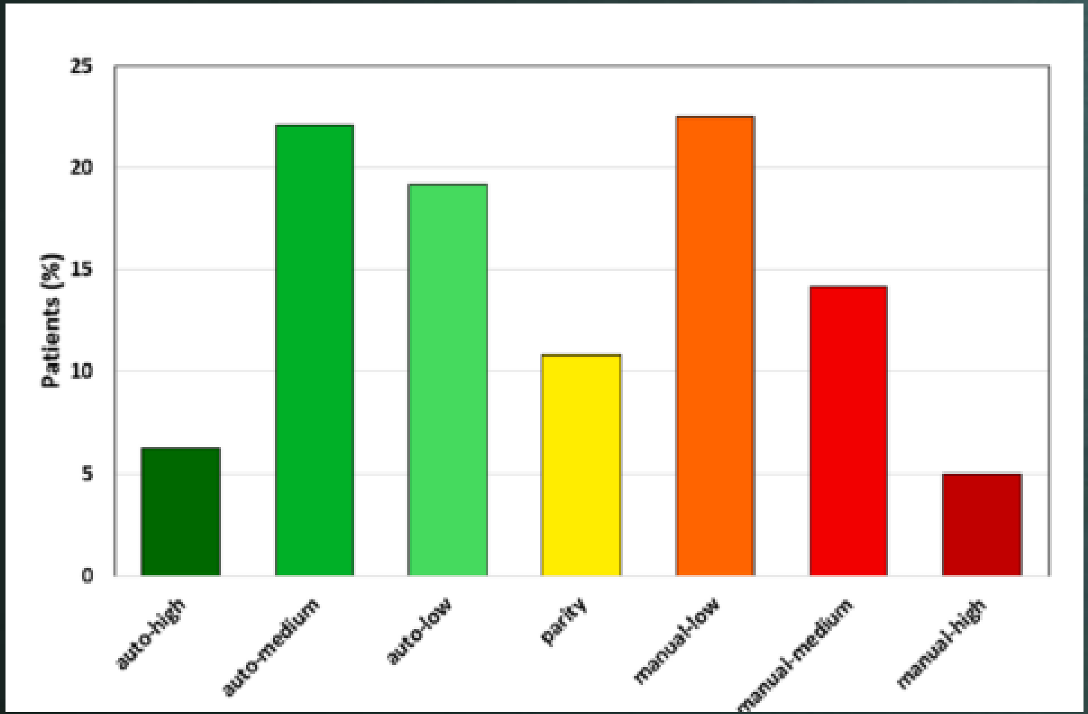
Results: PSQA comparison

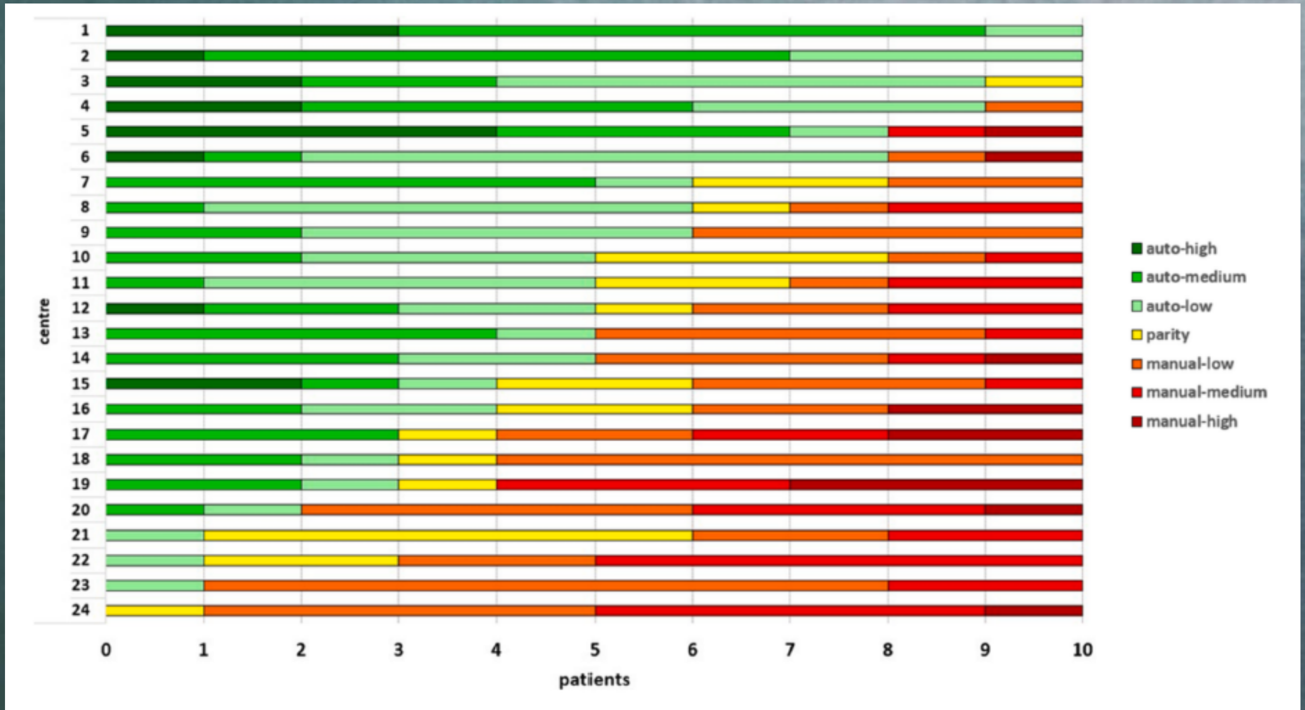






GPS in clinical practice – breast





Conclusion multicentre breast

Purpose: Evaluate a multicentre protocol for breast cancer radiotherapy to ensure reproducibility and plan quality across institutions.

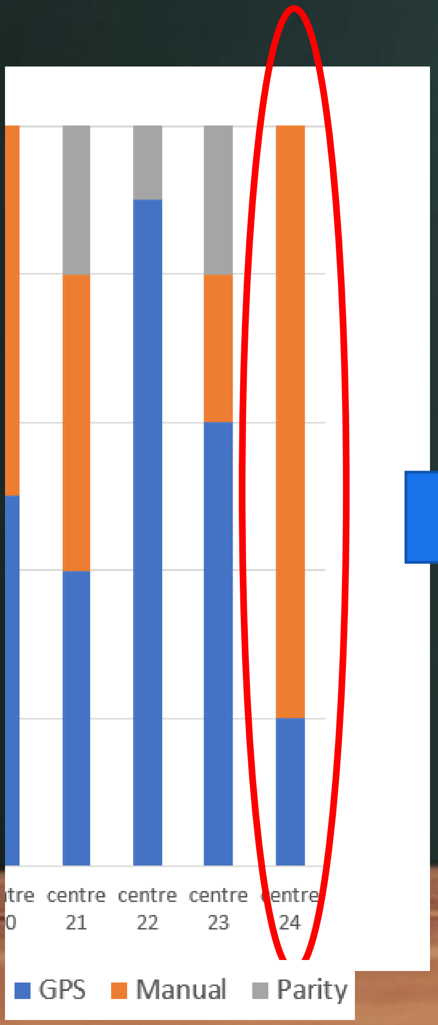
Main Findings: Good consistency in plan quality among centres despite different TPS and planners.Dose constraints for target coverage and OAR sparing were largely met. Variability observed in some dosimetric parameters, but all within clinically acceptable ranges. Inter-centre Variability:Small differences attributed to planner experience, contouring variability, and TPS optimization strategies demonstrates feasibility of harmonizing breast cancer RT planning across centres.

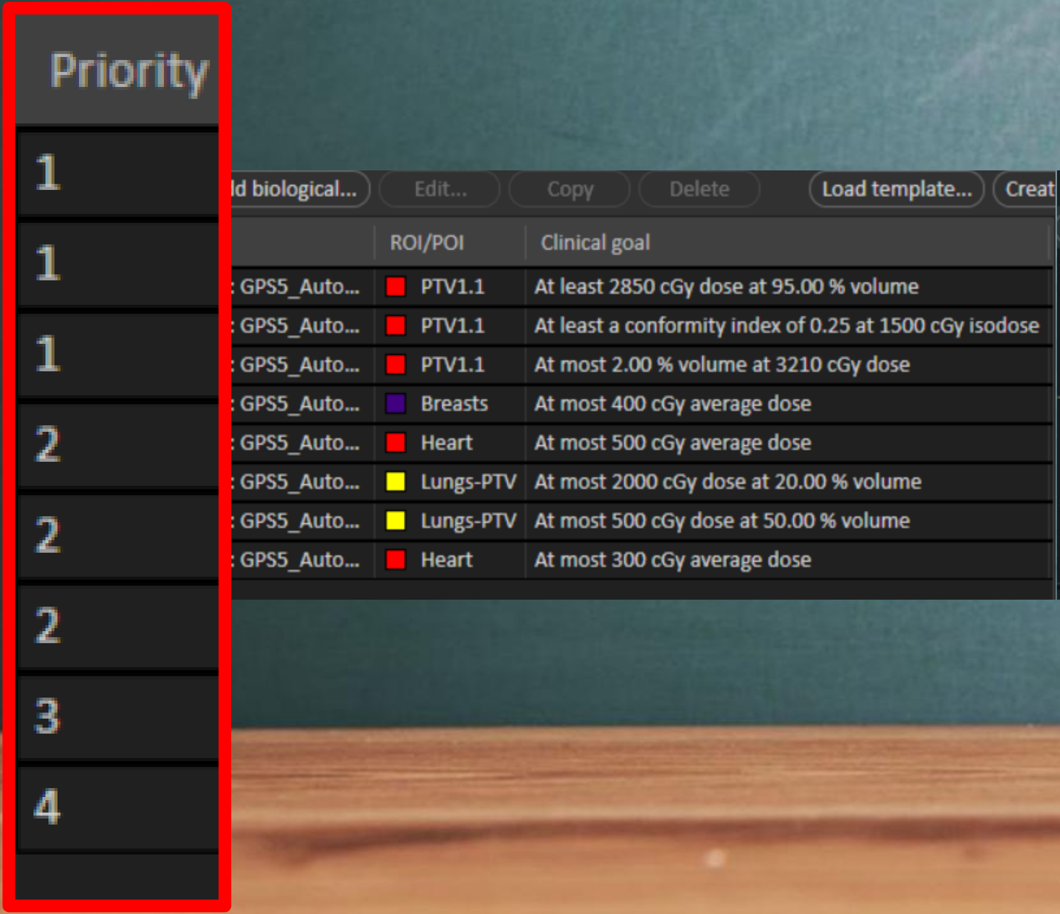
Strengths: Multicentre design provides strong evidence for protocol reproducibility. Highlights value of shared guidelines and centralized review for quality assurance.

Limitations: limited number of patients per centre may not capture all sources of variability. Further standardization of contouring and plan optimization may further reduce variability.

Implications: Results support implementation of shared planning protocols for clinical trials and cooperative studies. Central review and feedback loops are important to maintain consistency over time.

GPS in clinical practice – SBRT





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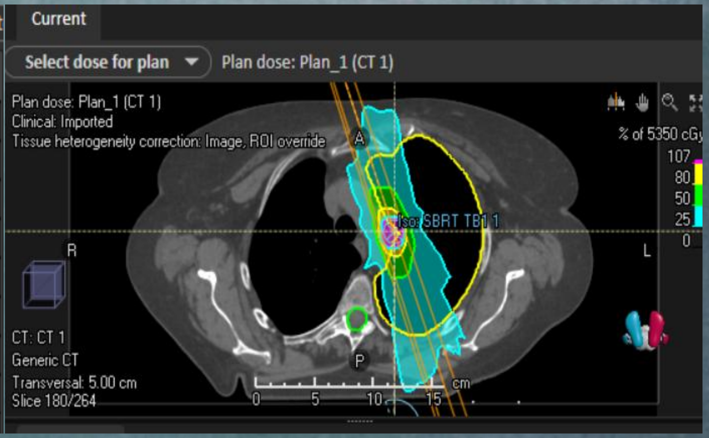
Priority		ROI/POI	Clinical goal
1	: GPS5_Auto...	PTV1.1	At least 2850 cGy dose at 95.00 % volume
1	: GPS5_Auto...	PTV1.1	At least a conformity index of 0.25 at 1500 cGy isodose
1	: GPS5_Auto...	PTV1.1	At most 2.00 % volume at 3210 cGy dose
2	: GPS5_Auto...	Breasts	At most 400 cGy average dose
2	: GPS5_Auto...	Heart	At most 500 cGy average dose
2	: GPS5_Auto...	Lungs-PTV	At most 2000 cGy dose at 20.00 % volume
3	: GPS5_Auto...	Lungs-PTV	At most 500 cGy dose at 50.00 % volume
4	: GPS5_Auto...	Heart	At most 300 cGy average dose



GPS in clinical practice – SBRT

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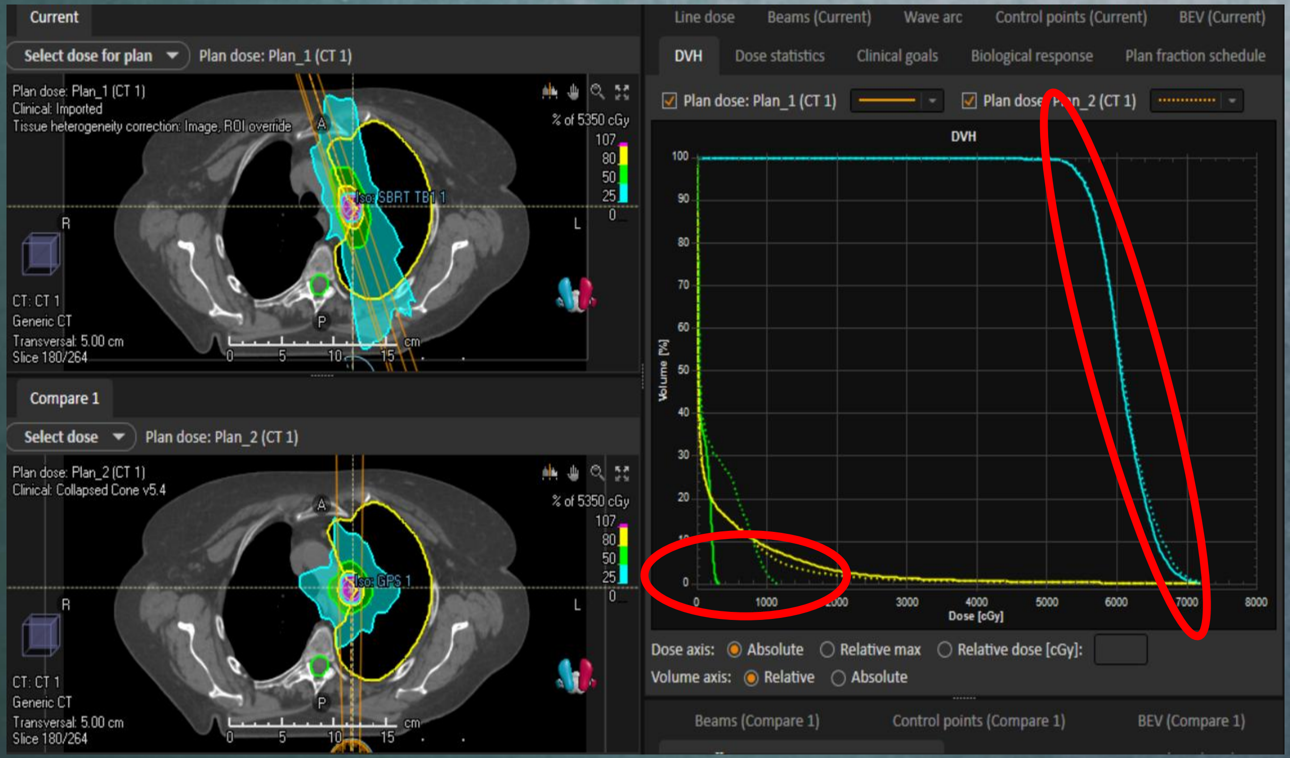
Original paper

Autoplanning in the setting of stereotactic body radiation therapy for lung cancer

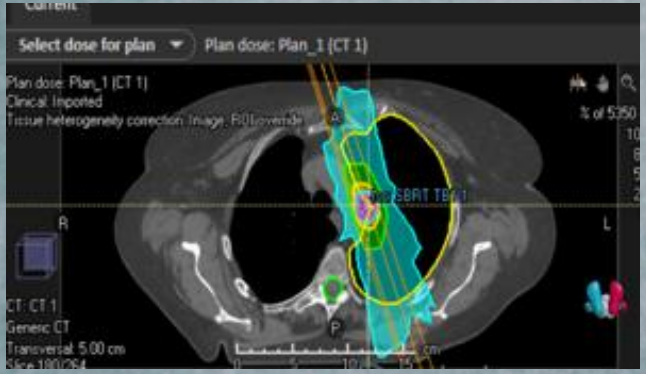
Erminia Infusino [a,1], Anna Ianiro [a,*,1], Marco D'Andrea [a], Stefania Zara [b], Valeria Landoni [a], Francesco Dionisi [c], Francesca Sperati [d], Francesco Quagliani [a], Antonella Soriani [a], Christian Fiandra [e]

[a] Medical Physics Department. IRCCS Regina Elena National Cancer Institute – IFO, Rome, Italy
[b] Tecnologie Avanzate, Turin, Italy
[c] Radiation Oncology Department. IRCCS Regina Elena National Cancer Institute – IFO, Rome, Italy
[d] Clinical Trial Center, Biostatistics and Bioinformatics Department, IRCCS San Gallicano Dermatological Institute – IFO, Rome, Italy
[e] University of Turin, Department of Oncology, Turin, Italy



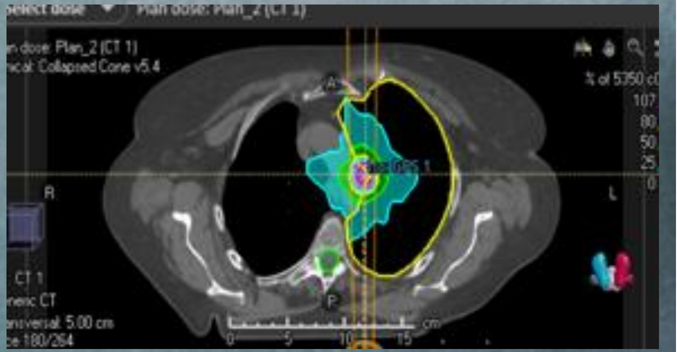
Manual Planning

20 lung SBRT cases (10 peripheral: 60 Gy/5 fx, 10 central: 60 Gy/8 fx).
VMAT (2–4 coplanar arcs, 6 MV FFF), Eclipse v15.6.
D2% ≤ 72 Gy, D98% ≥ 54 Gy, ITV Dmean ≥ 65 Gy.
AAA algorithm, 1.25 mm grid.



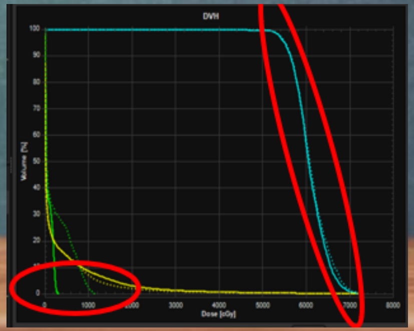
Automatic Planning (AP)

Guided Planning System (GPS) in RayStation v12A.
Same machine, arcs, isocenter as MP; CCC algorithm, 1.2 mm grid.



Quality Assurance

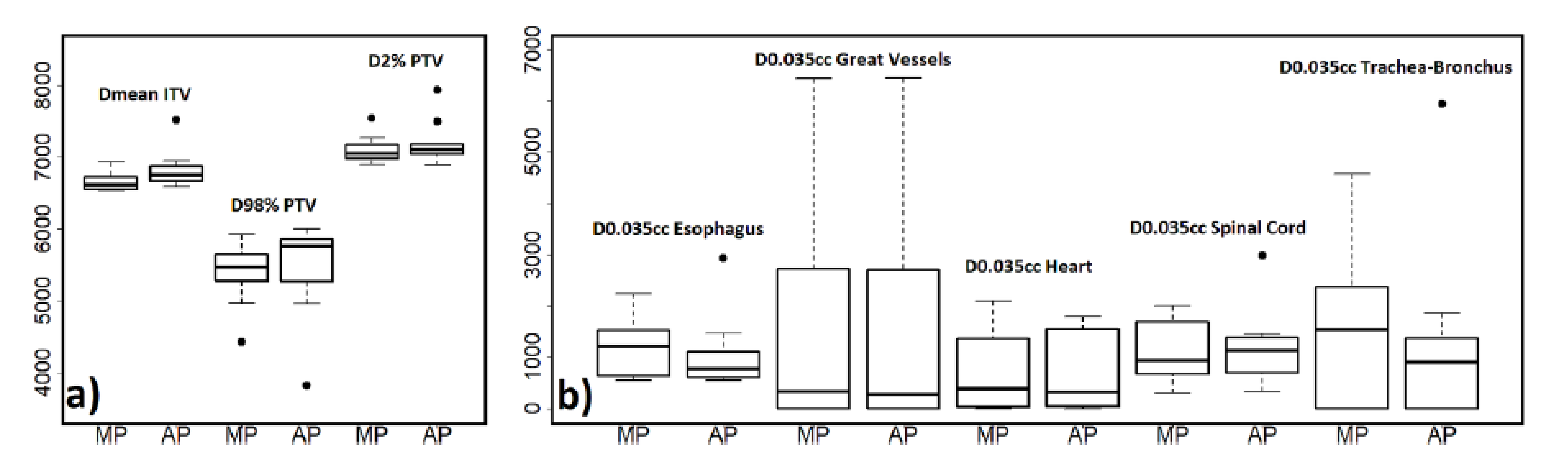
SRS MapCHECK + StereoPHAN phantom, 2%/2 mm gamma (≥ 90% pass).



Plan Comparison

DVH metrics, clinician blind review, gamma pass rate, MUs.
Plan quality metrics: Conformation Number, Homogeneity Index, Gradient Index.

GPS in clinical practice – SBRT



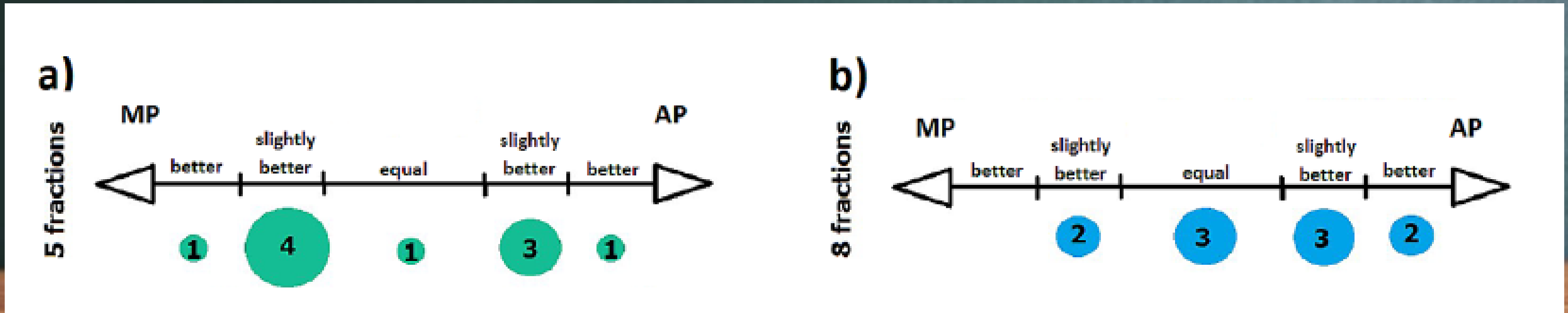


Fig. 3. Clinician's blind comparison results for (a) 5 and (b) 8 fractions scheme.

Conclusion GPS - SBRT

- *Automatic planning (AP) matched or outperformed manual planning (MP) in plan quality and consistency for lung SBRT.*

- *Clinician review confirmed AP plans were clinically acceptable in most cases (equal or better in 65%).*

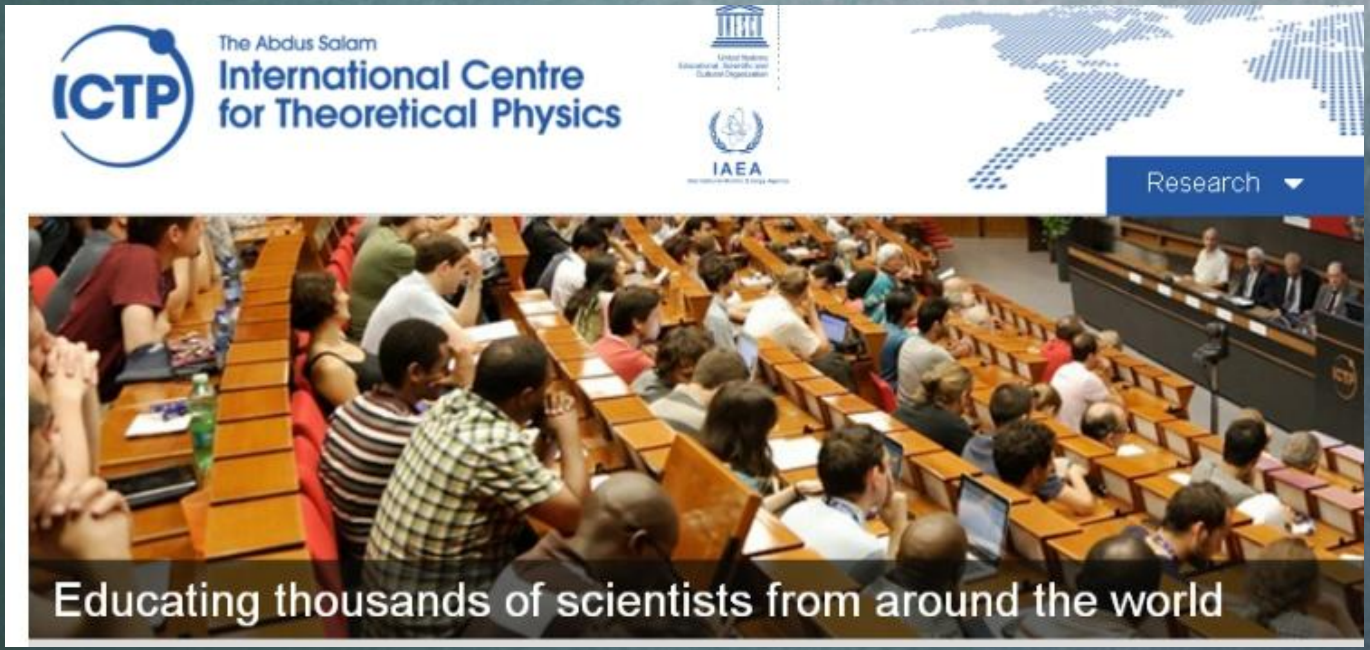
- *AP reduces inter-planner variability and saves time, serving as a strong starting point for planning.AP plans still require review and possible refinement before delivery.*

- *The center now uses GPS autoplanning routinely for lung SBRT and is validating it for other tumor sites*

Automation in RaySearch
Summary

- GPS may be considered as an advanced starting point for planning
  - *reduces inter-planner variability, saves time, harmonize optimization strategy serving as a strong starting point but* ***require*** *review and possible refinement before delivery*

GPS autoplanning routinely used in 30 centres across Italian country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