Dosimetric Consequences of Uncorrected Rotational Setup Errors During Stereotactic Body Radiation Therapy Case Study – Pancreatic Cancers

AAPM 2014 Undergraduate Fellow

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Outline

- Background
- Purpose
- Methods/Procedure
  - Original rotations
  - 0 degree rotations
- Results
  - From an individual patient
  - Combined results
  - From special cases
- Conclusion
- Questions

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+ Background

- Pancreatic cancer patients are treated on a Hexapod
  - Moves in 6 directions to align the patient to the isocenter
    - Translational directions: X,Y,Z
    - Rotational directions: pitch, yaw and roll
  - Unfortunately….

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Purpose

- How detrimental would it be to not correct for setup errors in the rotational directions?
- Therefore…
- To study the dosimetric consequences of uncorrected rotational set up errors in the pitch, yaw and roll directions.
  - Consequences to
    - PTV/GTV
    - Proximal normal tissue

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Methods/Procedure

- Retrospective study
  - Data from 10 SBRT pancreas patients were utilized
  - Rotational transformation were applied to original CT images to represent rotational setup errors
  - Clinical dosimetric plans were applied to the rotated CT images
  - Volume dose coverage to the important objective tissues were then analyzed and compared with the clinical plans

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Procedure

- Matlab code
  - Created a DICM file to rotate the images
- CT images and DICM file were uploaded into Slicer to do the rotations
- The images were then sent to Velocity where the ROI contours were fit
- The images and contours were then sent to Pinnacle for protocol check

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Original Rotations

- The original rotations were rotated along the spin posterior to the PTV
- There were 6 different sets of rotations
  - Creating a total of 60 plans

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Rotations Continued

Rotation	Pitch (degrees)	Yaw (degrees)	Roll (degrees)
1	3	3	3
2	2	2	2
3	1	1	1
4	3	0	0
5	0	3	0
6	0	0	3

- 1-3 were designed to explore the severity of larger rotational degrees
- 4-6 were designed to distinguish which direction is more unfavorable to the dosimetric plan.

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0 Degree Rotation

- Procedure was replicated with 0 degree rotations
- Done to ensure that the process was efficient
- For it to be an efficient process the protocol results should match the clinical plan
- Which it did….

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+ 0 Degree Rotation Results

Protocol Objective	Clinical Plan		0^{o} Rotation
GTV-V25 (%)	99.98		99.99
PTV-V33 (%)	92.75		92.31
PTV-V42.9 (cc)	0.02		0.01
Stomach Proximal -V15 (cc)	8.09		8.19
Stomach Proximal -V20 (cc)	2.82		2.77
Stomach Proximal -V33 (cc)	0.00		0.00
Bowel Proximal -V15 (cc)	4.05		4.12
Bowel Proximal -V20 (cc)	2.22		2.20
Bowel Proximal -V33 (cc)	0.04		0.03
Liver-V12 (%)	3.34		3.33
Kidneys-V12 (%)	16.28		15.97
Right Kidney -V12 (%)	15.84		15.72
Left Kidney -V12 (%)	16.76		16.54
Stomach-V12 (%)	4.60		4.60
Stomach-V33 (cc)	0.00		0.00
Spinal Cord -V8 (cc)	0.00		0.00

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Each Patient

- After the CT images were rotated and the dosimetric plans were applied…
- The results from each patient was collected and the data was analyzed
- The following data from patient 9, displaying the objectives that did not pass protocol
  - Pancreas PTV V33
  - Proximal Bowel V15

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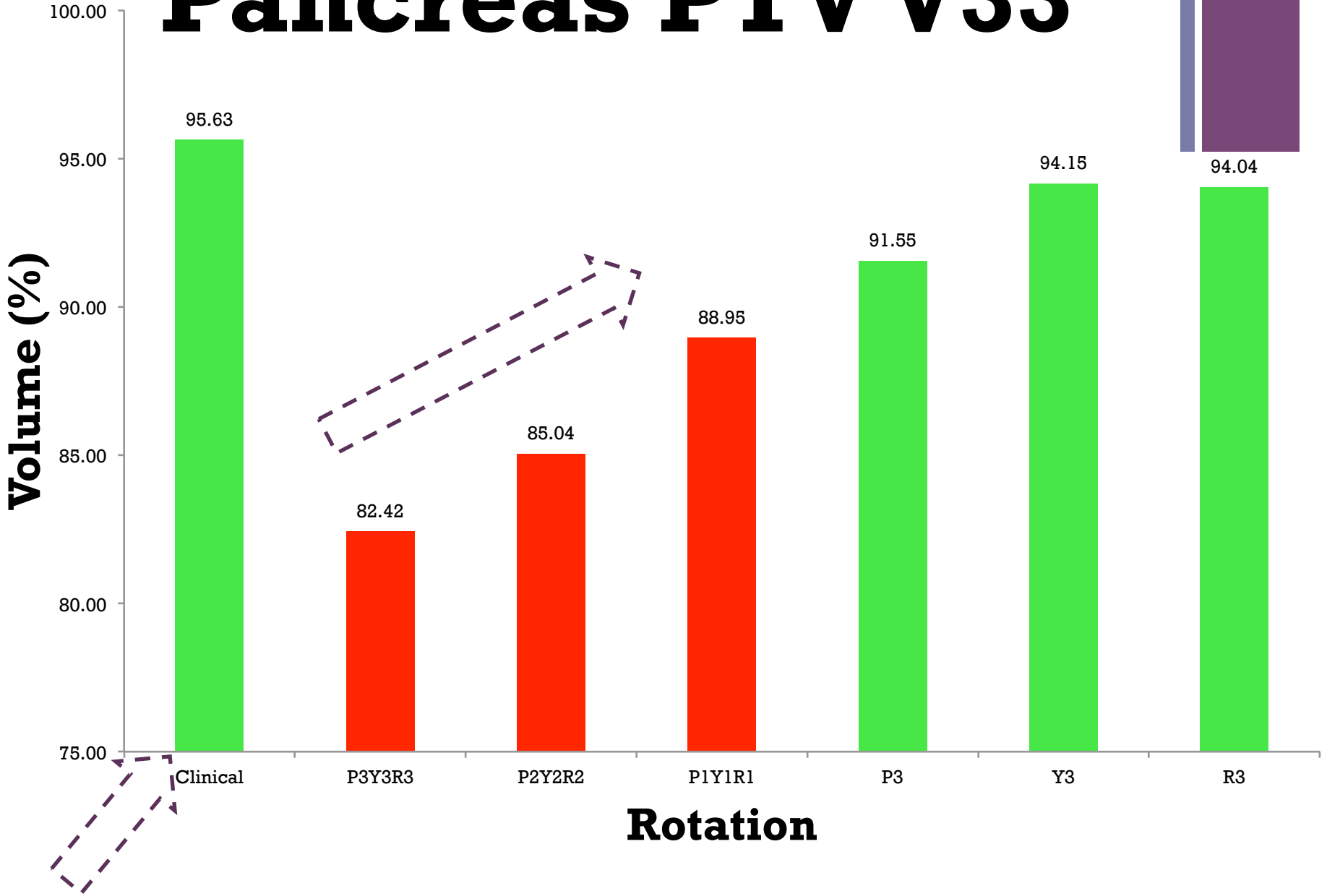
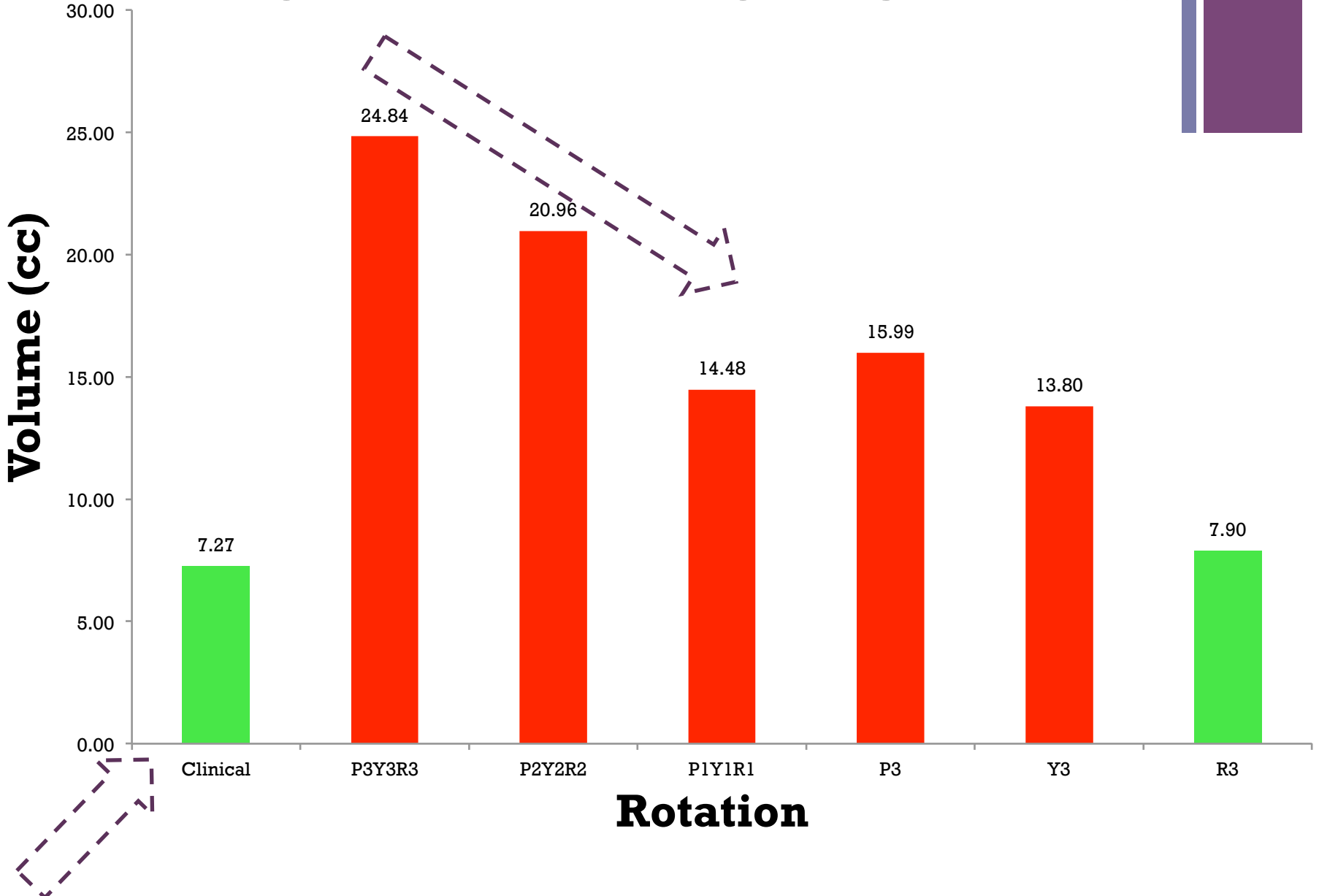
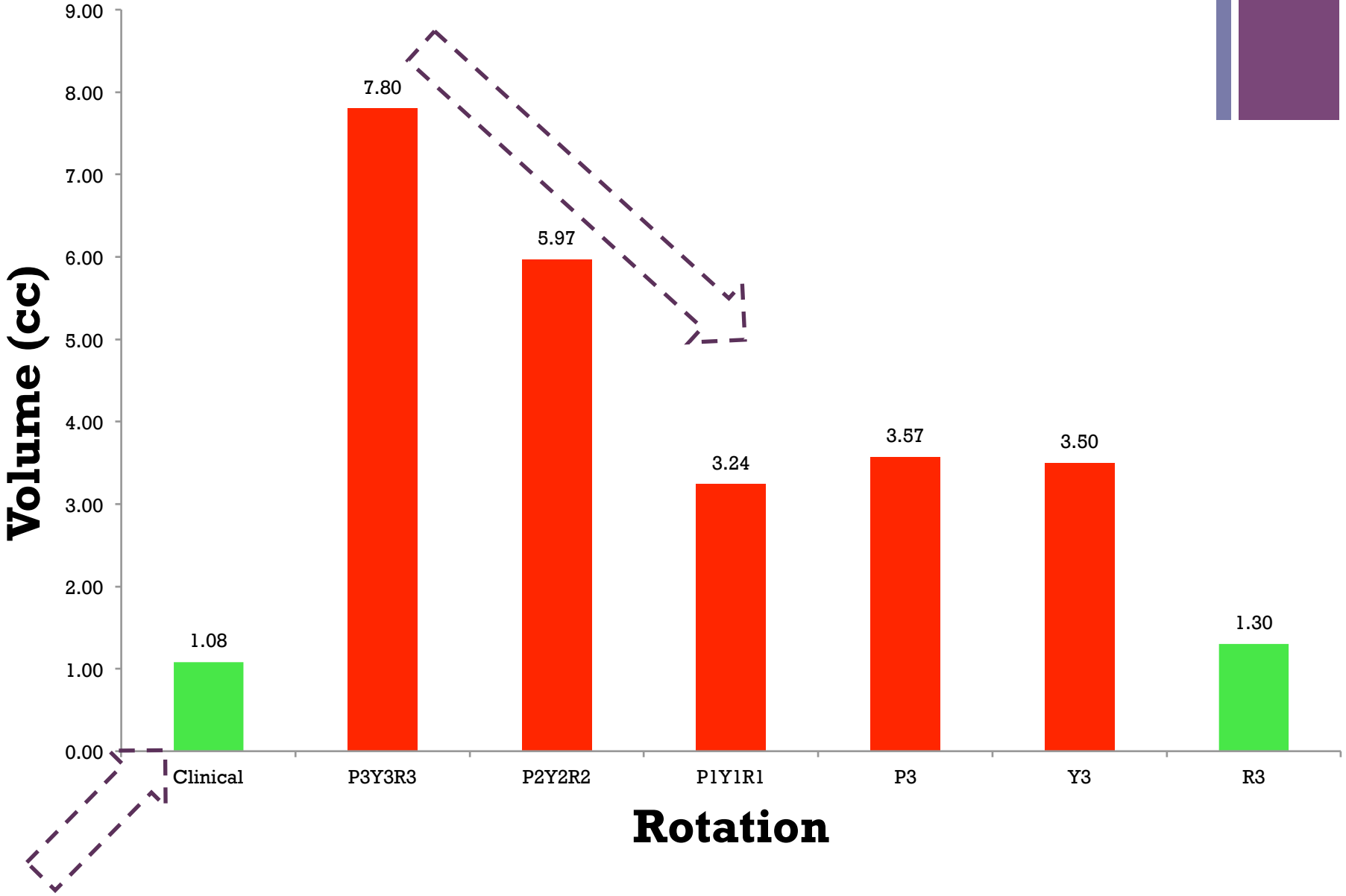
Pancreas PTV V33



Proximal Bowel V15



Proximal Bowel V20



Results for Patient 9

Objective	Clinical	P3Y3R3	P2Y2R2	P1Y1R1	P3	Y3	R3
GTV-V25 (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
PTV-V33 (%)	95.63	82.42	85.04	88.95	91.55	94.15	94.04
PTV-V42.9 (cc)	0.29	0.29	0.31	0.27	0.26	0.35	0.40
Stomach Proximal -V15 (cc)	7.24	0.88	0.67	2.69	3.44	4.55	7.75
Stomach Proximal -V20 (cc)	0.81	0.00	0.00	0.01	0.00	0.03	1.22
Stomach Proximal -V33 (cc)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bowel Proximal -V15 (cc)	7.27	24.84	20.96	14.48	15.99	13.80	7.90
Bowel Proximal -V20 (cc)	1.08	7.80	5.97	3.24	3.57	3.50	1.30
Bowel Proximal -V33 (cc)	0.00	0.51	0.37	0.13	0.12	0.10	0.00
Liver-V12 (%)	0.01	0.00	0.00	0.01	0.00	0.01	0.00
Kidneys-V12 (%)	5.30	7.20	7.05	6.45	4.82	6.09	5.98
Right Kidney -V12 (%)	0.34	0.15	0.20	0.21	0.26	0.22	0.17
Left Kidney -V12 (%)	10.46	14.52	14.14	12.94	9.57	12.19	11.99
Stomach-V12 (%)	6.81	2.22	2.23	4.06	4.18	5.37	7.14
Stomach-V33 (cc)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spinal Cord -V8 (cc)	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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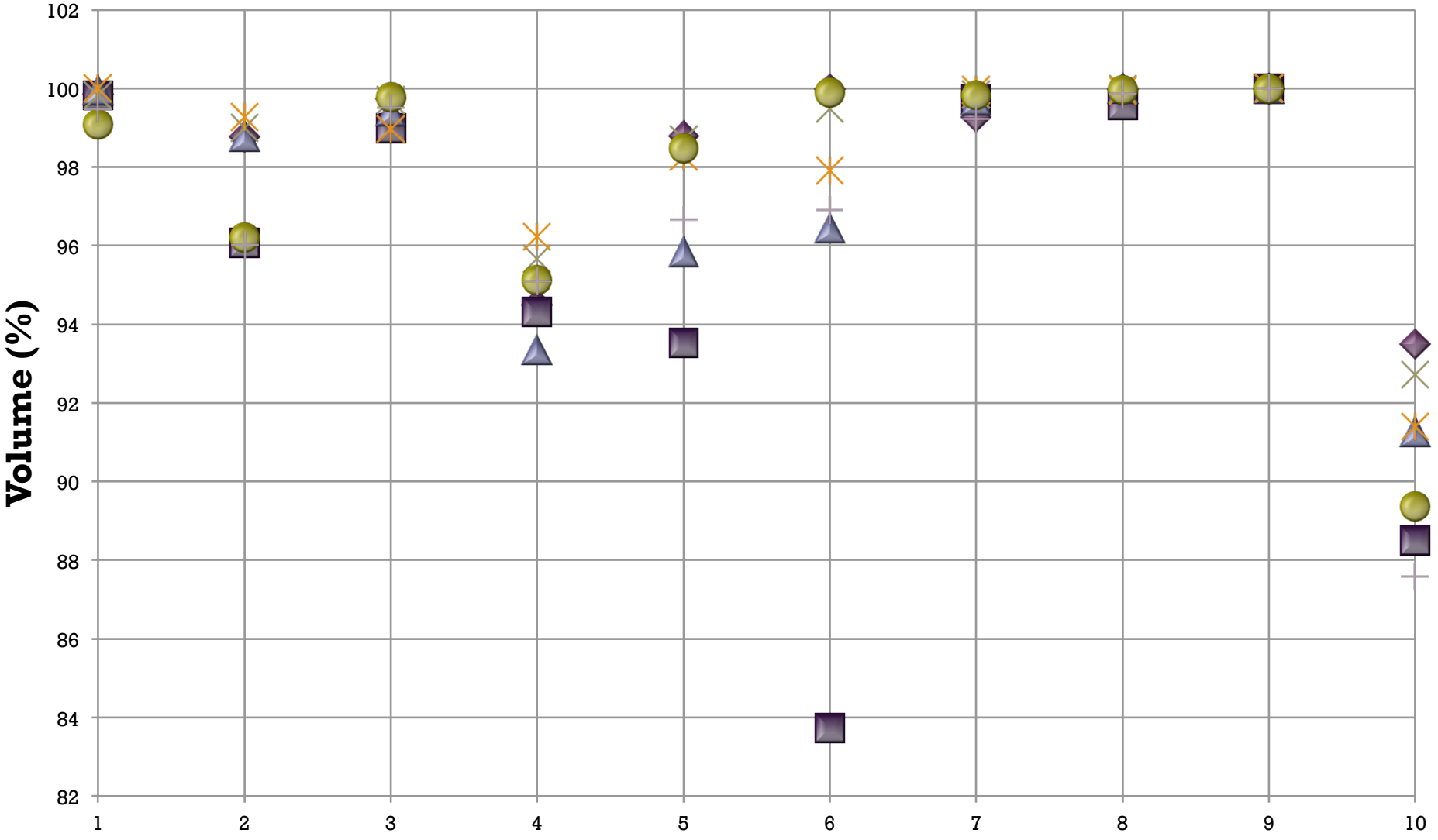
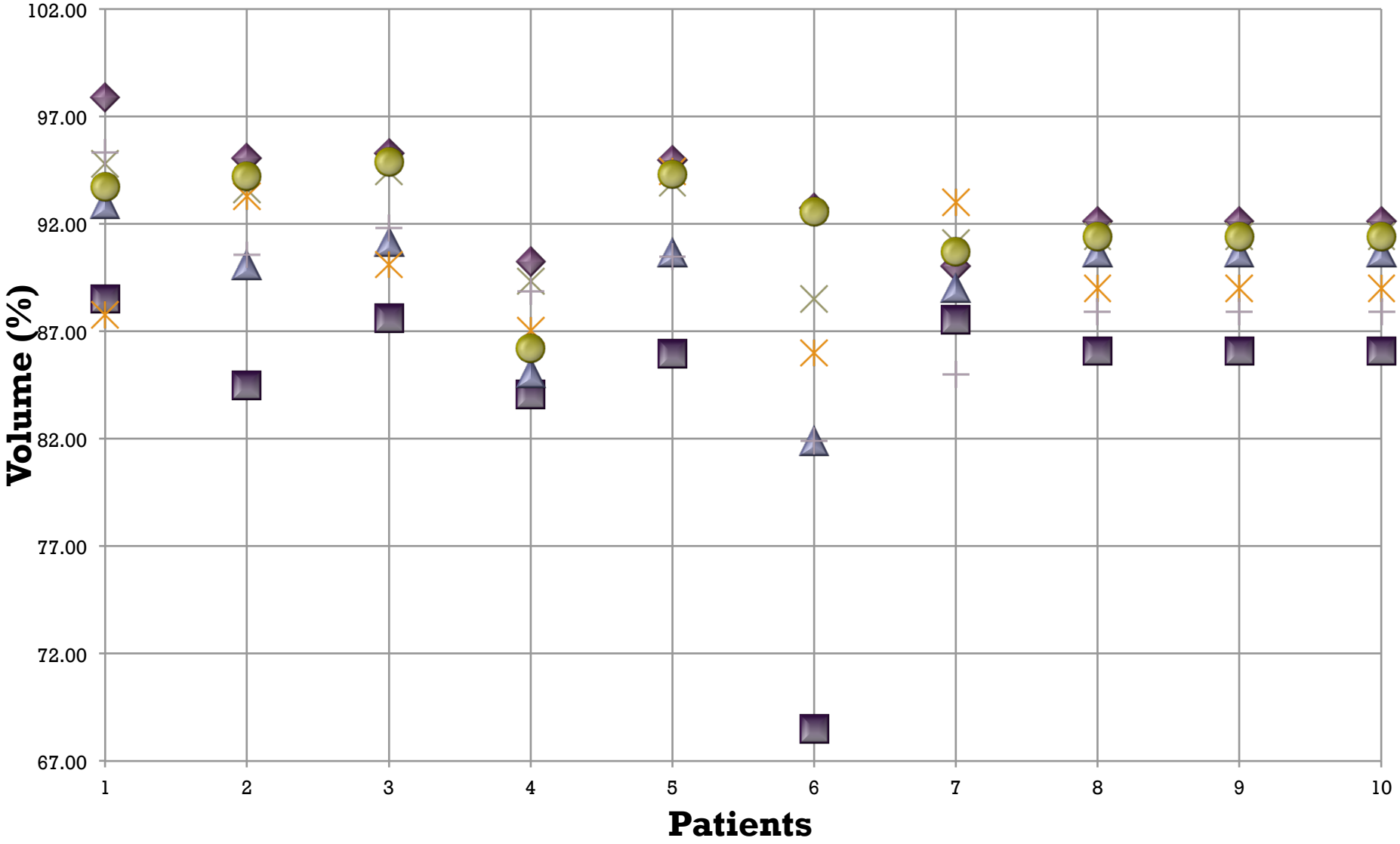
GTV V25



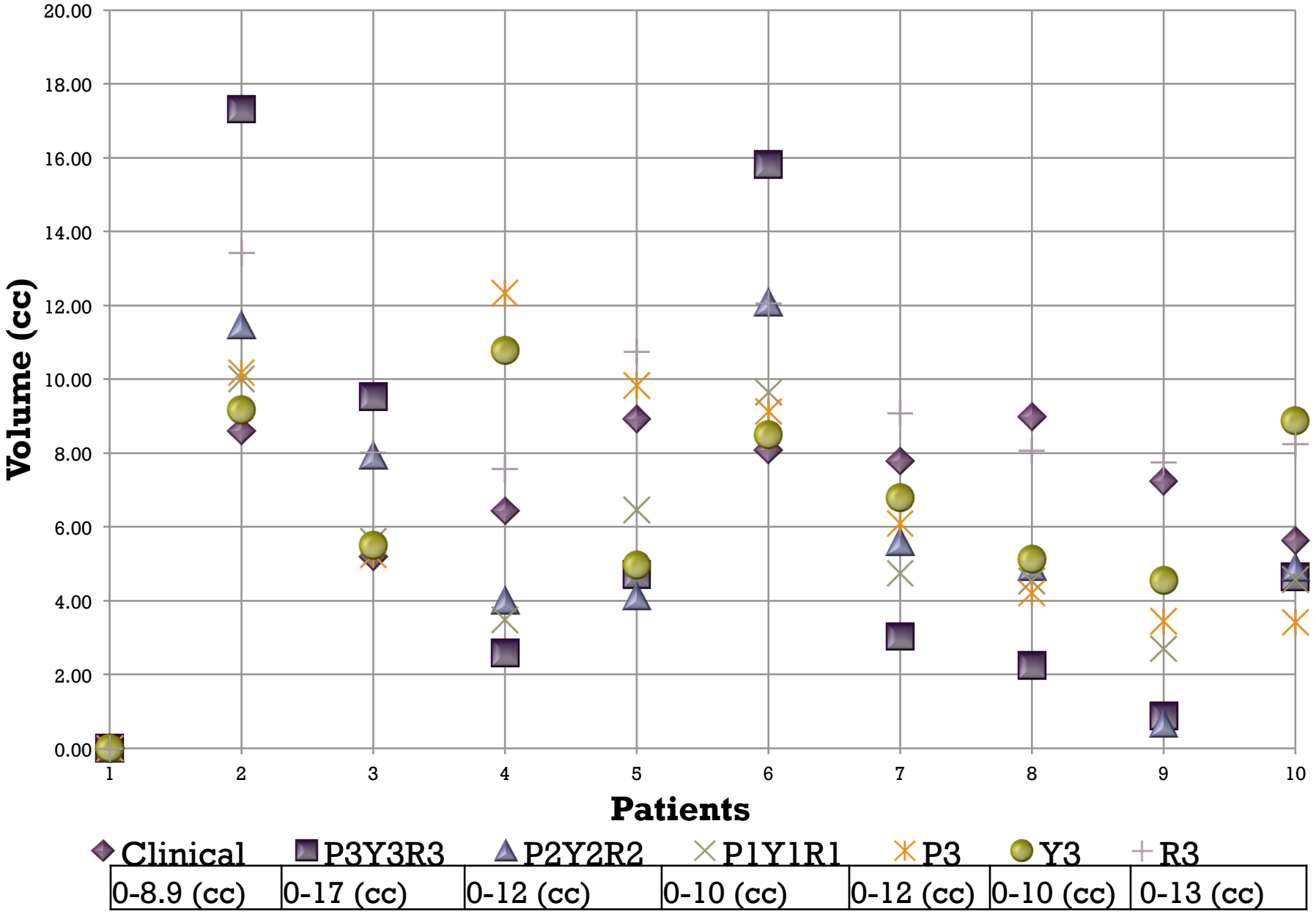
93-100 (%)	83-100 (%)	91-100 (%)	92-100 (%)	91-100 (%)	89-100 (%)	87-100 (%)

PTV V33

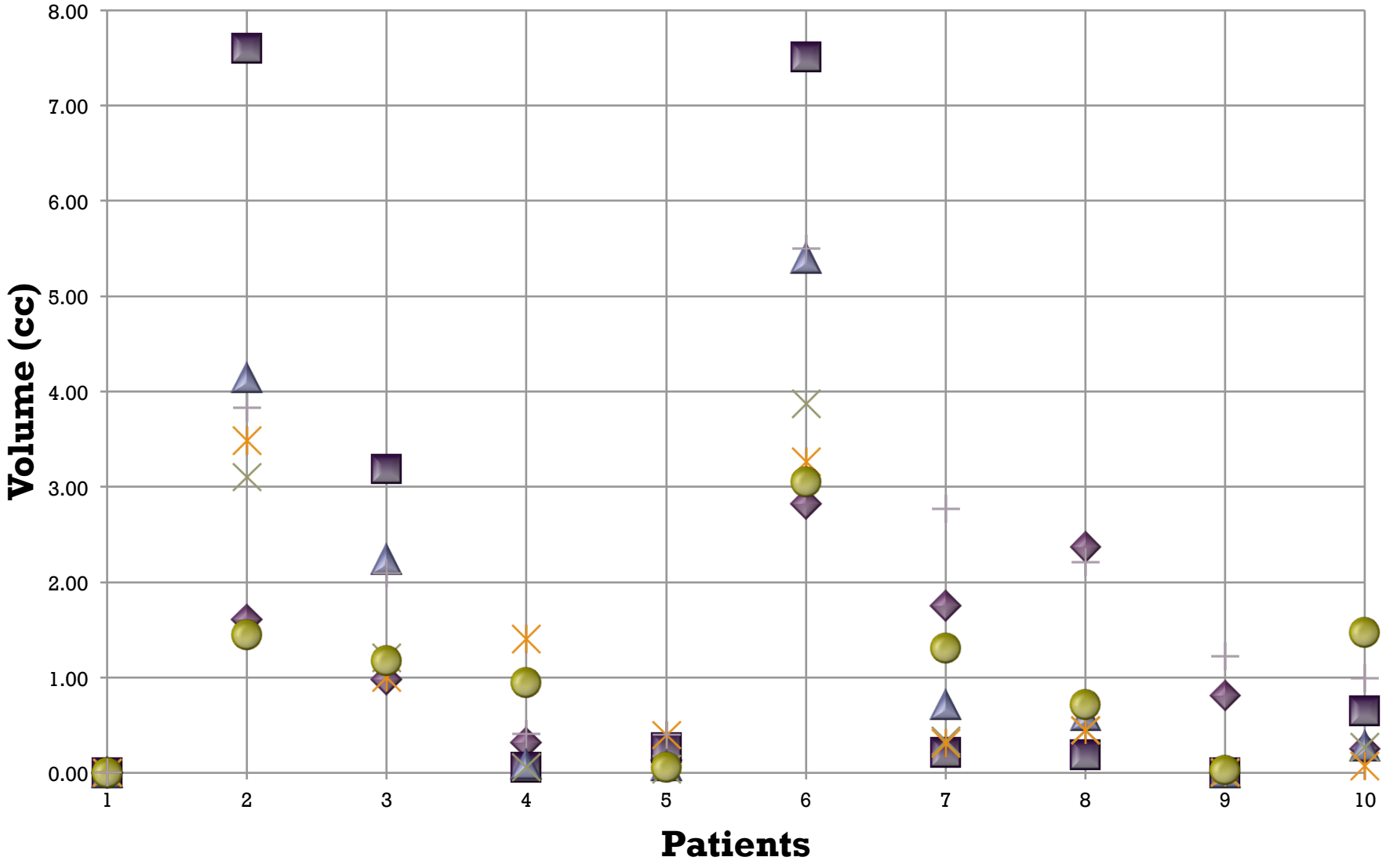


92-98 (%)	68-87 (%)	85-92 (%)	88-94 (%)	85-93 (%)	86-94 (%)	81-95 (%)

Proximal Stomach V15



Proximal Stomach V20



0-2.8 (cc)	0-7.5 (cc)	0-5.4 (cc)	0-3.8 (cc)	0-3.2 (cc)	0-3.0 (cc)	0-5.5 (cc)

Combined Ranges

Objective	Clinical	P3Y3R3	P2Y2R2	P1Y1R1	P3	Y3	R3
GTV V33(%)	93-100	83-100	91-100	92-100	91-100	89-100	87-100
PTV V33(%)	92-98	68-87	85-92	88-94	85-93	86-94	81-95
Stomach V15 (cc)	0-8.9	0-17	0-12	0-10	0-12	0-10	0-13
Stomach V20 (cc)	0-2.8	0-7.5	0-5.4	0-3.8	0-3.2	0-3.0	0-5.5

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Special Cases

- Opposite 3 degree direction rotation compared to the originals
- Different axis of rotation
  - Right lateral to the original rotation point
  - Inside the PTV
  - Superior and Posterior to the original rotation point
- Patient 6

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+ Results

Objectives	Clinical	P-3Y-3R-3	P3Y3R3
GTV-V25 (%)	99.98	99.44	83.72
PTV-V33 (%)	92.75	84.45	68.49
PTV-V42.9 (cc)	0.02	0.00	0.00
Stomach Proximal -V15 (cc)	8.09	4.83	15.81
Stomach Proximal -V20 (cc)	2.82	0.93	7.51
Stomach Proximal -V33 (cc)	0.00	0.00	0.00
Bowel Proximal -V15 (cc)	4.05	4.06	3.96
Bowel Proximal -V20 (cc)	2.22	2.23	1.78
Bowel Proximal -V33 (cc)	0.04	0.09	0.00
Liver-V12 (%)	3.34	4.08	2.10
Kidneys-V12 (%)	16.28	20.39	12.62
Right Kidney -V12 (%)	15.84	20.39	12.24
Left Kidney -V12 (%)	16.76	20.68	13.34
Stomach-V12 (%)	4.60	3.02	8.13
Stomach-V33 (cc)	0.00	0.00	0.00
Spinal Cord -V8 (cc)	0.00	0.00	0.00

Different Axis of Rotation

- Original-posterior to the PTV on the spine
- New axis of Rotations
  - Inside the PTV
  - Lateral to the original location
  - Posterior to the original location
  - Superior to the original location

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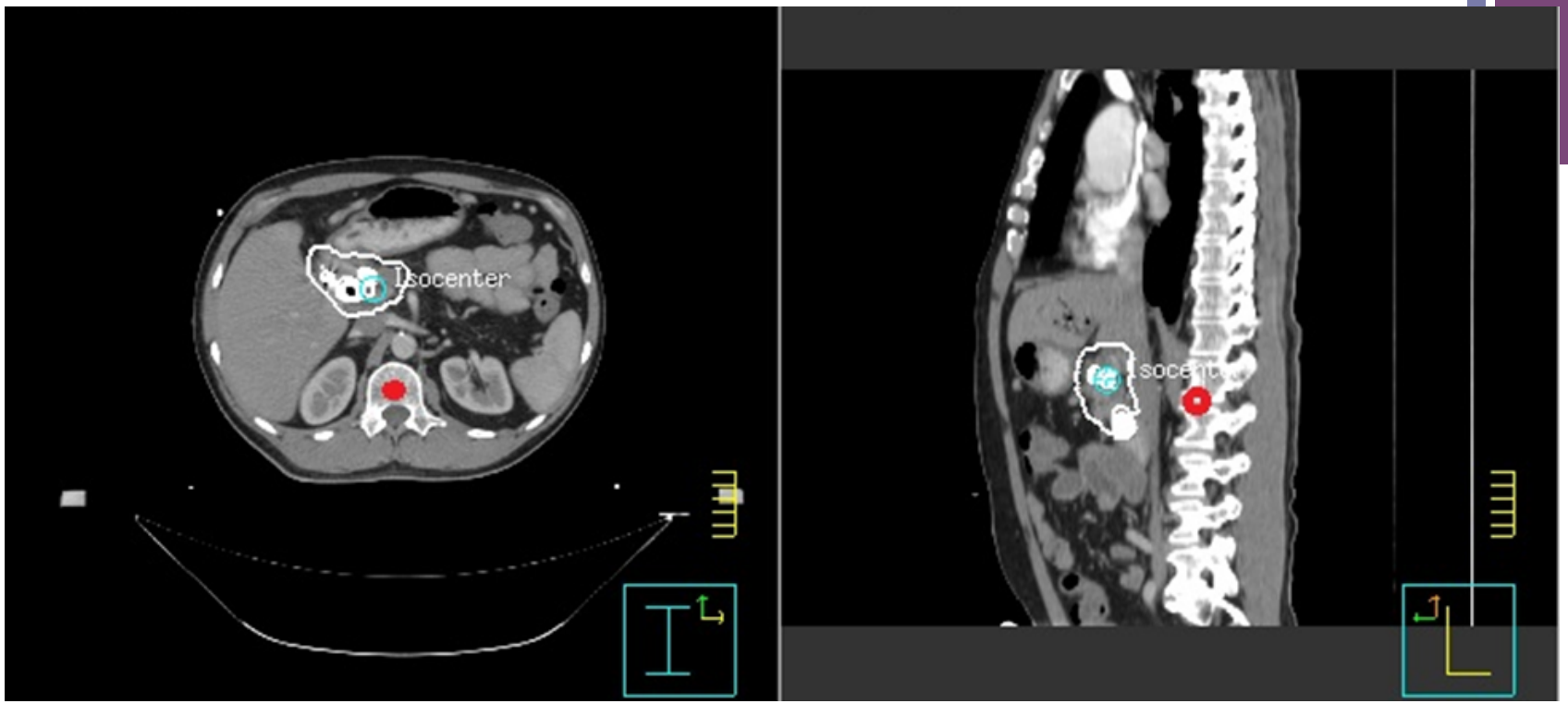
Original Axis of Rotation



This exemplifies the location for the original 6 rotations

58 mm posterior from the PTV

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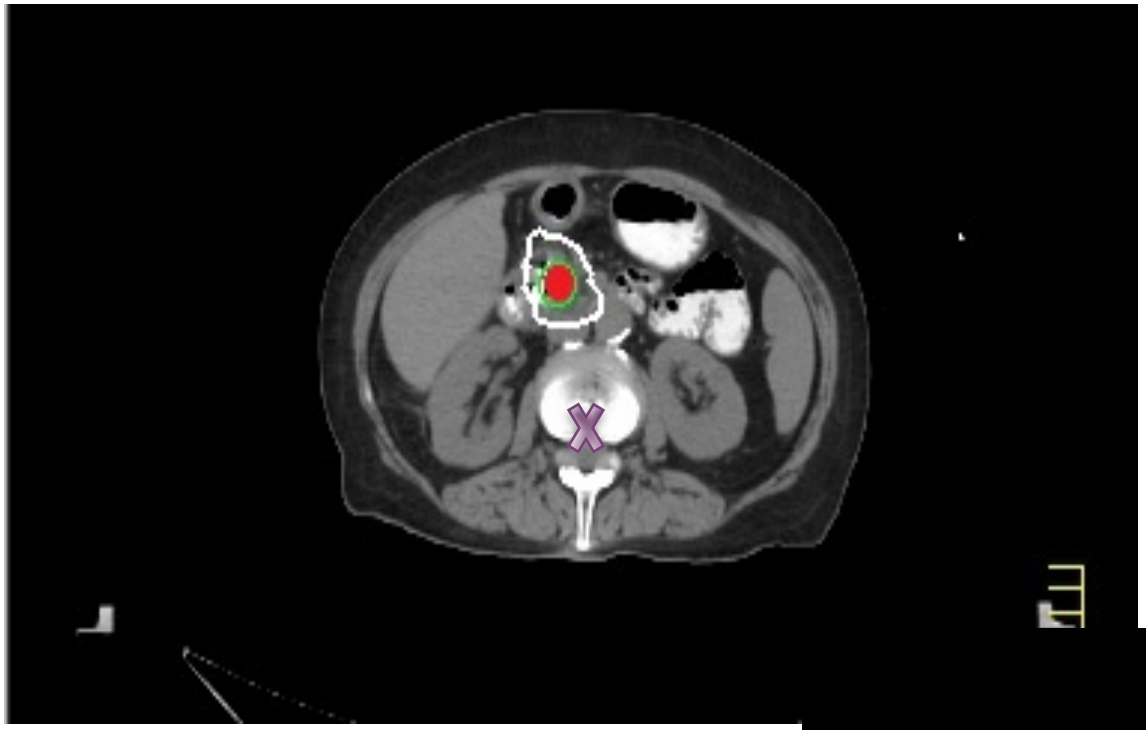

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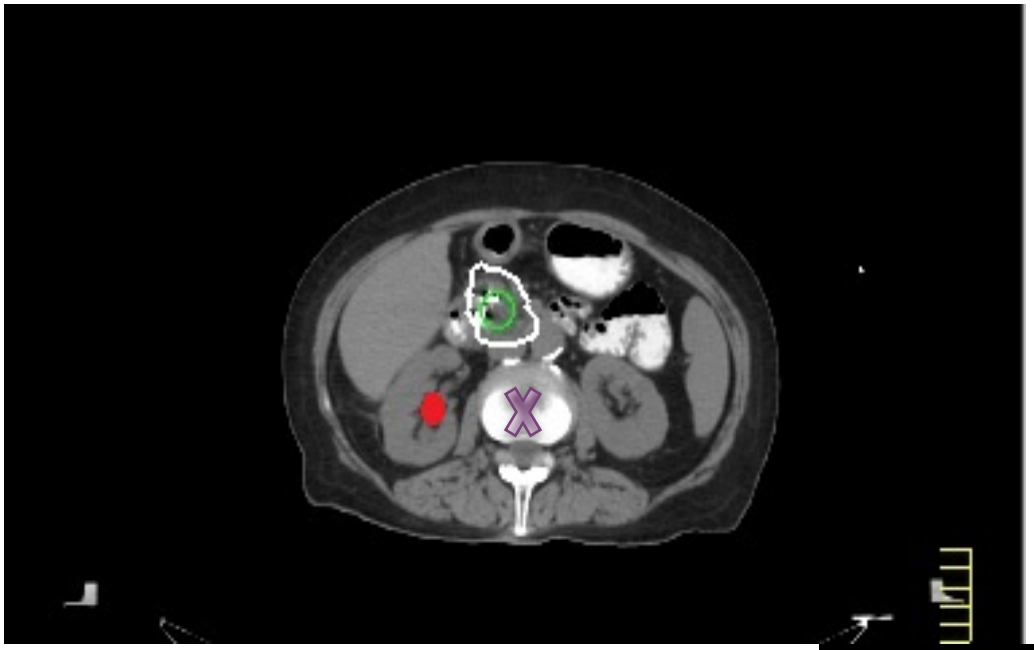
- X-Original axis of rotation
- Red-new axis of rotation on PTV

+ Results

Objective	Clinical		InsidePTV		Original
GTV-V25 (%)	99.98		99.48		83.72
PTV-V33 (%)	92.75		89.56		68.49
PTV-V42.9 (cc)	0.02		0.00		0.00
Stomach Proximal -V15 (cc)	8.09		11.04		15.81
Stomach Proximal -V20 (cc)	2.82		4.54		7.51
Stomach Proximal -V33 (cc)	0.00		0.00		0.00
Bowel Proximal -V15 (cc)	4.05		3.80		3.96
Bowel Proximal -V20 (cc)	2.22		1.96		1.78
Bowel Proximal -V33 (cc)	0.04		0.03		0.00
Liver-V12 (%)	3.34		3.33		2.10
Kidneys-V12 (%)	16.28		11.03		12.62
Right Kidney -V12 (%)	15.84		10.56		12.24
Left Kidney -V12 (%)	16.76		11.82		13.34
Stomach-V12 (%)	4.60		6.07		8.13
Stomach-V33 (cc)	0.00		0.00		0.00
Spinal Cord -V8 (cc)	0.00		0.00		0.00



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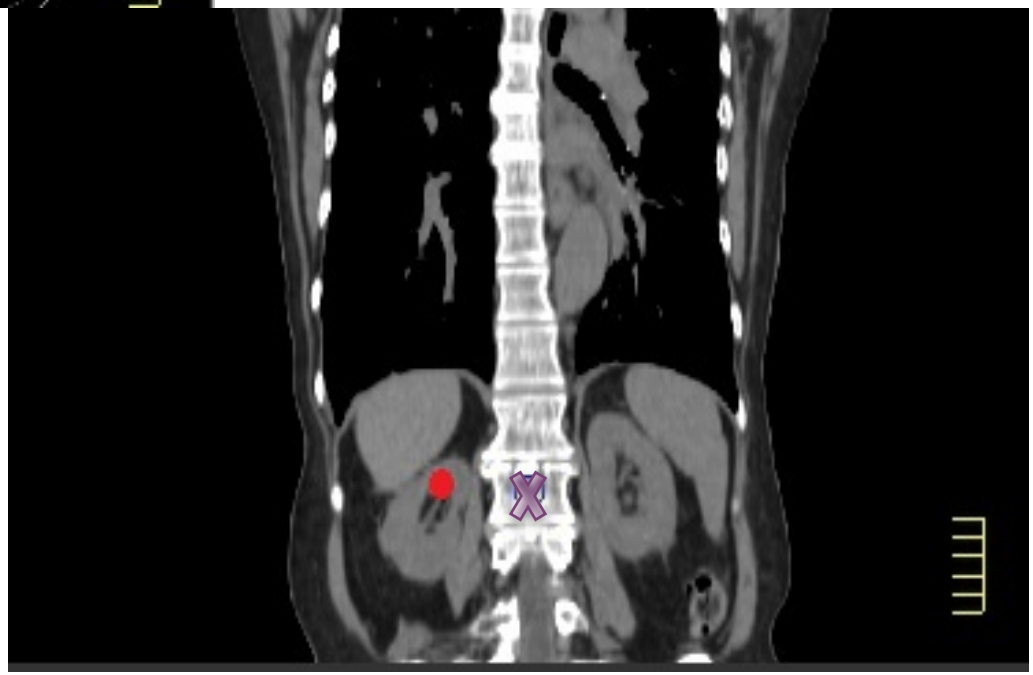
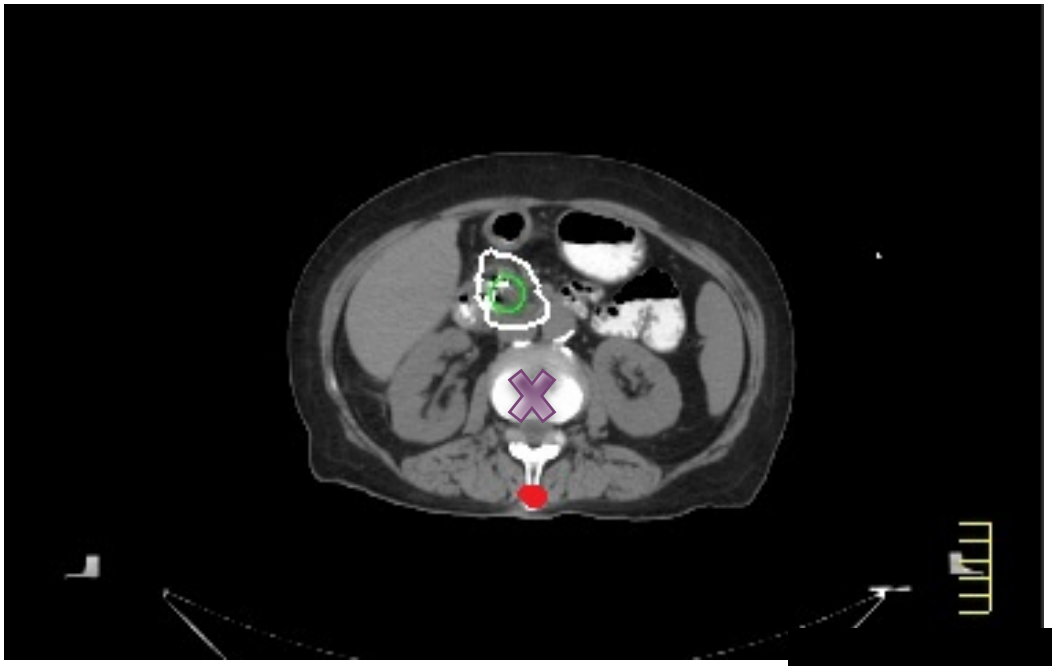


- X-original
- Red-60 mm right lateral to the original rotation point

Results

Objective	Clinical		Lateral		Original
GTV-V25 (%)	99.98		83.86		83.72
PTV-V33 (%)	92.75		68.77		68.49
PTV-V42.9 (cc)	0.02		0.00		0.00
Stomach Proximal -V15 (cc)	8.09		16.07		15.81
Stomach Proximal -V20 (cc)	2.82		7.12		7.51
Stomach Proximal -V33 (cc)	0.00		0.00		0.00
Bowel Proximal -V15 (cc)	4.05		6.12		3.96
Bowel Proximal -V20 (cc)	2.22		3.54		1.78
Bowel Proximal -V33 (cc)	0.04		0.04		0.00
Liver-V12 (%)	3.34		1.72		2.10
Kidneys-V12 (%)	16.28		12.63		12.62
Right Kidney -V12 (%)	15.84		15.65		12.24
Left Kidney -V12 (%)	16.76		9.31		13.34
Stomach-V12 (%)	4.60		8.38		8.13
Stomach-V33 (cc)	0.00		0.00		0.00
Spinal Cord -V8 (cc)	0.00		0.00		0.00



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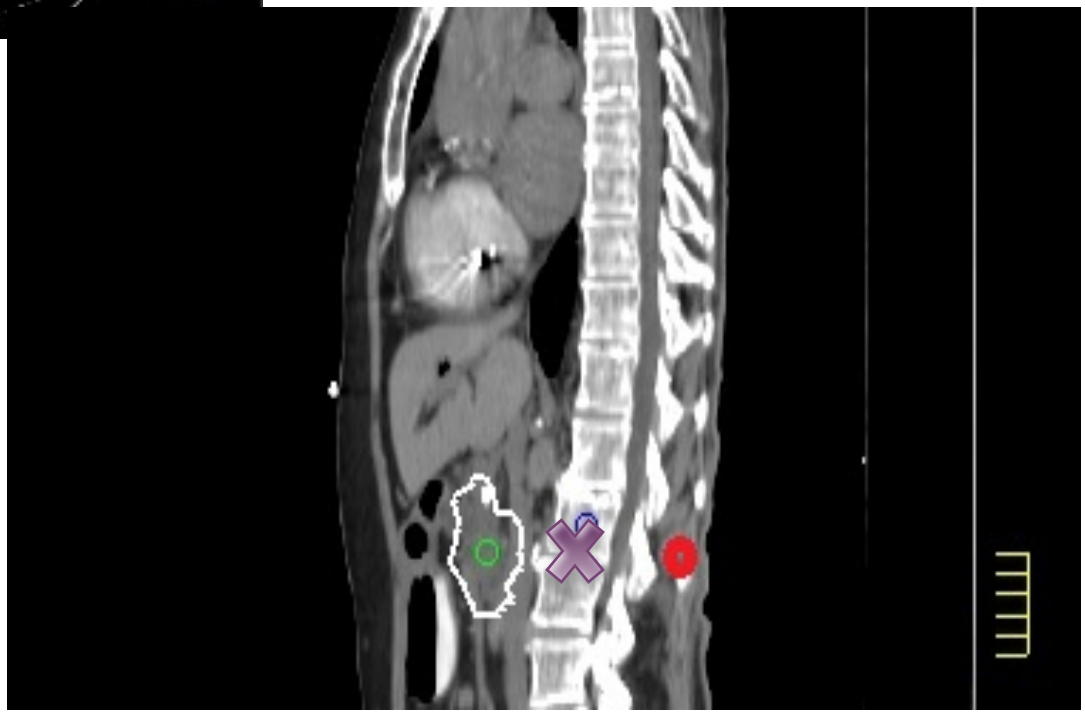
- X-original
- Red-58 mm posterior to the original rotation point



Results

Objective	Clinical	Posterior	Original
GTV-V25 (%)	99.98	85.78	83.72
PTV-V33 (%)	92.75	72.32	68.49
PTV-V42.9 (cc)	0.02	1.67	0.00
Stomach Proximal -V15 (cc)	8.09	20.10	15.81
Stomach Proximal -V20 (cc)	2.82	10.75	7.51
Stomach Proximal -V33 (cc)	0.00	0.15	0.00
Bowel Proximal -V15 (cc)	4.05	4.35	3.96
Bowel Proximal -V20 (cc)	2.22	2.04	1.78
Bowel Proximal -V33 (cc)	0.04	0.07	0.00
Liver-V12 (%)	3.34	2.64	2.10
Kidneys-V12 (%)	16.28	16.59	12.62
Right Kidney -V12 (%)	15.84	19.01	12.24
Left Kidney -V12 (%)	16.76	14.03	13.34
Stomach-V12 (%)	4.60	10.25	8.13
Stomach-V33 (cc)	0.00	0.15	0.00
Spinal Cord -V8 (cc)	0.00	0.02	0.00

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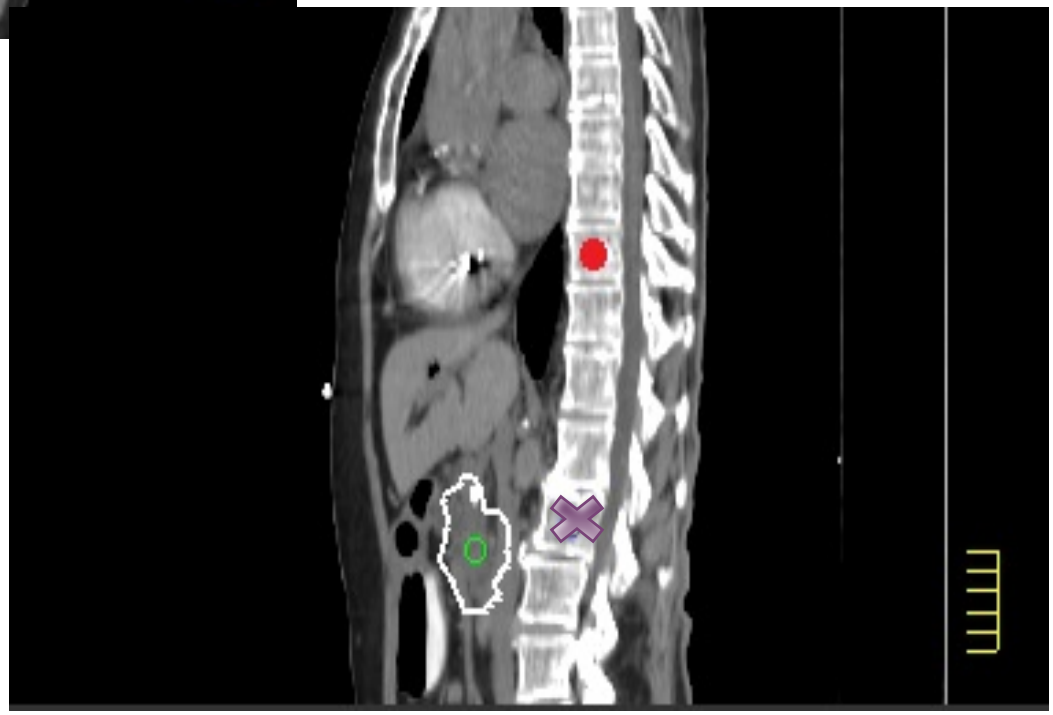
- X-original
- 115 mm superior to the original rotation point



Results

Objective	Clinical	Superior	Original
GTV-V25 (%)	99.98	97.88	83.72
PTV-V33 (%)	92.75	69.51	68.49
PTV-V42.9 (cc)	0.02	0.00	0.00
Stomach Proximal -V15 (cc)	8.09	5.75	15.81
Stomach Proximal -V20 (cc)	2.82	0.97	7.51
Stomach Proximal -V33 (cc)	0.00	0.00	0.00
Bowel Proximal -V15 (cc)	4.05	5.57	3.96
Bowel Proximal -V20 (cc)	2.22	3.38	1.78
Bowel Proximal -V33 (cc)	0.04	0.24	0.00
Liver-V12 (%)	3.34	4.02	2.10
Kidneys-V12 (%)	16.28	10.31	12.62
Right Kidney -V12 (%)	15.84	16.43	12.24
Left Kidney -V12 (%)	16.76	3.23	13.34
Stomach-V12 (%)	4.60	4.02	8.13
Stomach-V33 (cc)	0.00	0.00	0.00
Spinal Cord -V8 (cc)	0.00	0.89	0.00

Composite Results

Objective	Clinical	Lateral	OnPTV	Superior	Posterior	Original
GTV-V25 (%)	99.98	83.86	99.48	97.88	85.78	83.72
PTV-V33 (%)	92.75	68.77	89.56	69.51	72.32	68.49
PTV-V42.9 (cc)	0.02	0.00	0.00	0.00	1.67	0.00
Stomach Proximal -V15 (cc)	8.09	16.07	11.04	5.75	20.1	15.81
Stomach Proximal -V20 (cc)	2.82	7.12	4.54	0.97	10.75	7.51
Stomach Proximal -V33 (cc)	0.00	0.00	0.00	0.00	0.15	0.00
Bowel Proximal -V15 (cc)	4.05	6.12	3.8	5.57	4.35	3.96
Bowel Proximal -V20 (cc)	2.22	3.54	1.96	3.38	2.04	1.78
Bowel Proximal -V33 (cc)	0.04	0.04	0.03	0.24	0.07	0.00
Liver-V12 (%)	3.34	1.72	3.33	4.02	2.64	2.10
Kidneys-V12 (%)	16.28	12.63	11.03	10.31	16.59	12.62
Right Kidney -V12 (%)	15.84	15.65	10.56	16.43	19.01	12.24
Left Kidney -V12 (%)	16.76	9.31	11.82	3.23	14.03	13.34
Stomach-V12 (%)	4.60	8.38	6.07	4.02	10.25	8.13
Stomach-V33 (cc)	0.00	0.00	0.00	0.00	0.15	0.00
Spinal Cord -V8 (cc)	0.00	0.00	0.00	0.89	0.02	0.00

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Conclusion

- Based on the data there were some negative effects and common trends
  - Under-dosage to PTV and GTV
  - Over-dosage to normal tissue
- The 1 degree rotations were on average least detrimental to the normal tissue
- The 3 degree yaw was also on average least detrimental to the normal tissue
- The axis of rotation was least detrimental to the normal tissue

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How realistic is this study?

- We know that all machines align the patient to the isocenter
  - But these rotations moved the isocenter
- Therefore…
- I hope to be able to further investigate this research
  - Take the rotated images and move them in the translational directions to once again align the isocenter
  - Then analyze the radiation coverage to tumor and normal tissue

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Thank you!

Any questions?

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