The impact of the use of the SGRT technique on the Total Body Irradiation procedure based on own experience

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Greater Poland Cancer Centre est. 1953

GPCC Pila

2 TrueBeam

GPCC Poznan

4 TrueBeam

2 CyberKnife

1 Tomotherapy

1 IORT unit

1 FLASH unit not for clinic use

GPCC Kalisz

2 TrueBeam

SGRT system at GPCC

3 AlignRT system installations at GPCC Poznan + 1 AlignRT system installation at GGPC Pila (April 2024)

Implementation and experience with TBI technique

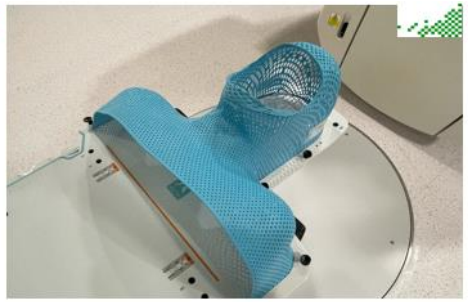
- Since 1993 classical TBI method (300 patients)
- February 2021 VMAT-TBI (63 patients)
- January 2023 decision to use SGRT for VMAT-TBI (16 patients)

Clinical background – TBI technique

- The total body irradiation technique (TBI) combined with chemotherapy is one of the conditioning methods commonly used before bone marrow transplantation in patients with hematologic malignancies
- The main goals of TBI irradiation:
  - to eliminate cancer cells remaining after chemotherapy
  - to suppress patient's immune system to reduce the risk of rejection of donor's bone marrow
- The irradiation schemes used in TBI vary depending on the type of disease, patient's condition, type of transplant, dose rate, and fractionation
  - In our center four different irradiation regimens are used:
    - 2 Gy (once daily)
    - 4 Gy (twice daily 2 Gy fractions given over 1 day)
    - 8 Gy (twice daily 2 Gy fractions given over 2 days)
    - 12 Gy (twice daily 2 Gy fractions given over 3 days)
- The main assumptions of the TBI procedure are to achieve uniform dose distribution throughout the body except the lungs (dose reduction to 9 Gy)
- One of the irradiation methods used in the procedure is VMAT-TBI (arc radiotherapy using beam intensity modulation)

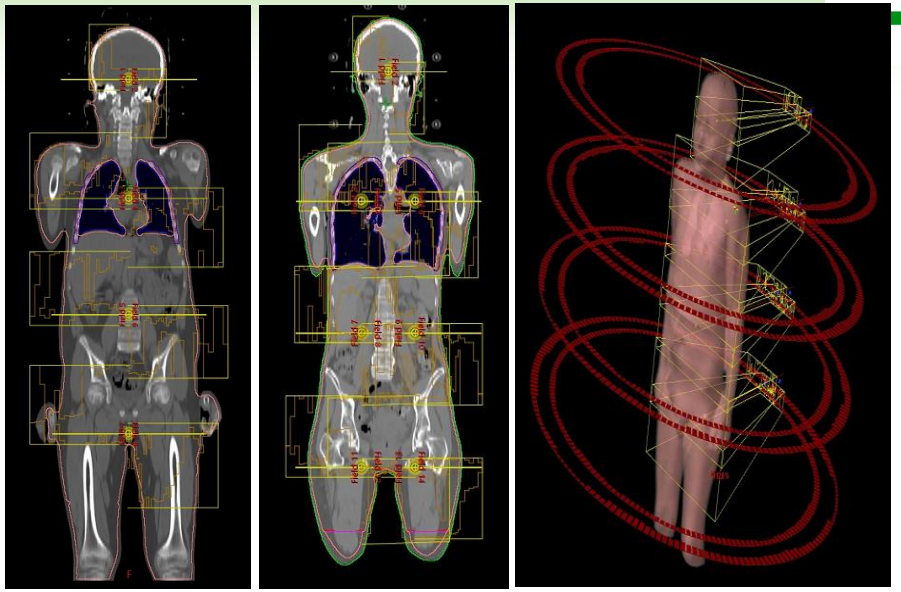
TBI-VMAT technique - patient preparation and immobilization

- Two sets of computed tomography (CT) data were obtained for each patient (the head-first scan from the top of the head to the lower thigh, and the feet-first scan from toes to upper thigh)
- The scans were acquired with 5 mm slice thickness in a free breathing mode
- Patient position: each patient was placed in a supine position with the arms along the body
- Immobilisation devices used included five-point thermoplastic masks for the head, neck and shoulders, dedicated plate Alta (Qfix) for the thorax, abdomen, pelvis and lower extremities and vacuum bag for feet

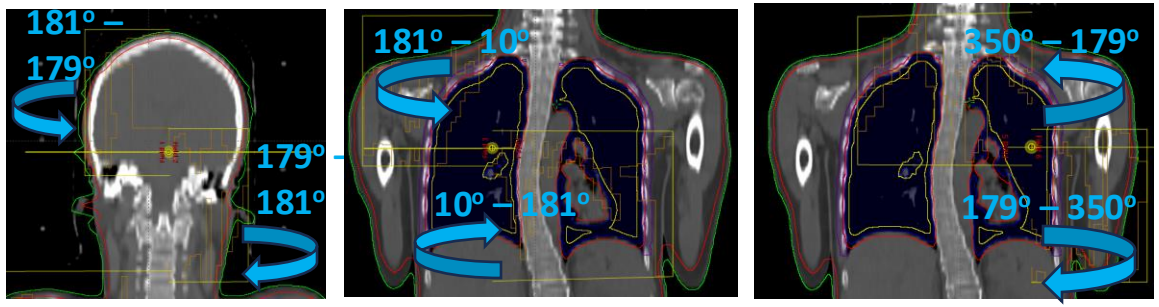




- The PTV included the entire body, trimmed to 5 mm below the skin. For total doses above 9 Gy, the PTV encompassed the entire body except for the lungs
- The only organ at risk is the lungs

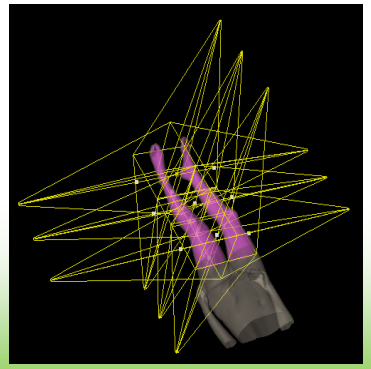
TBI-VMAT technique - treatment plan preparation



- 9 isocenters (same coordinates in the lateral X and anterior-posterior Z directions)
- 18 arcs optimized at the same time
- Collimator: 90°
- Field width: 40cm
- Isocenter positions and field dimensions adjusted to the patient's anatomy
- Energy: 6MV photons
- Optimization goals:
  - for PTV: 95% of the PTV volume will receive at least 95% of the prescribed dose
  - for lungs: limiting the mean dose below 9Gy



- Due to the lack of critical organs in the area from the mid-femur to the feet, this part of the patient's body is irradiated using 3DCRT technique four photon fields (box) with 3 isocenters (Legs-TBI)



This study aims to

(1) To report our experience with the VMAT-TBI strategy:

- Focused on irradiation planning, delivery, and execution time

(2) To evaluate the impact of Surface Guided Radiotherapy (SGRT) AlignRT on VMAT-TBI:

- Comparison was made between two patient groups

Group	Number of patients	Dose/Frequency	Technique
With SGRT	10	6 pts: 2 Gy daily	VMAT-TBI
		4 pts: 12 Gy (2 Gy × 2 daily)	
Without SGRT	10	6 pts: 2 Gy daily	VMAT-TBI (match PTV volume & Body length)
		4 pts: 12 Gy (2 Gy × 2 daily)	

(3) To present a case study:

- A pediatric patient was treated with VMAT-TBI 12 Gy using anesthesia and SGRT

Schema of irradiation VMAT-TBI without SGRT

- 10 patients: 6 pts - 2 Gy (once daily) and 4 pts - 12 Gy (twice daily 2 Gy fractions given over 3 days)

9 isocenters VMAT-TBI

Head

Lung R / L

Elbow R / L

Abdomen R / L

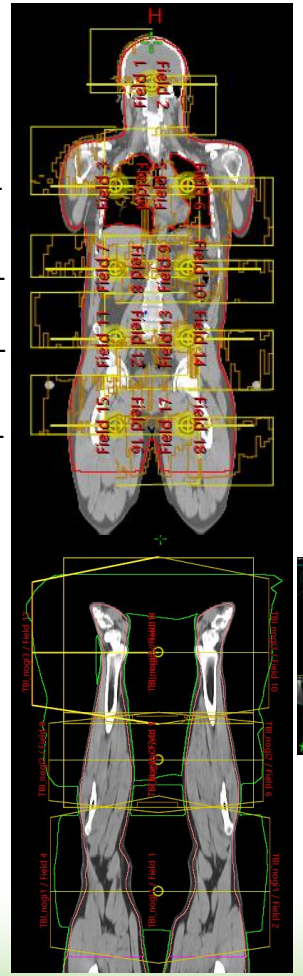
Pelvis R / L

3 isocenters
Legs -TBI

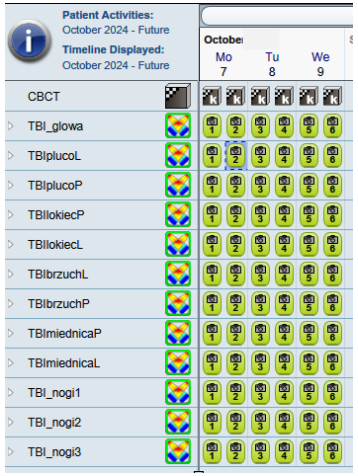
Leg 3

Leg 2

Leg 1



Scheduling



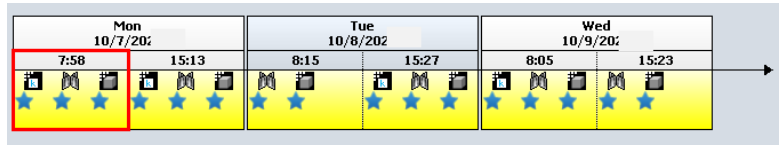
Fraction time include:

Pre-setup Imaging

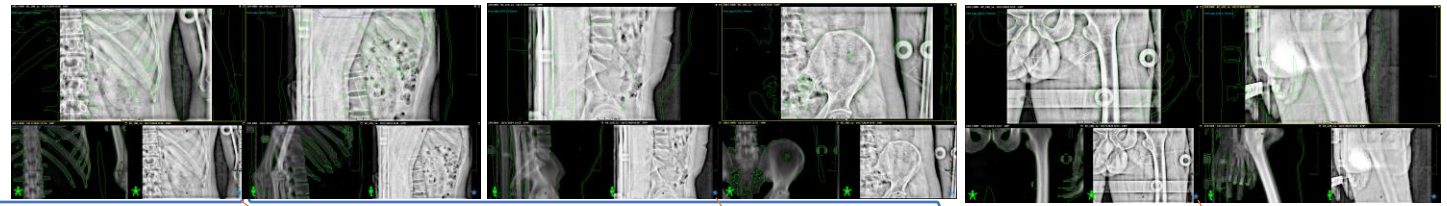
Imaging

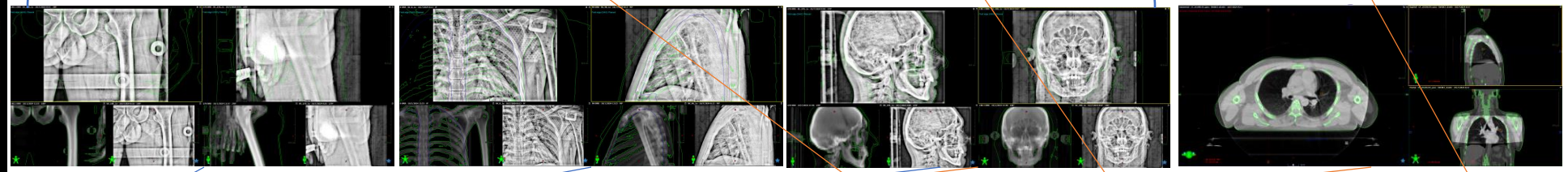
BeamOn

Session timeline



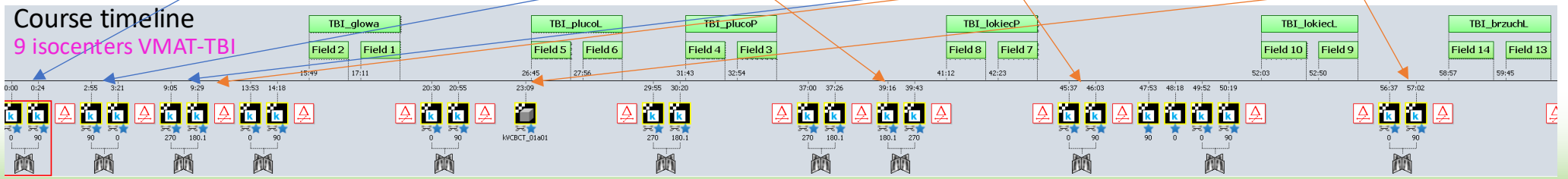
Imaging





Course timeline

9 isocenters VMAT-TBI



Schema of irradiation VMAT-TBI without SGRT

- 10 patients: 6 pts - 2 Gy (once daily) and 4 pts - 12 Gy (twice daily 2 Gy fractions given over 3 days)

9 isocenters VMAT-TBI

Head

Lung R / L

Elbow R / L

Abdomen R / L

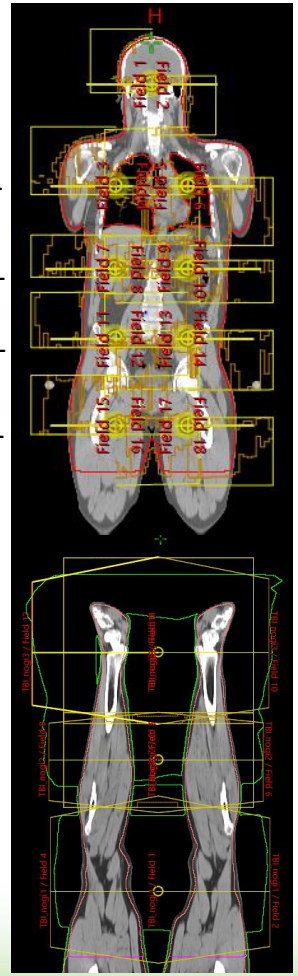
Pelvis R / L

3 isocenters Legs -TBI

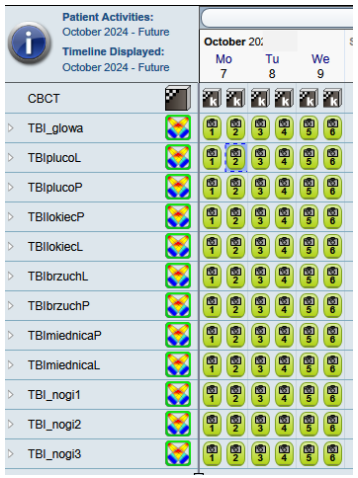
Leg 3

Leg 2

Leg 1



Scheduling



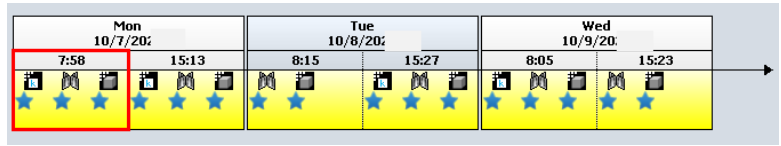
Fraction time include:

Pre-setup Imaging

Imaging

BeamOn

Session timeline



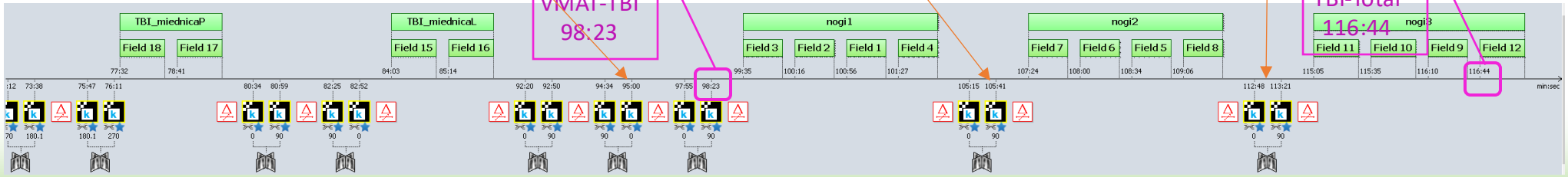
VMAT-TBI without SGRT

		No kV+CBCT
Tue	4/4/2023 8:08	45 (45 New)
Tue	4/4/2023 15:58	41 (41 New)
Wed	4/5/2023 8:11	39 (39 New)
Wed	4/5/2023 15:41	35 (35 New)
Thu	4/6/2023 8:07	33 (33 New)
Thu	4/6/2023 15:22	43 (43 New)

Imaging

Course timeline

3 isocenters Legs -TBI



Schema of irradiation VMAT-TBI with SGRT

- 10 patients: 6 pts - 2 Gy (once daily) and 4 pts - 12 Gy (twice daily 2 Gy fractions given over 3 days)

9 isocenters VMAT-TBI

Head

Lung R / L

Elbow R / L

Abdomen R / L

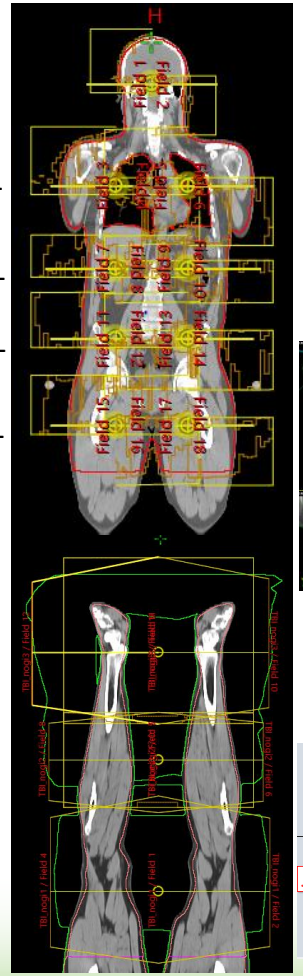
Pelvis R / L

3 isocenters Legs -TBI

Leg 3

Leg 2

Leg 1



VMAT-TBI without SGRT — No kV+CBCT

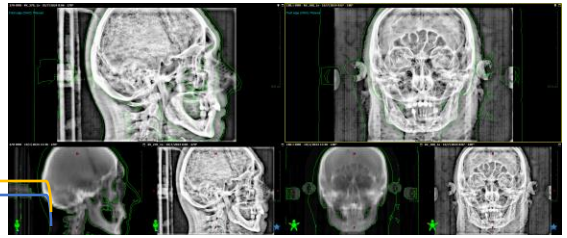
Tue	4/4/2023 8:08	45 (45 New)
Tue	4/4/2023 15:58	41 (41 New)
Wed	4/5/2023 8:11	39 (39 New)
Wed	4/5/2023 15:41	35 (35 New)
Thu	4/6/2023 8:07	33 (33 New)
Thu	4/6/2023 15:22	43 (43 New)

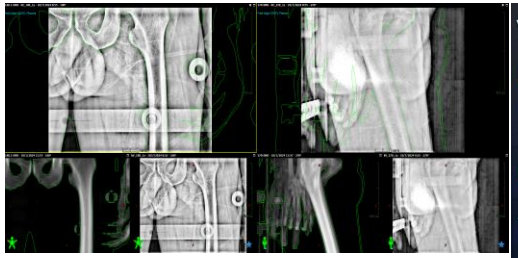
VMAT-TBI with SGRT — No kV+CBCT

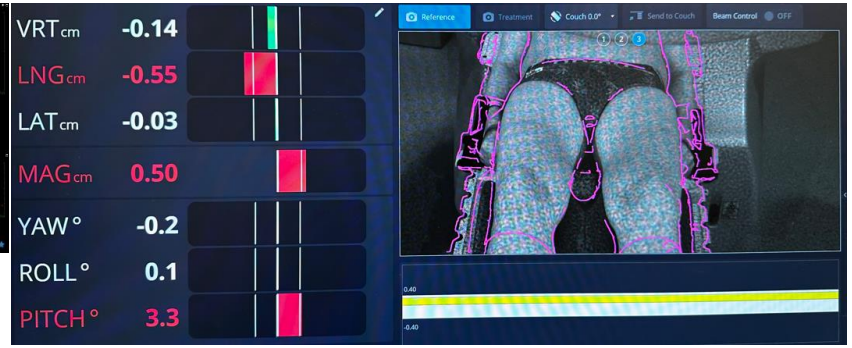
Mon	10/7/2024 7:58	33 (33 New)
Mon	10/7/2024 15:13	31 (31 New)
Tue	10/8/2024 8:15	35 (35 New)
Tue	10/8/2024 15:27	33 (33 New)
Wed	10/9/2024 8:05	35 (35 New)
Wed	10/9/2024 15:23	33 (33 New)

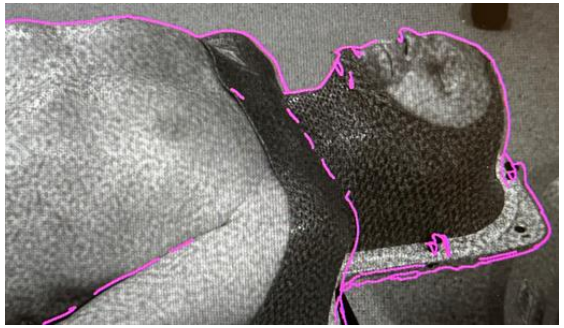
Imaging

Pre-setup Imaging

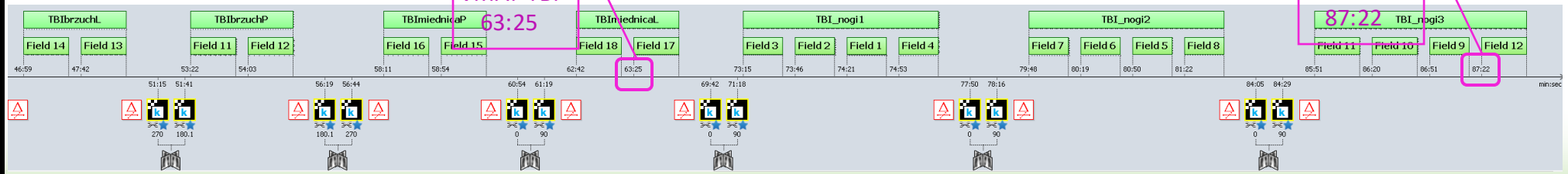






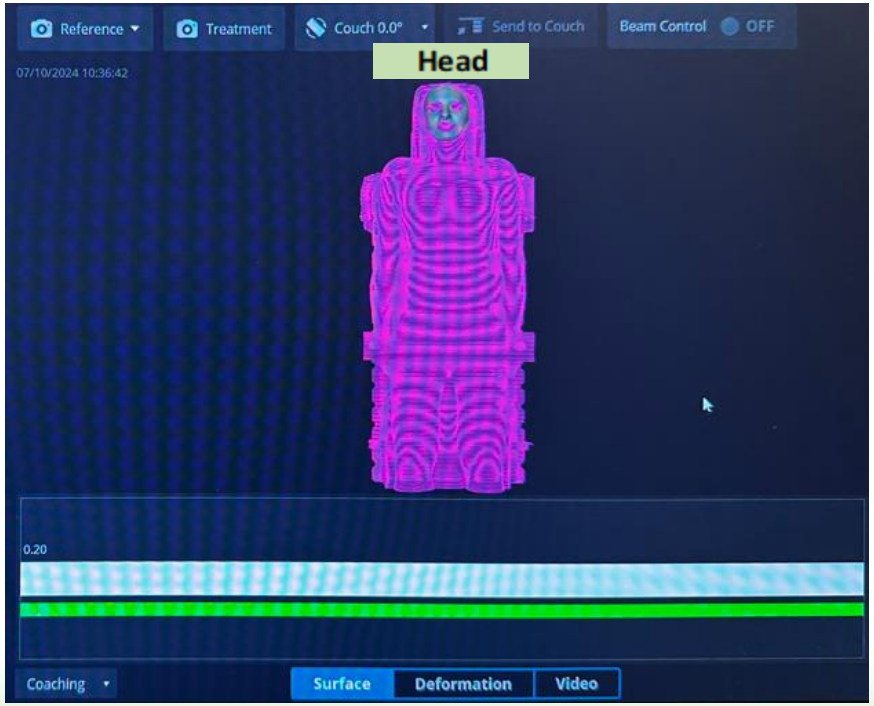


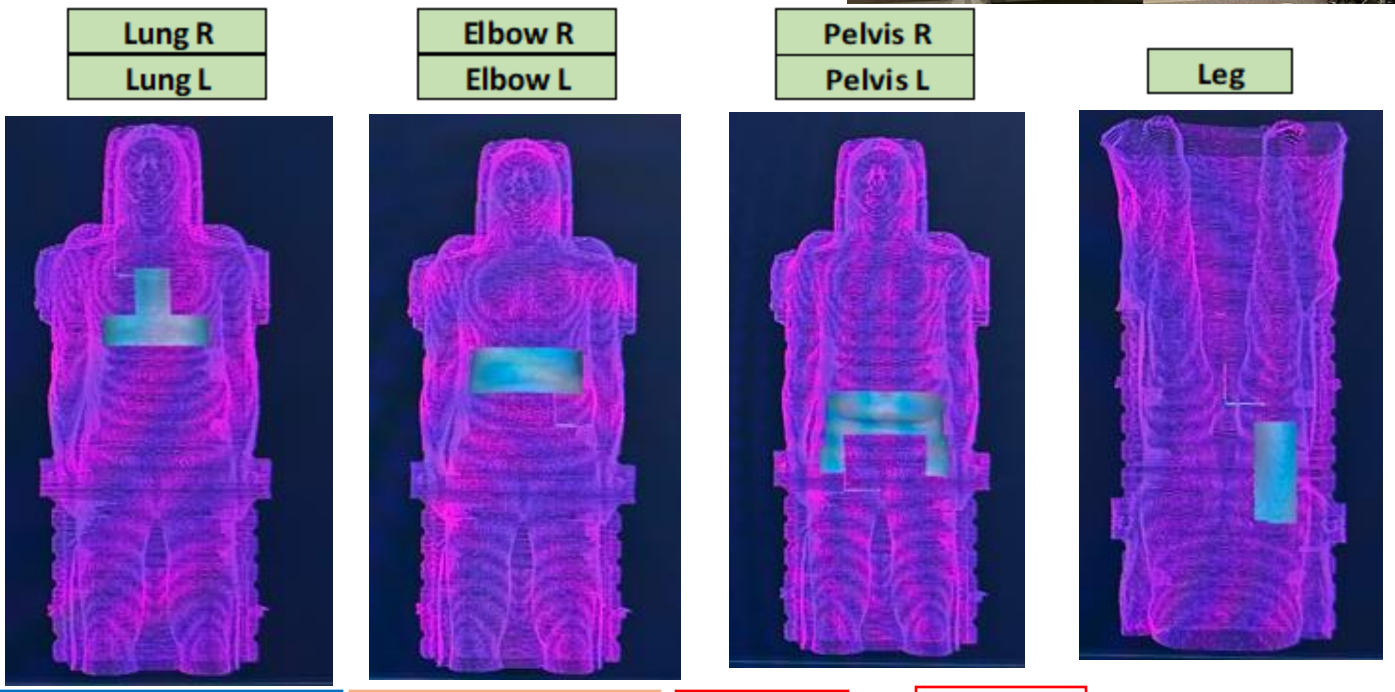
Course timeline TBI



Use VRT for TBI-VMAT treatment

- SGRT was used exclusively for pre-setup, the setup and imaging of a specific isocenter TBI technique
- Each isocenter has its own ROI's area
- Perform the treatment delivery without beam control (e.g., blanket or other covering)

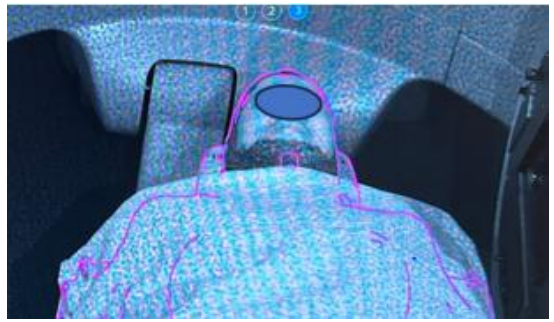


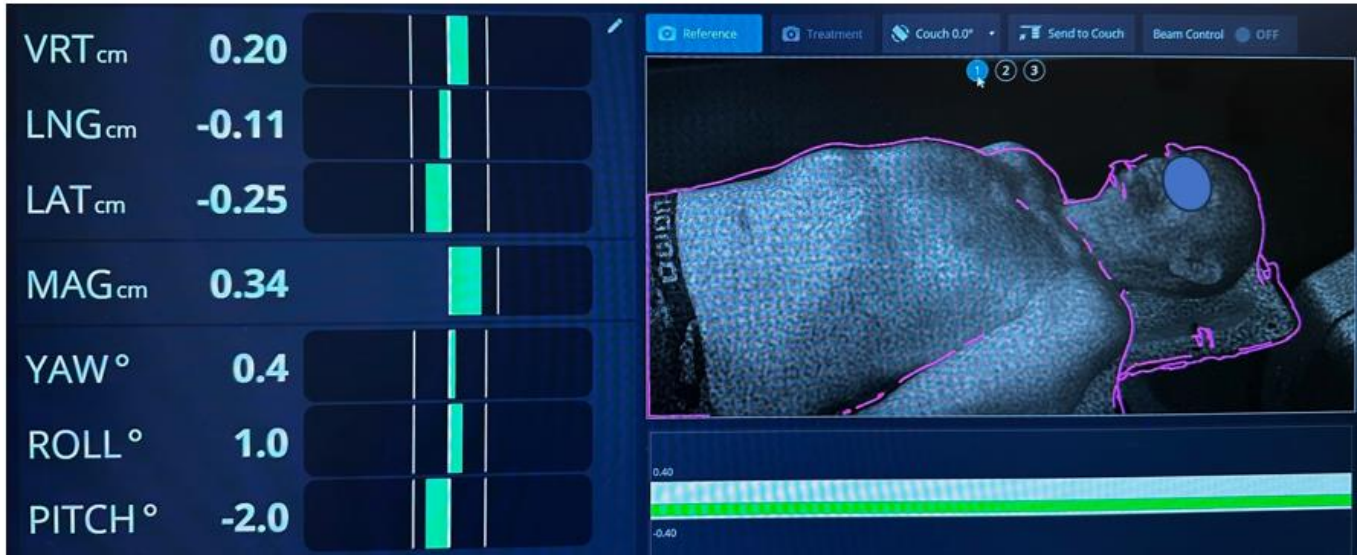


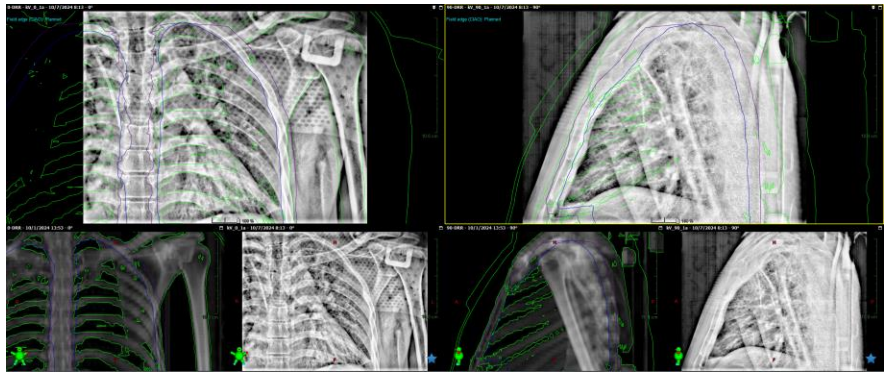
Pre-setup imaging	Imaging isocenters	BeamOn	→ VMAT-TBI	TBI
Pre-setup imaging	Imaging isocenters	BeamOn	→ Legs-TBI	

Patient’s positiong during Pre-setup and imaging

- Use only the standard postural video view for each isocenter
- New SGRT references are not taken, as the CT scan provides the most detailed references (without the use of blankets or other coverings)





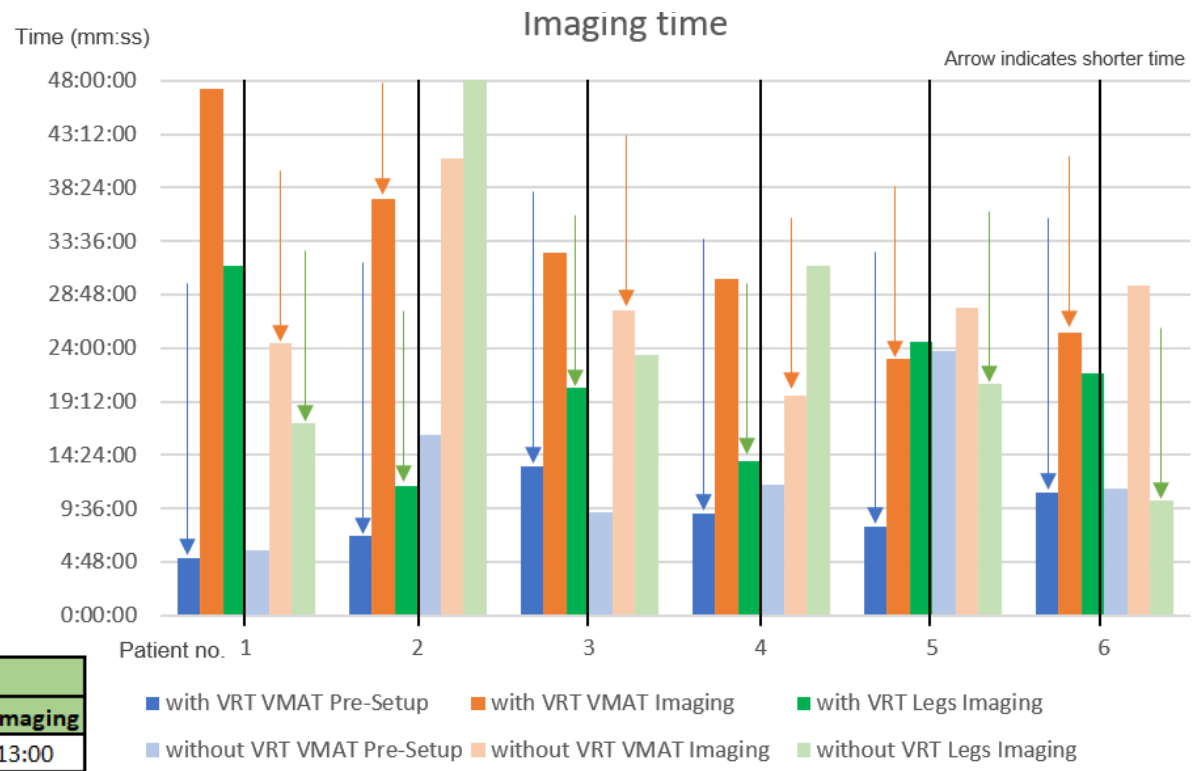


- Benefits: The patient setup was based on SGRT, with new monitoring capture, eliminating the need for any skin markings

Pre-setup imaging and imaging time for VMAT-TBI, Legs-TBI

- 6 pts: 2 Gy daily treated with and without SGRT

- Pre-setup imaging for VMAT-TBI and Legs-TBI was completed in less time with SGRT
- The duration of VMAT-TBI imaging was extended when using SGRT, due to the combined influence of kV imaging and SGRT
- Treatment setups have become more efficient since the implementation of SGRT in the TBI workflow



	with SGRT			without SGRT		
Patient no.	VMAT Pre-Setup	VMAT Imaging	Legs Imaging	VMAT Pre-Setup	VMAT Imaging	Legs Imaging
1	5:09:00	47:12:00	31:26:00	5:52:00	24:26:00	17:13:00
2	7:07:00	37:21:00	11:40:00	16:13:00	41:00:00	50:19:00
3	13:21:00	32:37:00	20:27:00	9:20:00	27:25:00	23:22:00
4	9:09:00	30:12:00	13:51:00	11:46:00	19:44:00	31:21:00
5	8:02:00	23:02:00	24:37:00	23:43:00	27:40:00	20:49:00
6	11:03:00	25:23:00	21:46:00	11:21:00	29:36:05	10:18:00
mean	8:58:30	32:37:50	20:37:50	13:02:30	28:18:31	25:33:40
min	5:09:00	23:02:00	11:40:00	5:52:00	19:44:00	10:18:00
max	13:21:00	47:12:00	31:26:00	23:43:00	41:00:00	50:19:00

VMAT-TBI

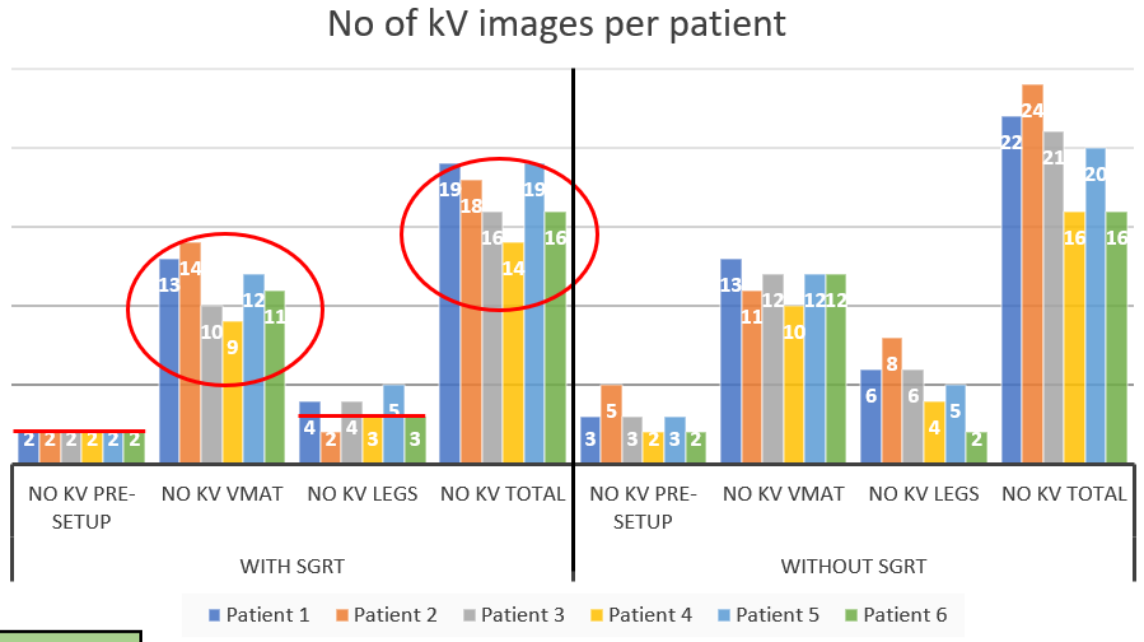
Legs-TBI

Pre-setup imaging | Imaging isocenters

Number of kV images for pre-setup and imaging in VMAT-TBI and Legs-TBI

- 6 pts: 2 Gy daily treated with and without SGRT

- Decrease repeat 2D kV imaging for pre-setup and imaging to an average of one image per isocenter
- Especially by reducing the number of images in the legs imaging
- The total number of images using SGRT was ultimately lower
- Minimization of patient dose from kV and/or CBCT imaging process



	with SGRT				without SGRT			
Patient no.	No kV Pre-Setup	No kV VMAT	No kV Legs	No kV Total	No kV Pre-Setup	No kV VMAT	No kV Legs	No kV Total
1	2	13	4	19	3	13	6	22
2	2	14	2	18	5	11	8	24
3	2	10	4	16	3	12	6	21
4	2	9	3	14	2	10	4	16
5	2	12	5	19	3	12	5	20
6	2	11	3	16	2	12	2	16
mean	**2**	**12**	**4**	**17**	**3**	**12**	**5**	**20**
min	**2**	**9**	**2**	**14**	**2**	**10**	**2**	**16**
max	**2**	**14**	**5**	**19**	**5**	**13**	**8**	**24**

VMAT-TBI

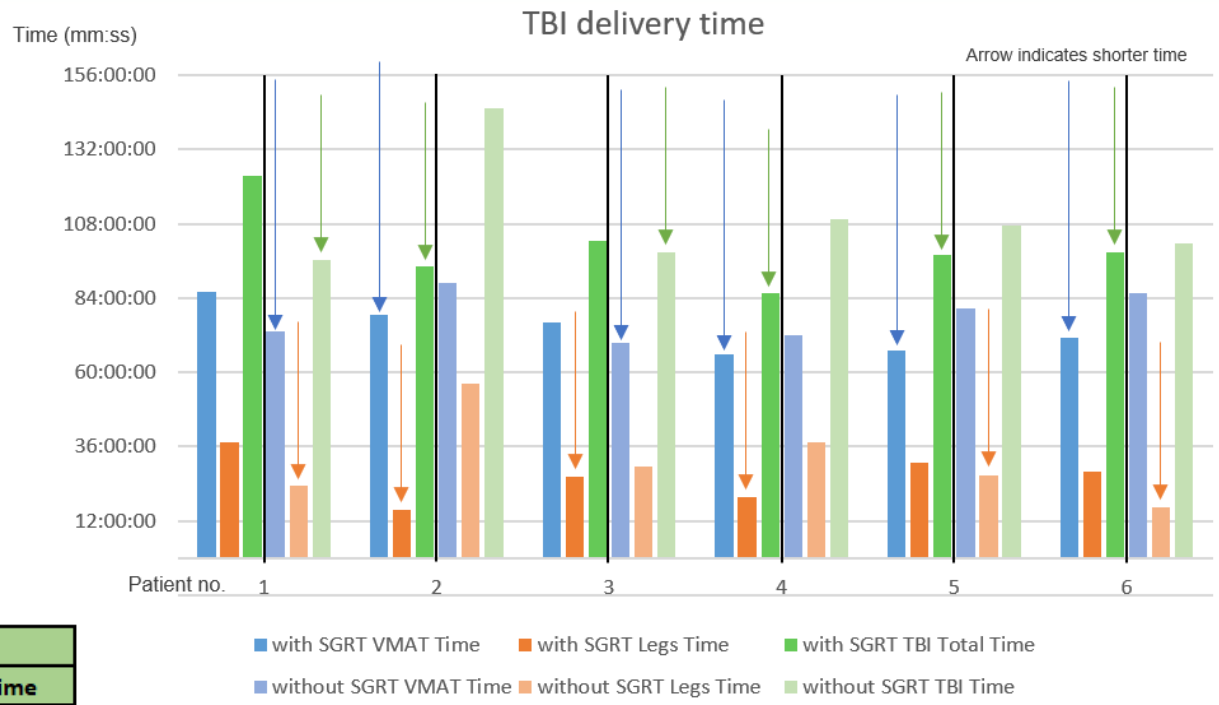
Legs-TBI

Pre-setup No kV

Imaging No kV

Total delivery time for VMAT-TBI and Legs-TBI with and without SGRT

- 6 pts: 2 Gy daily treated with and without SGRT
- The total delivery time for VMAT-TBI and Legs-TBI is shorter or equel when SGRT is used
- The total delivery time was reduced to approximately 100 minutes per case for adult VMAT-TBI treatments



	with SGRT			without SGRT		
Patient no.	VMAT Time	Legs Time	TBI Total Time	VMAT Time	Legs Time	TBI Time
1	86:05:00	37:26:00	123:31:00	73:05:00	23:13:00	96:18:00
2	78:40:00	15:40:00	94:20:00	88:56:00	56:19:00	145:15:00
3	76:01:00	26:27:00	102:28:00	69:23:00	29:22:00	98:45:00
4	65:43:00	19:51:00	85:34:00	71:58:00	37:21:00	109:19:00
5	67:13:00	30:37:00	97:50:00	80:41:00	26:49:00	107:30:00
6	71:05:00	27:46:00	98:51:00	85:28:00	16:18:00	101:46:00
mean	74:07:50	26:17:50	100:25:40	78:15:10	31:33:40	109:48:50
min	65:43:00	15:40:00	85:34:00	69:23:00	16:18:00	96:18:00
max	86:05:00	37:26:00	123:31:00	88:56:00	56:19:00	145:15:00

VMAT-TBI

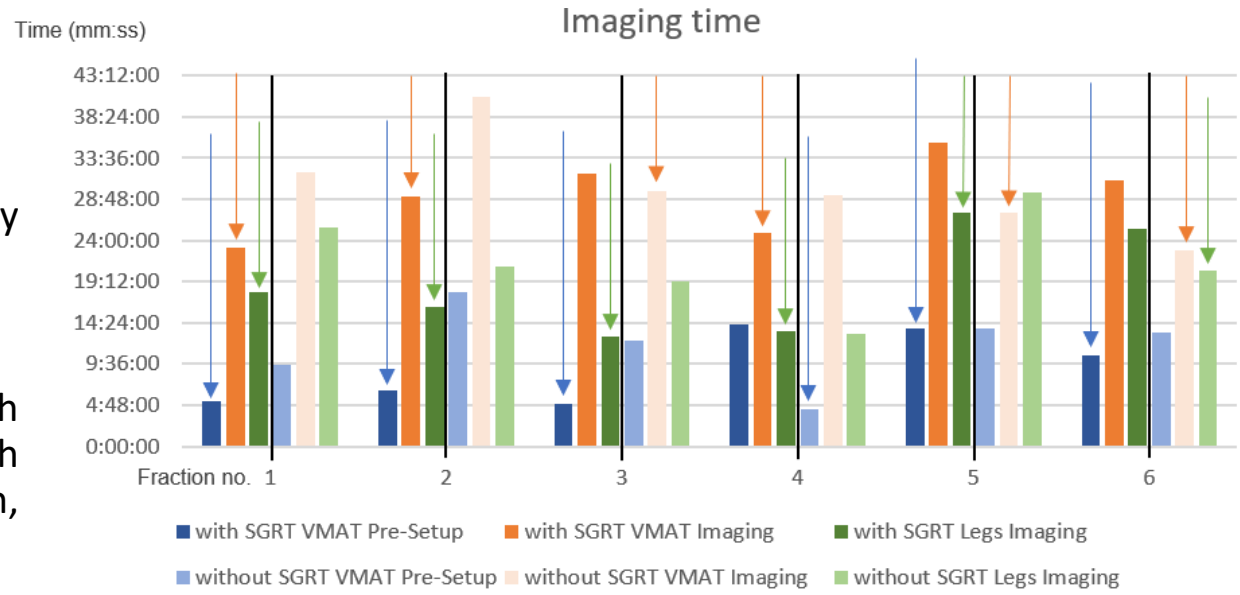
Legs-TBI

Pre-setup Time

Imaging Time

Pre-setup imaging and imaging time for VMAT-TBI, Legs-TBI

- 4 pts: 12 Gy (2 Gy × 2 daily) treated with and without SGRT
- How do the pre-setup and imaging times for 1 patient vary between fractions with SGRT and without SGRT?
- The fraction time depends on the patient's condition, which worsens midway through treatment, usually around the 4th fraction. Due to the administration of e.g. dose and protein, the patient experiences chills, nausea, and a high temperature



	with SGRT			without SGRT		
No. of fractions	VMAT Pre-Setup	VMAT Imaging	Legs Imaging	VMAT Pre-Setup	VMAT Imaging	Legs Imaging
1st	5:16:00	23:06:00	17:57:00	9:29:00	31:53:00	25:30:00
2nd	6:31:00	29:03:00	16:19:00	18:02:00	40:41:00	21:01:00
3rd	5:01:00	31:44:00	12:49:00	12:22:00	29:49:00	19:14:00
4th	14:15:00	24:50:00	13:30:00	4:22:00	29:16:00	13:04:00
5th	13:48:00	35:20:00	27:11:00	13:41:00	27:12:00	29:34:00
6th	10:40:00	30:58:00	25:17:00	13:20:00	22:50:00	20:33:00

VMAT-TBI

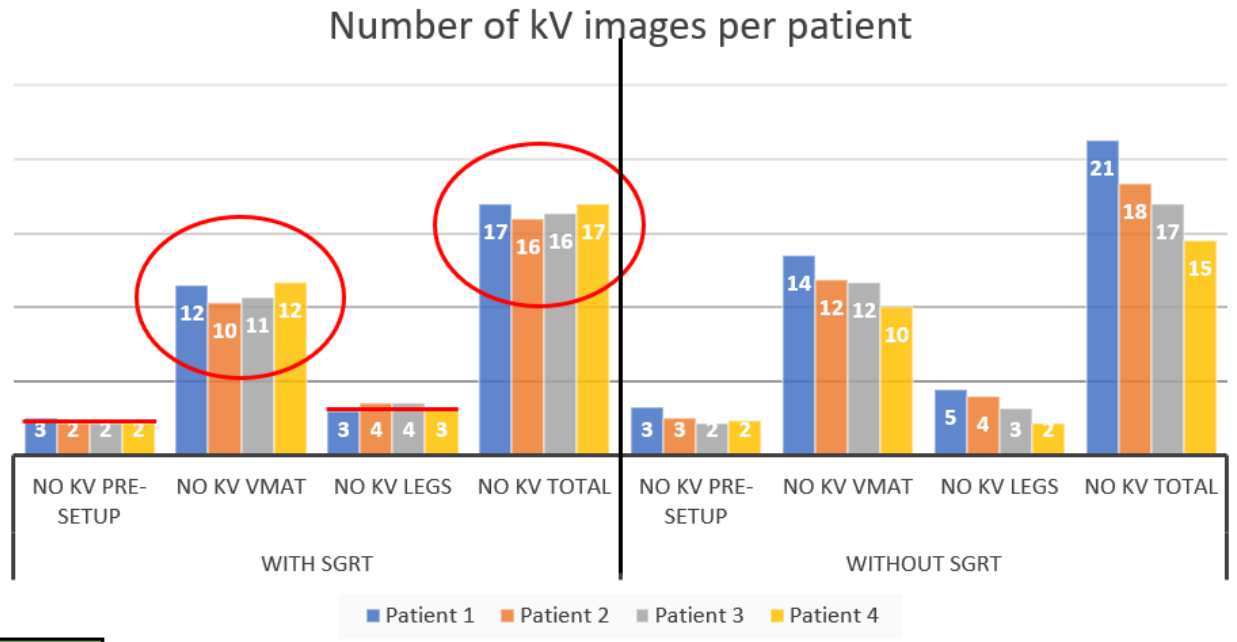
Legs-TBI

Pre-setup Time | Imaging Time

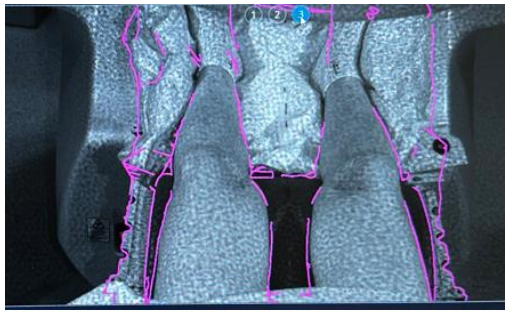
Number of kV images for pre-setup and imaging in VMAT-TBI and Legs-TBI

- 4 pts: 12 Gy (2 Gy × 2 daily) treated with and without SGRT

- Decrease repeat 2D kV imaging for pre-setup and imaging in VMAT and Legs TBI
- Especially by reducing the number of images in the legs imaging, the total number of images using SGRT was ultimately lower
- Minimization of patient dose from kV and/or CBCT imaging process



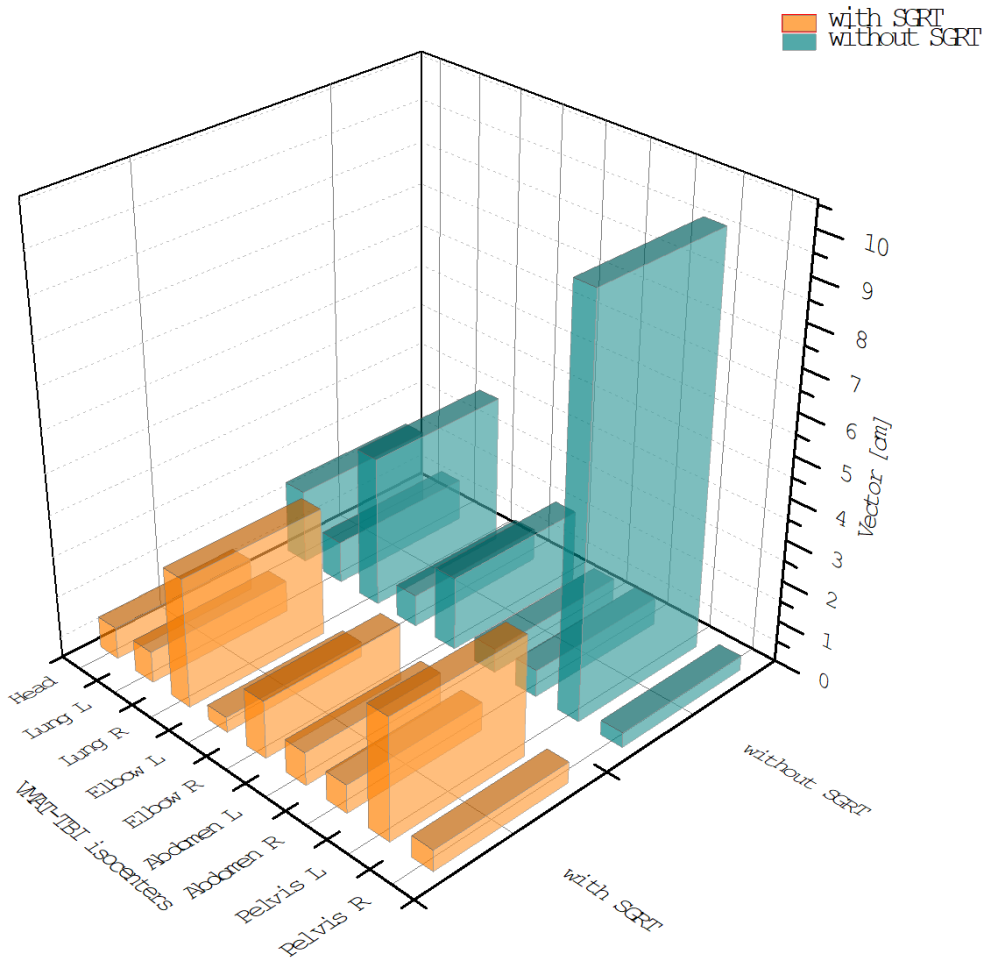
	with SGRT				without SGRT			
Patient no.	No kV Pre-Setup	No kV VMAT	No kV Legs	No kV Total	No kV Pre-Setup	No kV VMAT	No kV Legs	No kV Total
1	3	12	3	17	3	14	5	21
2	2	10	4	16	3	12	4	18
3	2	11	4	16	2	12	3	17
4	2	12	3	17	2	10	2	15
mean	2	11	3	17	3	12	3	18
min	2	10	3	16	2	10	2	15
max	3	12	4	17	3	14	5	21



How does it appear in the number of vector displacement for VMAT-TBI at 2 Gy?

- 6 pts: 2 Gy daily treated with and without SGRT
- Vector displacement for VMAT-TBI with SGRT is lower than for treatments without SGRT
- Higher values for the pelvis and lung isocenters, which contributed by the pre-setup TBI procedure

	with SGRT		without SGRT	
Isocentre	Vector [cm]	SD	Vector [cm]	SD
Head	0.77	0.31	1.80	0.92
Lung L	0.76	0.92	1.02	0.76
Lung R	3.13	2.26	3.65	3.13
Elbow L	0.37	0.20	0.77	0.51
Elbow R	1.39	1.66	1.77	1.64
Abdomen L	0.80	0.38	0.59	0.51
Abdomen R	0.69	0.74	0.65	0.32
Pelvis L	2.95	3.19	9.82	4.54
Pelvis R	0.52	0.25	0.36	0.29



$$V = \sqrt{x^2 + y^2 + z^2}$$

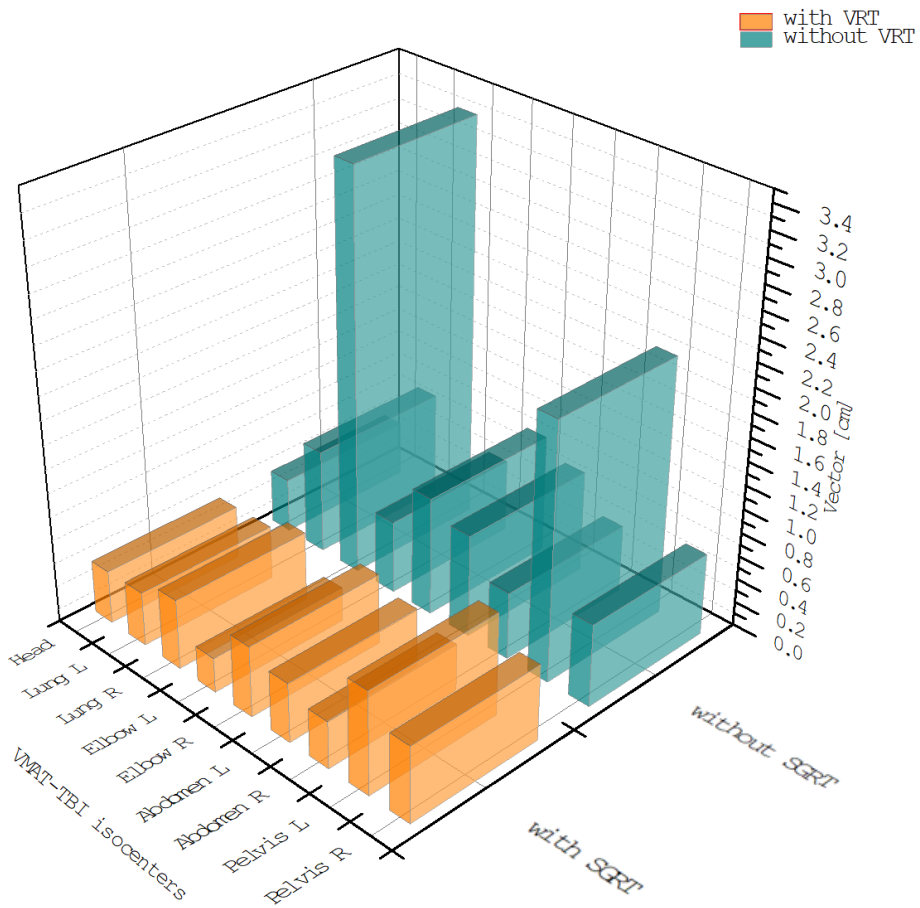
How does it appear in the number of vector displacement for VMAT-TBI at 12 Gy?

- 4 pts: 12 Gy (2 Gy × 2 daily) treated with and without SGRT

- Vector displacement for VMAT-TBI with SGRT is lower than without SGRT for all isocenters during the analysis of all 6 fractions

- The pelvis and lung isocenters, which contribute to the pre-setup TBI procedure, have significantly lower values for VMAT-TBI with SGRT

	all 6 fractions			
	with SGRT		without SGRT	
Isocentre	Vector [cm]	SD	Vector [cm]	SD
Head	0.45	0.66	0.46	0.45
Lung L	0.45	0.23	0.87	0.53
Lung R	0.59	0.42	3.36	6.31
Elbow L	0.29	0.17	0.61	0.35
Elbow R	0.60	0.29	1.00	1.54
Abdomen L	0.50	0.39	0.86	1.02
Abdomen R	0.40	0.25	0.56	0.37
Pelvis L	0.87	0.45	2.16	3.47
Pelvis R	0.64	0.46	0.69	0.45



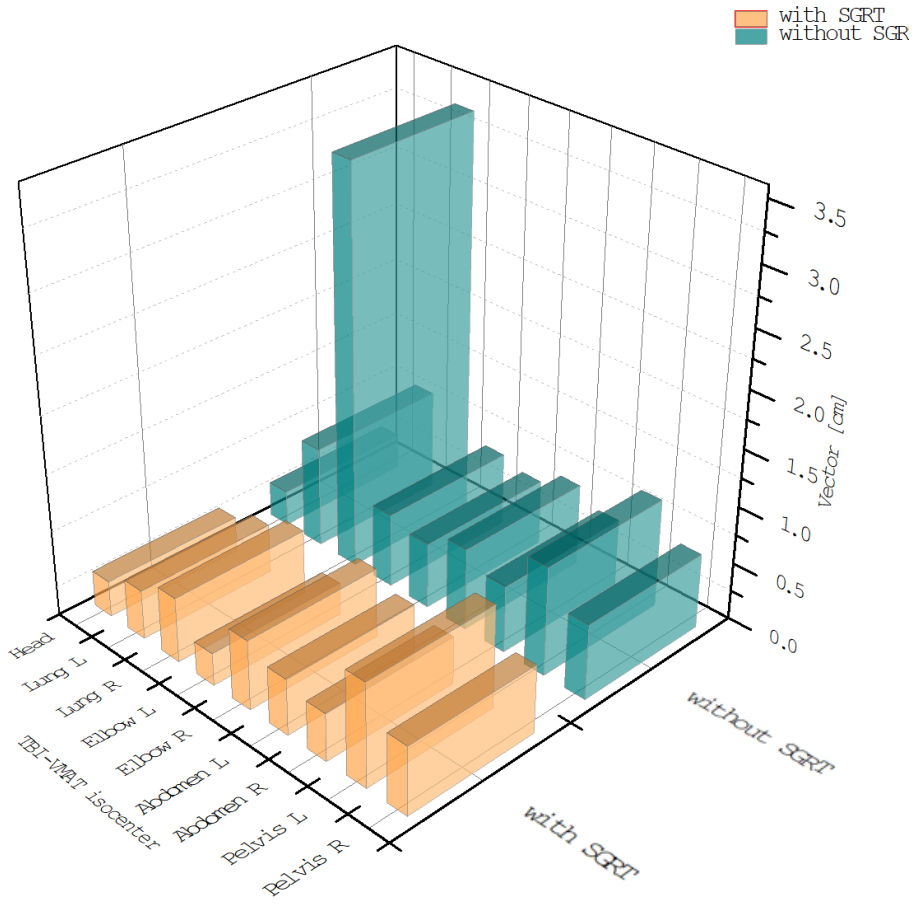
$$V = \sqrt{x^2 + y^2 + z^2}$$

How does it appear in the number of vector displacement for VMAT-TBI at 12 Gy?

- 4 pts: 12 Gy (2 Gy × 2 daily) treated with and without SGRT

- Vector displacement for VMAT-TBI with SGRT is lower than without SGRT for the analysis of 5 fractions excluding the 1st one (when the isocenter positions are established)
- The difference in vector displacement for 5 fractions between VMAT-TBI with and without SGRT is not as large when analyzing all 6 fractions

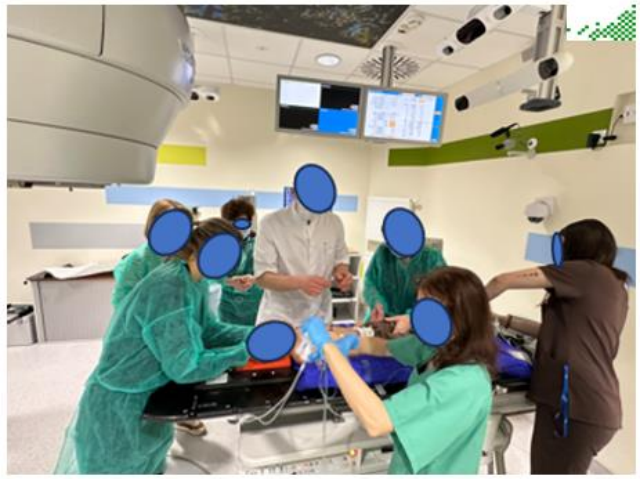
	5 fractions without 1 fraction			
	with SGRT		without SGRT	
Isocentre	Vector [cm]	SD	Vector [cm]	SD
Head	0.31	0.17	0.31	0.19
Lung L	0.43	0.22	0.88	0.55
Lung R	0.57	0.38	3.46	6.87
Elbow L	0.28	0.17	0.64	0.31
Elbow R	0.61	0.30	0.57	0.23
Abdomen L	0.49	0.38	0.72	0.60
Abdomen R	0.42	0.27	0.58	0.37
Pelvis L	0.91	0.44	0.95	0.83
Pelvis R	0.60	0.46	0.66	0.38



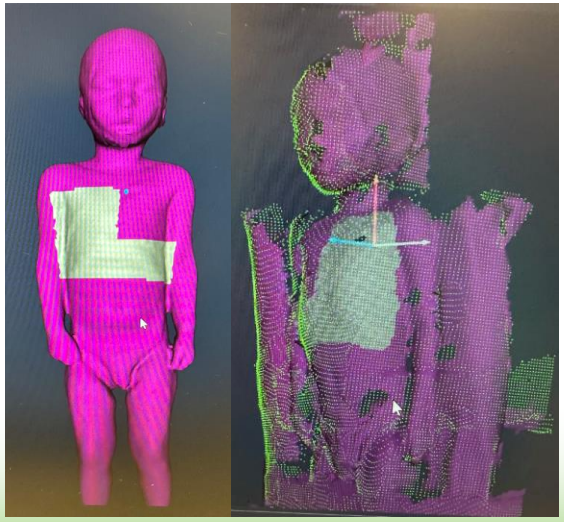
$$V = \sqrt{x^2 + y^2 + z^2}$$

Case experience with a child (3 yrs) treated VMAT-TBI with anesthesia plus SGRT

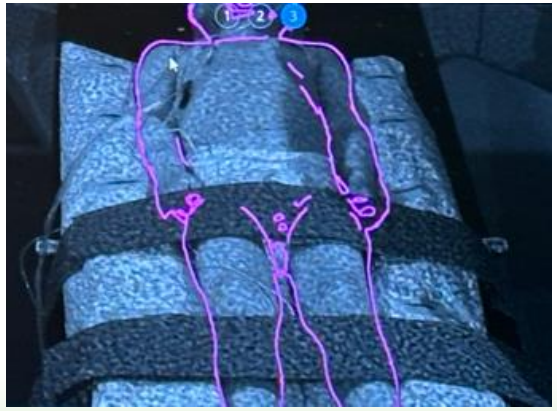
- 12 Gy - 6 fractions, 6 isocenters, bolus, and immobilization mask with a vacuum bag. A large staff is involved, including doctors (radiotherapists, anesthesiologists), medical physicists, RTTs, and nurses



- ROI area for a particular isocenters
- Use treatment capture and postural video for pre-setup and imaging

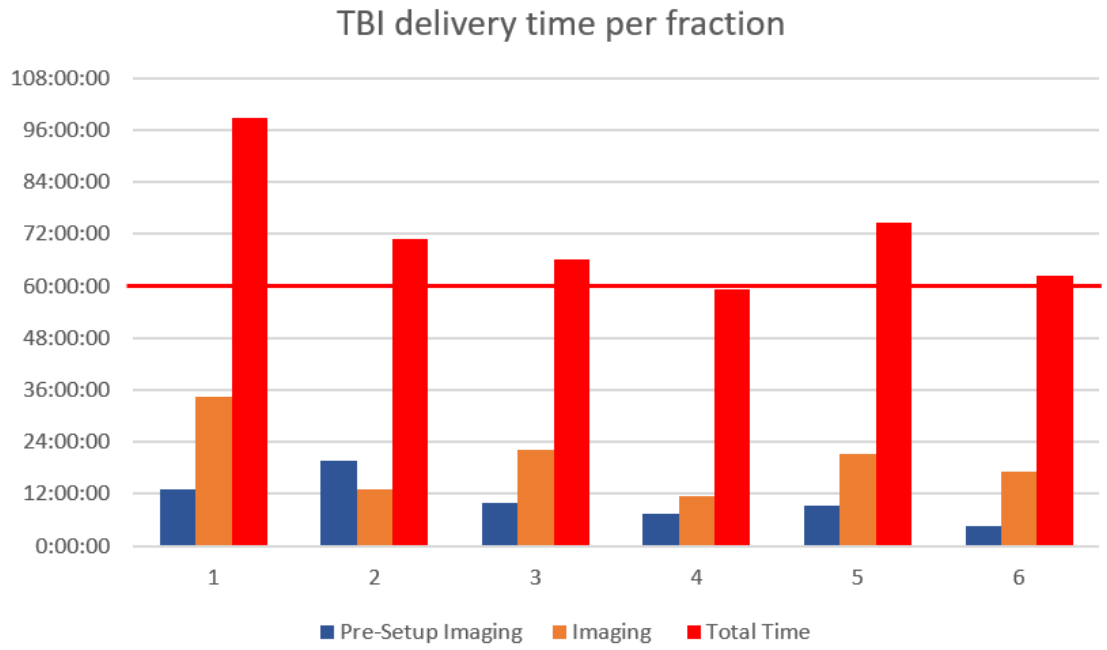


- Problems:
- Treatment with the blanket and immobilization belts, bolus, medical cables
- Despite anesthesia, the patient moves their arms and legs
- Lack of beam control during treatment



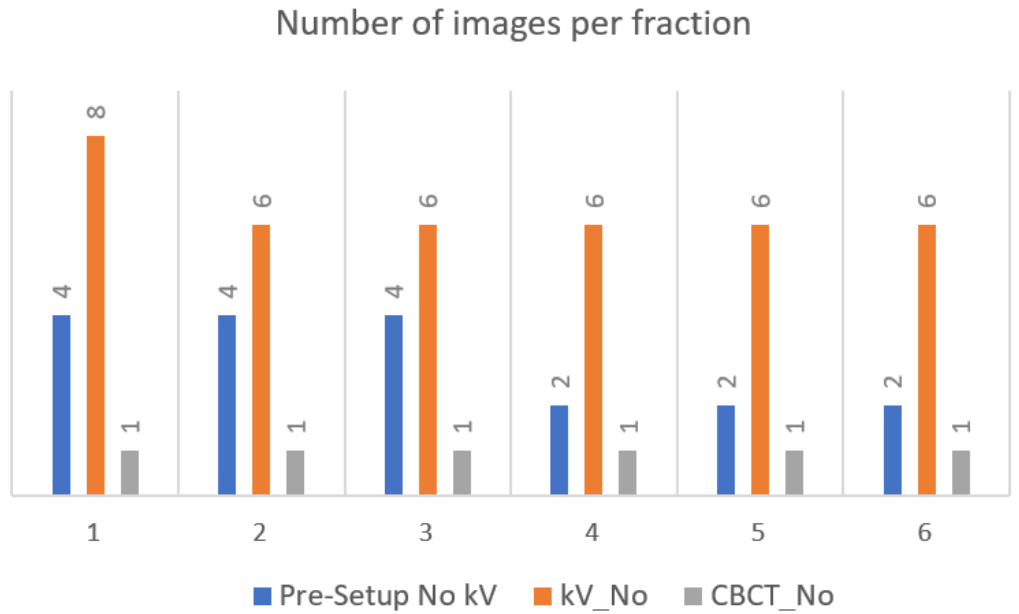
Case experience with a child (3 yrs) treated VMAT-TBI with anesthesia plus SGRT

- How does it appear in the number?
- The treatment time depends greatly on the child's condition and the process of sedation



No. of fractions	Pre-Setup Imaging	Imaging	Total Imaging
1st	13:06:00	34:34:00	98:43:00
2nd	19:38:00	12:59:00	70:53:00
3rd	9:57:00	22:13:00	66:19:00
4th	7:33:00	11:28:00	59:19:00
5th	9:25:00	21:06:00	74:45:00
6th	4:29:00	17:01:00	62:30:00

- The number of kV images (= 6) is equal to the number of isocenters (= 6) in the VMAT-TBI



No. of fractions	No kV Pre-Setup	No kV VMAT	No kCBCT
1st	4	8	1
2nd	4	6	1
3rd	4	6	1
4th	2	6	1
5th	2	6	1
6th	2	6	1

Conclusion

- Using SGRT improved VMAT-TBI workflow, reduced setup and imaging time
- Aditionally, enhanced patient safety and treatment quality
- Moreover, the SGRT system enabled safe treatment delivery to < 60 minutes for children treated with anesthesia


THANK YOU FOR
your attention