مدينة الملك عبدالله الطبية بالعاصمة المقدسة
KING ABDULLAH MEDICAL CITY IN HOLY CAPITAL

Treatment Planning Evaluation of Volumetric Modulated Arc Therapy (VMAT) for Craniospinal Irradiation (CSI)

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Aim

1. Simplify and standardize the treatment planning technique for CSI cases in terms of

???? No of iso-centers

???? location of iso-centers

???? Arcs arrangements

???? The need of avoidance sectors

???? Optimization objectives.

2. Assess

Dose conformity $CI_{95\%}$

Dose homogeneity in the planning target volume HI

Reducing the dose to organs at risk.

Evaluating the integral dose (ID) received by normal tissue.

Reduce the planning time and waiting time for patients to start their radiotherapy course

Patients Selection

- Data were collected retrospectively between April 2015 and December 2016.

- 4 male patients (3 adults and 1 pediatric) had received CSI by volumetric modulated arc therapy [VMAT].

Craniospinal Irradiation [CSI]

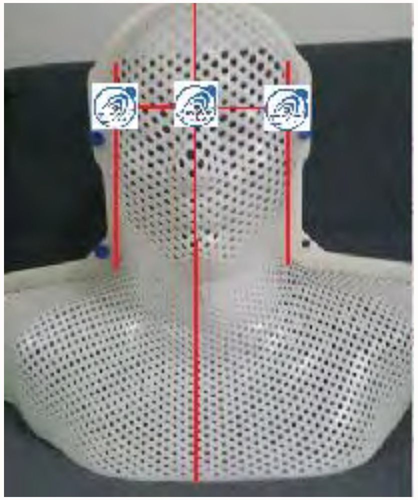
- Craniospinal irradiation (CSI) is an essential component for the treatment of primary intracranial tumors.

- CSI is technically challenging due to the large and irregular target volume and the radiosensitivity of the spinal cord and other critical structures.

- VMAT type of volumetric modulated arc therapy provides intensity modulated radiation therapy (IMRT) with:
- Moving multi-leaf collimator (MLC),
- Changing dose rate,
- And gantry speed modulation.

Patients Setup and CT Simulation

- Supine position (HFS).
- Immobilized using head-and-neck thermoplastic masks with arms were comfortably resting at sides of the body.
- (CT) images were acquired using a 2.5 mm slice intervals from the vertex down to include the true pelvis.
- The reference markers for the brain are defined as the intersection between patient mid line and mid-plane 2 cm above the outer canthus of both eyes.



Target volumes

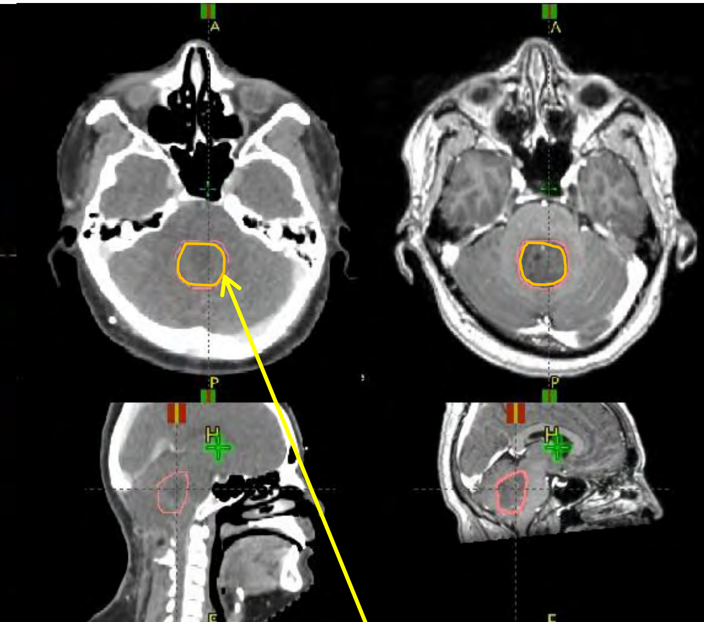
CTV45Gy = GTV + residual

PTV45Gy= was delineated by adding a uniform 3-mm margin to the CTV45Gy

CTV54Gy = GTV +margin

PTV54Gy= was delineated by adding a uniform 3-mm margin to the CTV54Gy

PTV36Gy = CTV with 5mm margin



GTV ç primary tumor site

CTV36Gy = Whole brain with its meninges + spinal cord down to the caudal end of the thecal sac usually S2

OAR

Lenses
Optic nerves
Optic chiasm,
Cochlea,
Eyes
Heart,
Lungs
Liver
Brain stem
Pituitary
Kidneys

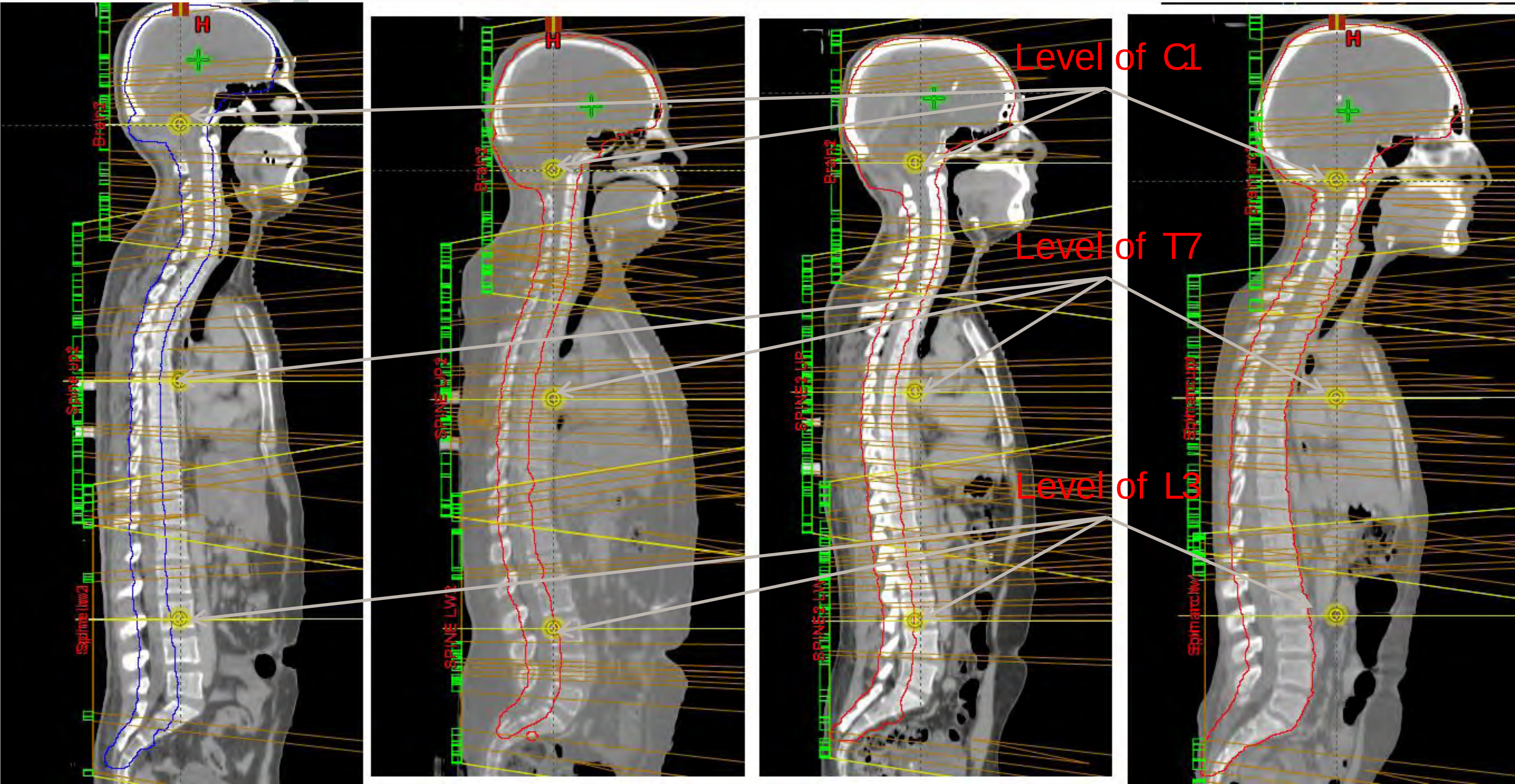
The shell (dummy structure) is delineated all around and out of the target, with 5 cm thickness and1 cm margin (distance) to the target

Patients Data

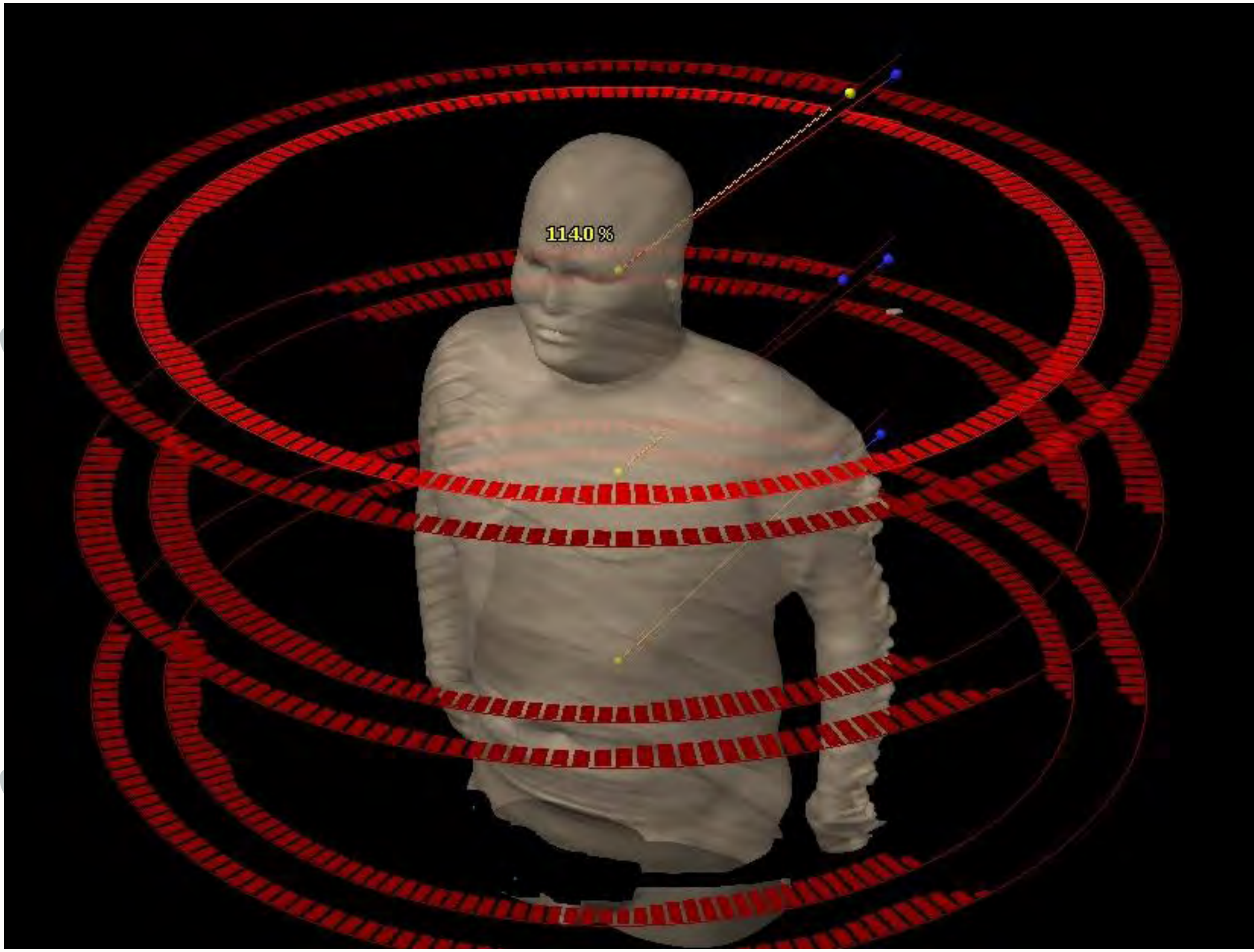
	Patient A	Patient B	Patient C	Patient D
Age and Gender	30Y/ M	25Y /M	28Y /M	13Y/ M
Patient positioning	Supine	Supine	Supine	Supine
PTV length (cm)	84	77	77	66
PTV Volume (cm^3)	30025	2917	3349	2796
CSI dose prescription Gy	36	36	36	36
Posterior fossa boost	18	18	18	18
Dose/fraction Gy	1.8	1.8	1.8	1.8

Iso-centres placement

- 3 isocenters were created shifted apart on the basis of the patient length and almost equidistantly separated



ARCS Arrangements



VMAT used 2 coplanar complete arcs, with opposite directions of rotation (181Á-179Á CW, and 179Á-181Á CCW, with collimator angles of (10Á for CW and 350Á for CCW)

Avoidance sectors for the spinal arcs from 250Á to 290Á and from 70Á to 110Á to avoid the beam entering PTV through shoulders or arms

ID	Gantry Rotation	Couch Angle	Collimator Angle	Energy	MU
Brain1	181.0CW179.0	0.0	10.0	6X	
Brain2	179.0CCW181.0	0.0	350.0	6X	
SPINE1 UP	181.0CW179.0	0.0	10.0	6X	
SPINE2 UP	179.0CCW181.0	0.0	350.0	6X	
SPINE1 LW	181.0CW179.0	0.0	10.0	6X	
SPINE2 LW	179.0CCW181.0	0.0	350.0	6X	

Jaw Tracking

Avoidance Sectors

ID	Couch Angle	Collimator Angle	Gantry Rotation	Avoidance Sector 1		Avoidance Sector 2	
Brain1	0.0	10.0	181.0CW179.0				
Brain2	0.0	350.0	179.0CCW181.0				
SPINE1 UP	0.0	10.0	181.0CW179.0	250.0	290.0	70.0	110.0
SPINE2 UP	0.0	350.0	179.0CCW181.0	110.0	70.0	290.0	250.0
SPINE1 LW	0.0	10.0	181.0CW179.0	250.0	290.0	70.0	110.0
SPINE2 LW	0.0	350.0	179.0CCW181.0	110.0	70.0	290.0	250.0

Plan Information

Normal Tissue Objective 250/Manual

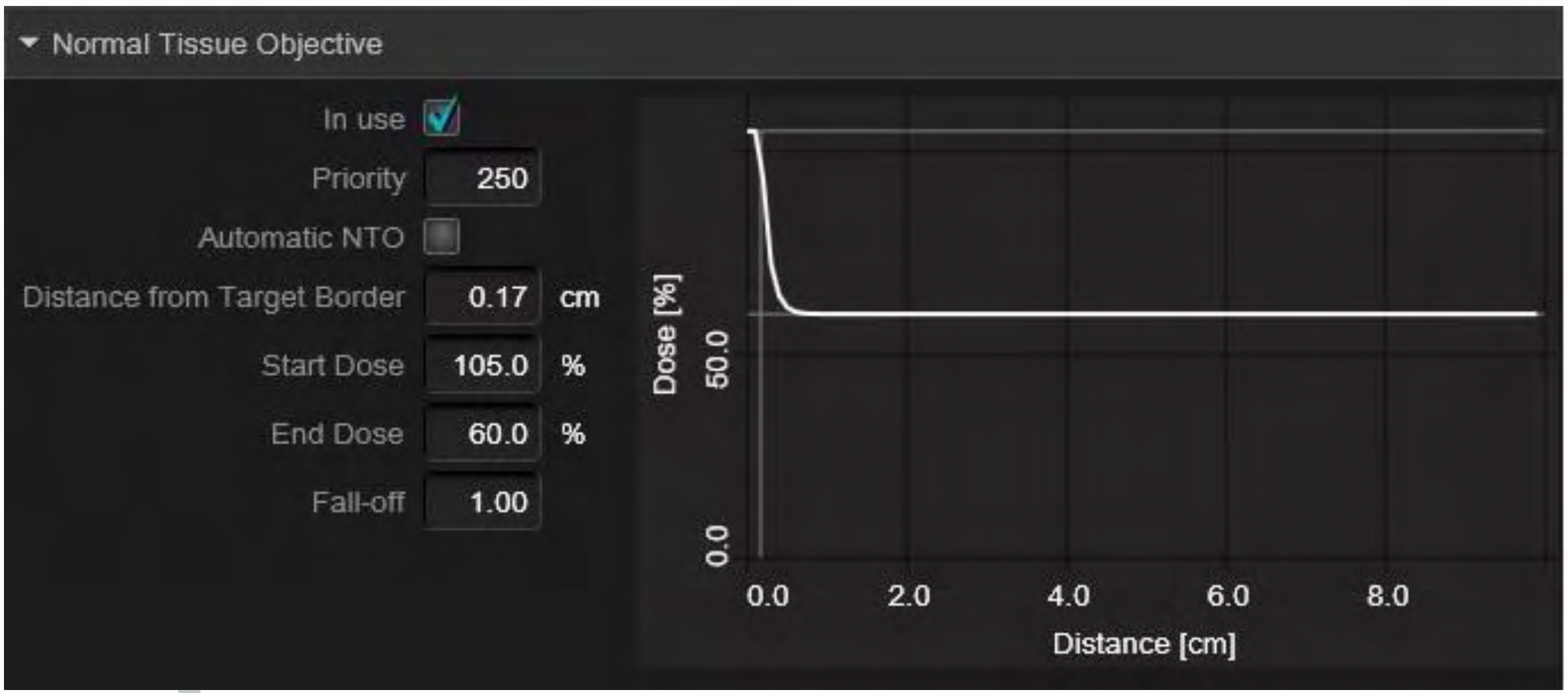
	Patient A	Patient B	Patient C	Patient D
Isocenters/ Arc arrangement				
MLC type	120 millennium	120 millennium	120 millennium	120 millennium
Number of isocenters	3	3	3	3
Locations of socenters	a: C1 b: T7 c: L3	a: C1 b: T7 c: L3	a: C1 b: T7 c: L3	a: C1 b: T7 c: L3
Brain Isocenter (x,y,z)	0,-7,-2	0,-7,-4	0,-7,-2	0,-6,-1
Upper spinal Isocenter (x,y,z)	0,-34,-2	0,-32,-4	0,-32,-2	0,-25,-1
Lower spinal Isocenter (x,y,z)	0,-61,-2	0,-57,-4	0,-57,-2	0,-44,-1
Distance between isocenters(cm)	a: 27 b: 27	a: 25 b: 25	a: 25 b: 25	a: 19 b: 19
Overlaps Length(cm)	5 , 7.5	9 , 5	6.5 , 7.5	5 , 3
Number of arcs	6	6	6	6
Number of arcs / isocente	2	2	2	2
X and Y Jaws Settings (cm)				
Brain ACRS	X: 23, Y29	X: 22, Y:30	X: 26, Y:30	X: 20, Y:28
Upper spinal ARCS	X: 17, Y36	X :16, Y:33	X: 17, Y:34	X: 20, Y:27
Lower spinal ARCS	X 20, Y35	X: 20, Y:33	X: 22, Y:33	X: 23, Y:25
Total number of MUs	921	934	910	856

Treatment Plans Optimization

My approach was to:

Å Find a suitable balance between dose objectives and dose constrains .

Å Reduce the dose outside the target by implementing the tool (NTO) with the following parameters: fall-off = 1 , distance from the border = 1.7 mm, the start dose is 105% and the end dose is 60%.



Treatment Plans Optimization

Å Increase dose conformality inside the PTV and minimize the dose gradient
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Å Target dose coverage and homogeneity were given the highest priority.

Å Organs like heart, kidneys, lungs, lenses and liver were highly prioritized while eyes and optic nerves were given slightly lower weightings

Å The total dose to brainstem and pituitary fossa was kept below their tolerance level during the entire treatment course

Treatment Plan Evaluation

- At least 95% of the target volume received 95% of the prescribed dose.

- The conformity was measured with a conformity index (CI), defined as the ratio between the 95% isodose volume and the volume of the CSI PTV

$$CI = (V_{95\%} / \text{total PTV})$$

- Heterogeneity was measured with a homogeneity index (HI), defined as

$$HI = D_{5\%} / D_{95\%}$$

D_5 = the dose received by 5% of the volume

D_{95} = the dose received by 95% of the volume

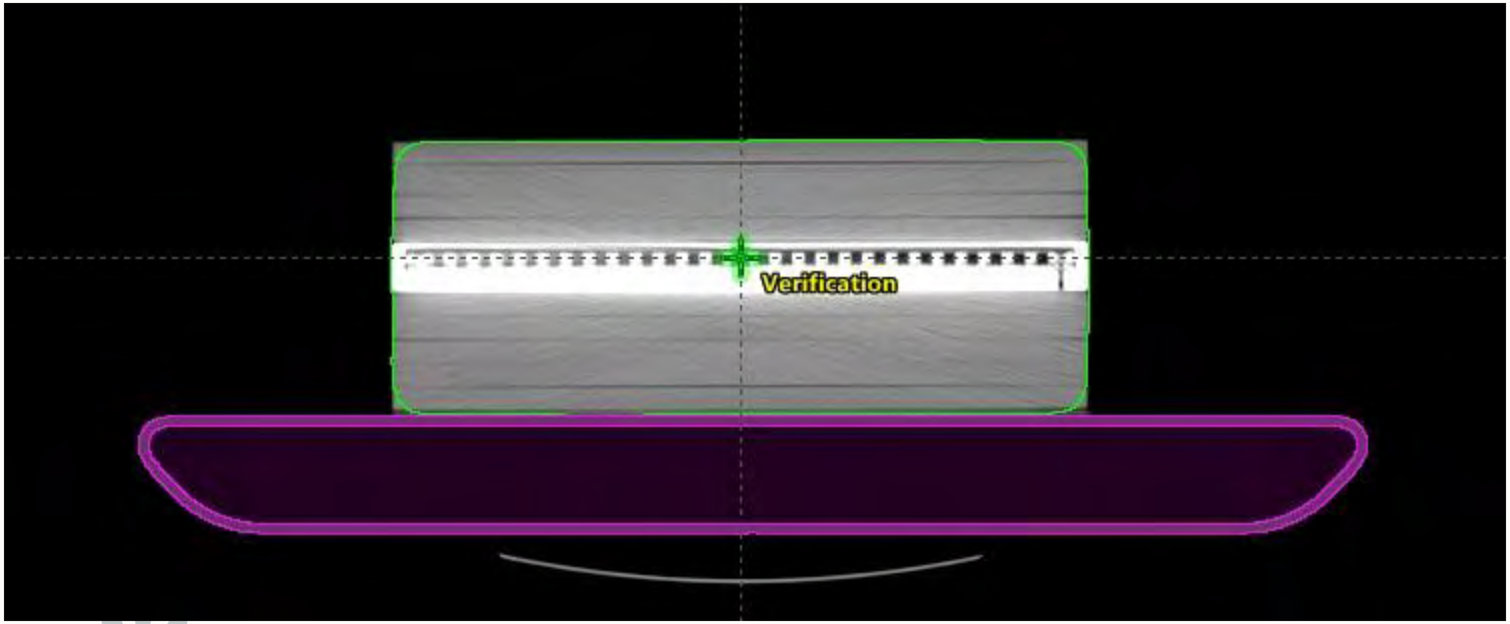
- The bath and shower effect of was also considered by reporting the percentage volume of both lungs receiving low dose radiation (V_{5Gy}) for all patients

The dosimetric parameters for target volume

- Target mean dose
- D2% (the dose received by 2% of the volume)
- D5% (the dose received by 5% of the volume)
- D50% (the dose received by 50% of the volume)
- D95% (the dose received by 95% of the volume)
- D98% (the dose received by 98% of the volume),
- D2% was taken as a marker for maximum dose
- D98% as a marker for minimum dose

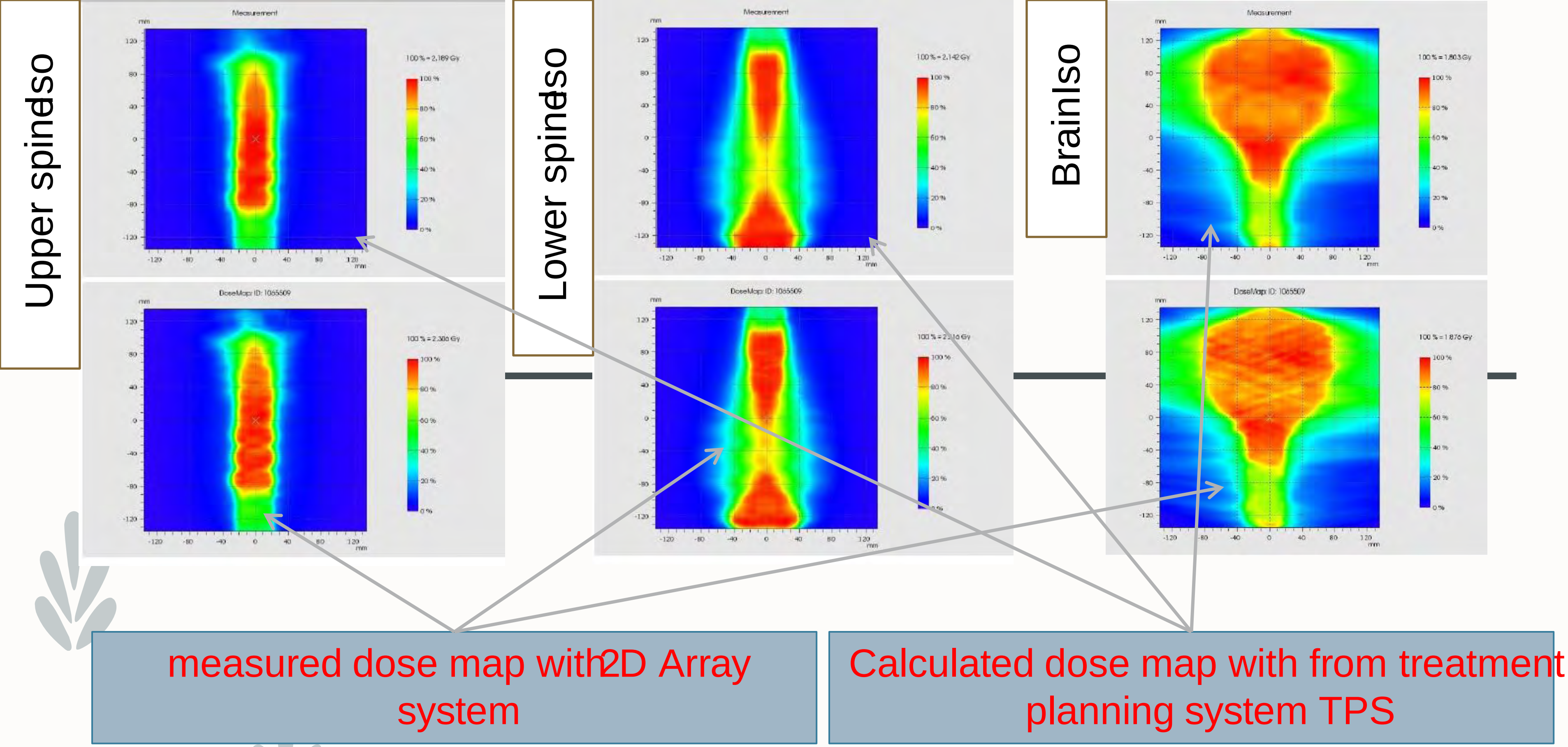
Pre ðTreatment plan QA

- Creating verification treatment plan then separated them into three-sub plans
- Plans calculated on TPS with the assembly of parallel slabs of water equivalent phantom and 2D-Array dosimetry system.



Pre ðTreatment plan QA

Plans were measured with the linear accelerator under identical geometric setup with CT image.



- The accepting criteria is above 90% with

3mm distance to agreement

3% dose difference with reference to local dose

95% PTV coverage

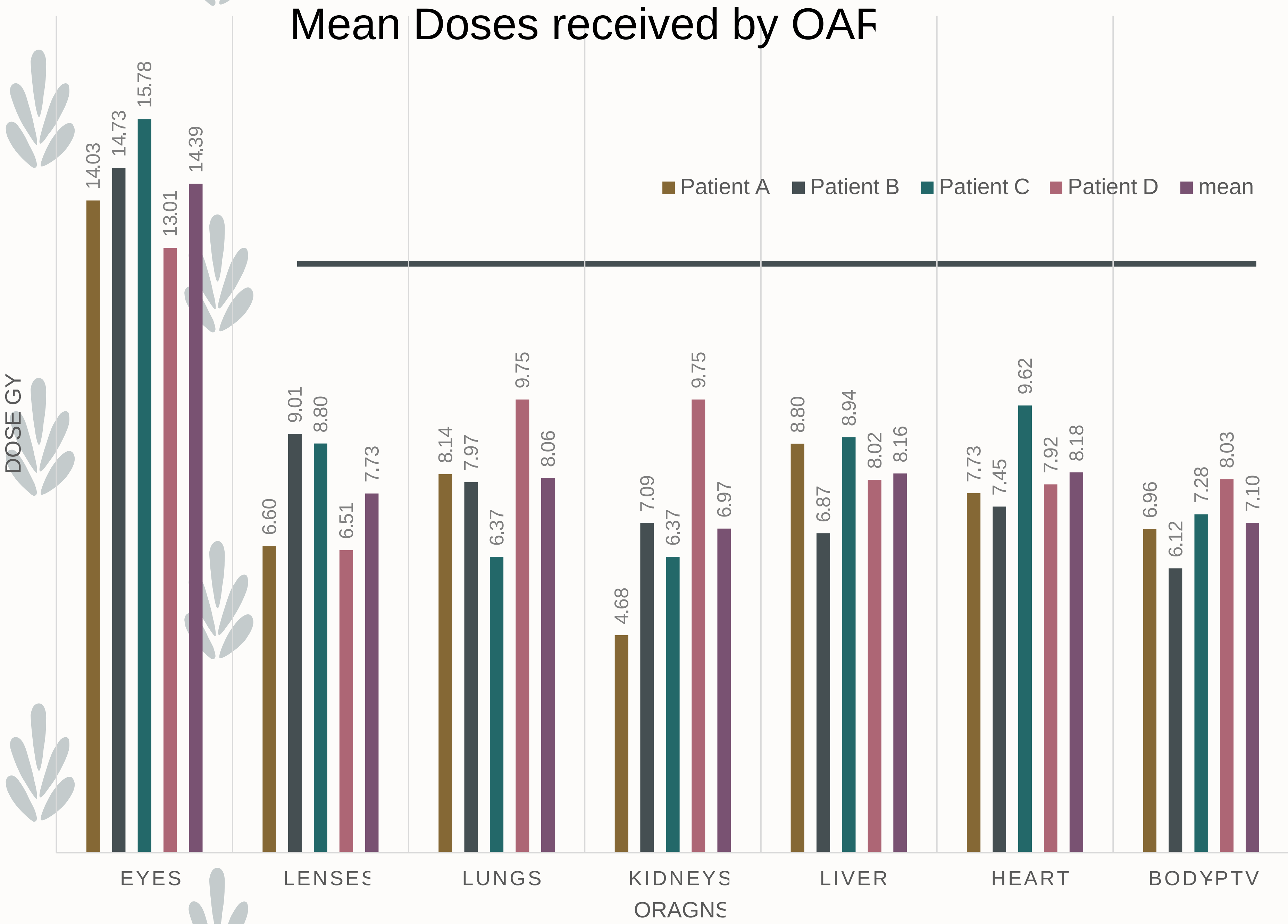
Results

- VMAT- CSI treatment plans for the four patients were able to produce a very good coverage of the target and sparing of the surrounding critical structures

- HI values closer to 1.0 (1.13), which indicates a good uniformity throughout the PTV.

- Mean CI95% was 0.99, this indicate a very good coverage of the target and sparing of the surrounding critical structures.

	Patient A	Patient B	Patient C	Patient D	Mean
PTV Parameters	36 Gy	36 Gy	36 Gy	36 Gy	
mean (Gy)	36.0	36.6	36.3	36.0	36.23
D2% (Gy)	37.5	39.3	38.1	38.1	38.25
D5% (Gy)	36.2	38.7	37.7	37.7	37.58
D50% (Gy)	36.2	36.6	36.6	36.3	36.43
D98% (Gy)	33.3	33.8	33.1	31.8	33.00
D95% (Gy)	34.2	34.6	34.2	33.0	34.00
$CI_{95\%}$	1.01	1.05	0.99	0.91	0.99
HI	1.15	1.12	1.10	1.14	1.13


Mean Doses received by OAR
Patient A
Patient B
Patient C
Patient D
mean
DOSE GY
14.03
14.73
15.78
13.01
14.39
6.60
9.01
8.80
6.51
7.73
8.14
7.97
6.37
9.75
8.06
4.68
7.09
6.37
9.75
6.97
8.80
6.87
8.94
8.02
8.16
7.73
7.45
9.62
7.92
8.18
6.96
6.12
7.28
8.03
7.10
EYES
LENSES
LUNGS
KIDNEYS
LIVER
HEART
BODY-PTV
ORAGNS

VMAT plans show an increase in the volume of the area receiving low dose radiation

The low-dose spread to Lung tissues was evaluated by the volume of the both lungs receiving 5aGy dose of Ó (V_{5Gy}).

	Patient A	Patient B	Patient C	Patient D
Lung V_{5Gy}	70%	71.9%	72.6%	85%

Discussion and conclusion

- (VMAT) for CSI is a novel radiation technique, which can achieve highly conformal dose distributions with improved target volume coverage and sparing of normal tissues compared with conventional radiotherapy techniques.
- VMAT has the potential to offer additional advantages, such as reduced treatment delivery time compared with conventional radiotherapy (IMRT).
- Rapid Arc for CSI eliminates the field junction matching difficulties.
- Development and evaluation of multiple isocentric volumetric modulated arc therapy technique for craniospinal axis radiotherapy planning.

Discussion and conclusion

- A major source of concern with VMAT and IMRT is the increase in low dose radiation to surrounding normal tissue, which potentially increases the risk of secondary malignancy.
- Although the theoretical risk of secondary malignancy induction with VMAT should be lower as VMAT generally uses fewer MU compared with conventional fixed field IMRT.
- Follow-up of patients treated with these techniques will be required to accurately quantify this risk.

THANK YOU