IAEA-CN301-095

DOSIMETRIC VERIFICATION OF RADIOTHERAPY TREATMENT PLANNING SYSTEM USING THORAX PHANTOM

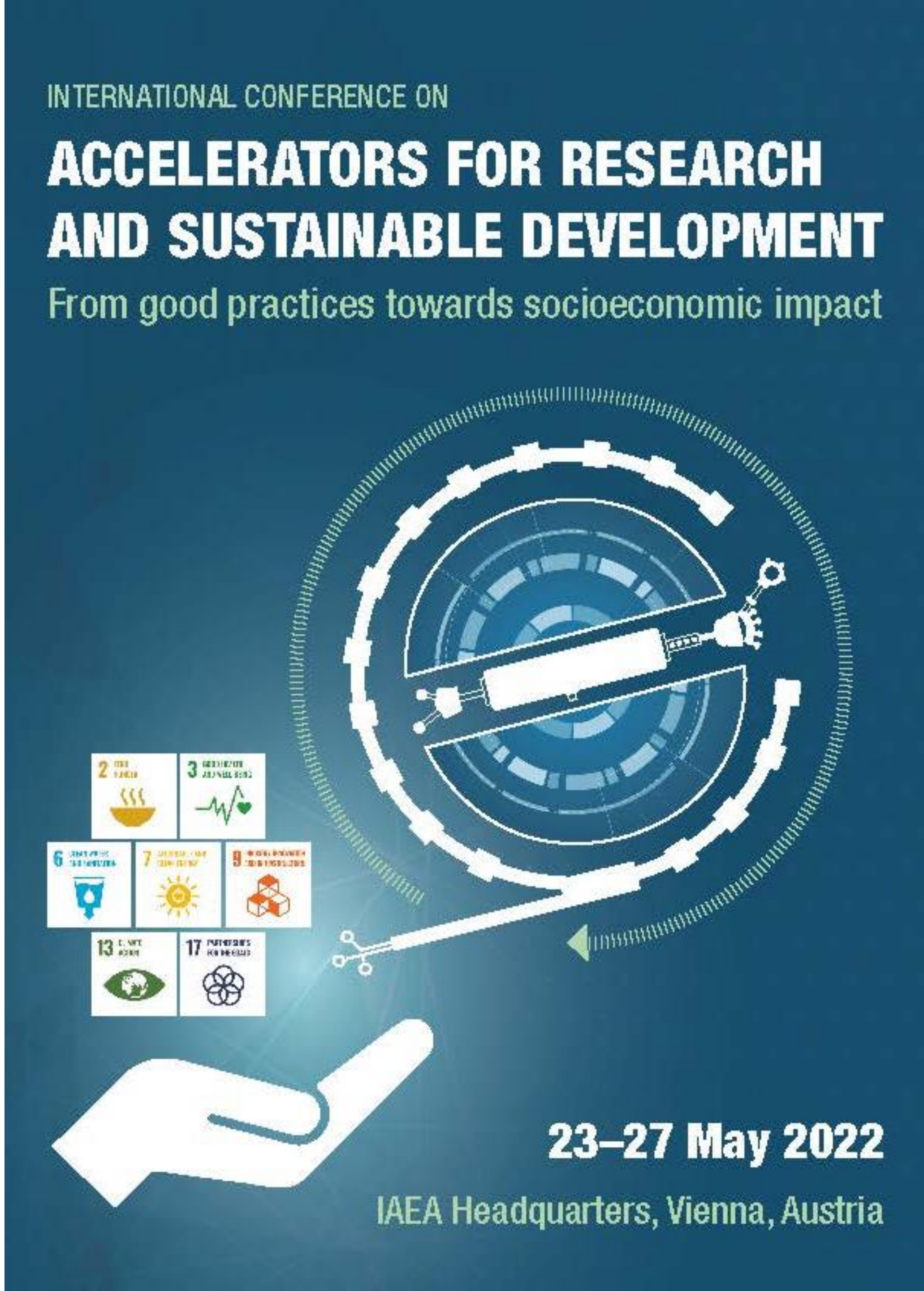
TPS Verification Of a LINAC

Rajada Khatun[1], Shirin Akter[1], S. M. E. Kabir[2], Ashrafun Nahar Monika[1], Md. Mahfuzur Rahman[1], M. M. Ahasan[1]

[1]Bangladesh Atomic Energy Commission, Dhaka

[2]Delta Hospital Ltd., Tolarbag, Mirpur, Dhaka

(contact-rajadakhatunhasi@gmail.com)



Thorax Phantom & Accessories
(Model: 002LFC)

Material	Physical density (g/cm²)	Electron density per cm²x10²³	Electron density relative to water
Lung	0.21	0.69	0.207
Bone	1.60	5.03	1.506
Muscle	1.06	3.48	1.042
Adipose	0.96	3.17	0.949
Plastic water (body)	1.04	3.35	1.003

- Elliptical in shape & represents an average human torso in proportion, density & 2D structure
- Completed with a set of four certified electron density reference plugs

***CIRS: Computerized Imaging Reference System, USA**

Outline

- ✓Introduction
- ✓Aim of the study
- ✓Scope of the study
- ✓Materials and Methods
- ✓Results
- ✓Discussions
- ✓Conclusion

Introduction & Objectives

Introduction

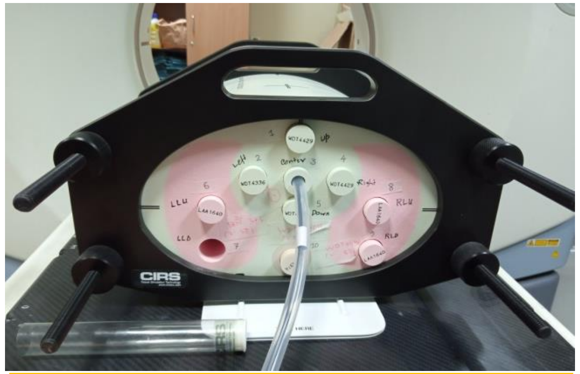
- QA is essential for every treatment modality, but in case of RTP it is of special interest. Because it deals with the most vulnerable patients like cancer.
- Reduction of dosimetric errors and uncertainties plays an important role in the radiotherapy treatment.
- Based on clinical dose-response curves, the overall accuracy of the dose delivery should be less than 5%.

Objectives

- Verification of TPS, i.e. to verify the Hounsfield units (HU) to relative electron density (RED) conversion curve stored in the TPSs.
- Verification of dosimetric error, i. e. to observe the range of deviations between calculated and measured doses.

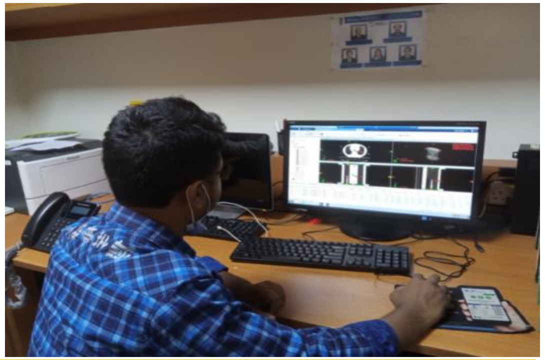
Materials

FC65-P
(IBA Chamber)



Thorax Phantom (CIRS Model 002LFC)

Somatom Emotion (SIEMENS)

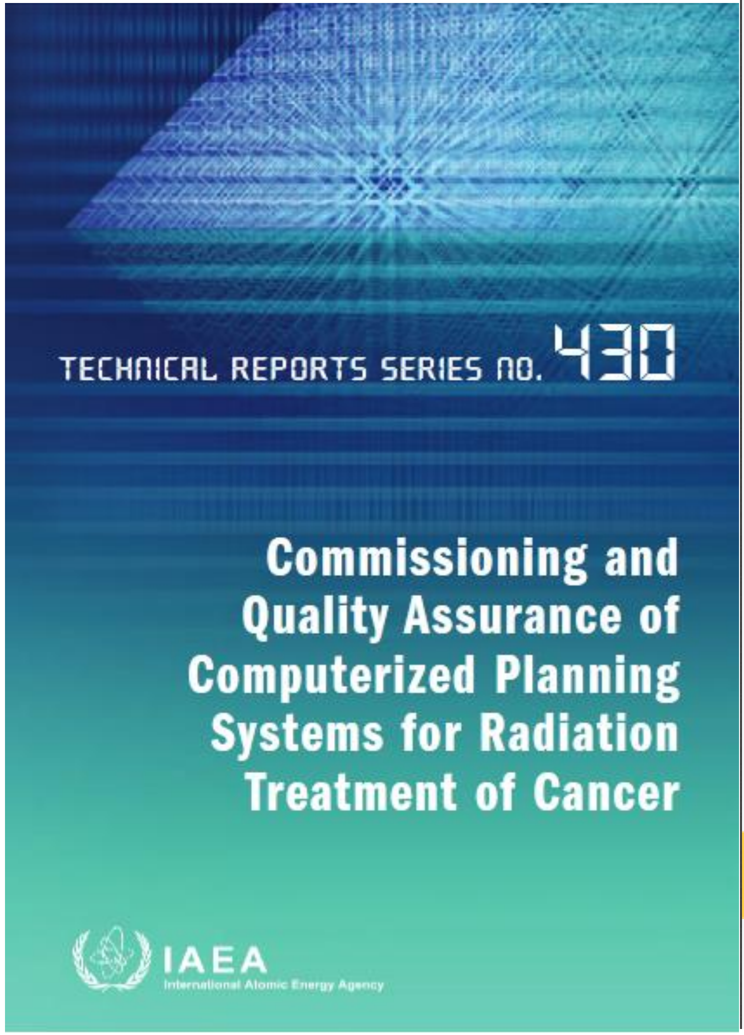


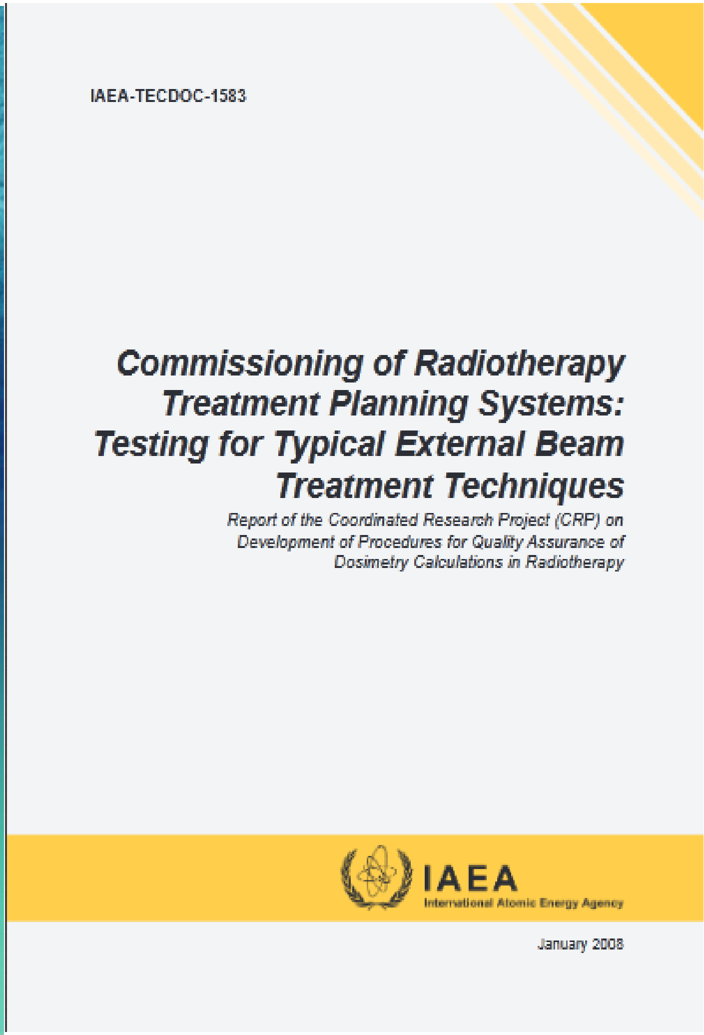
Eclipse TPS version 13.7

Linac (Varian, True Beam)

DOSE 1 Reference Class Electrometer (IBA)

Materials (Protocol)

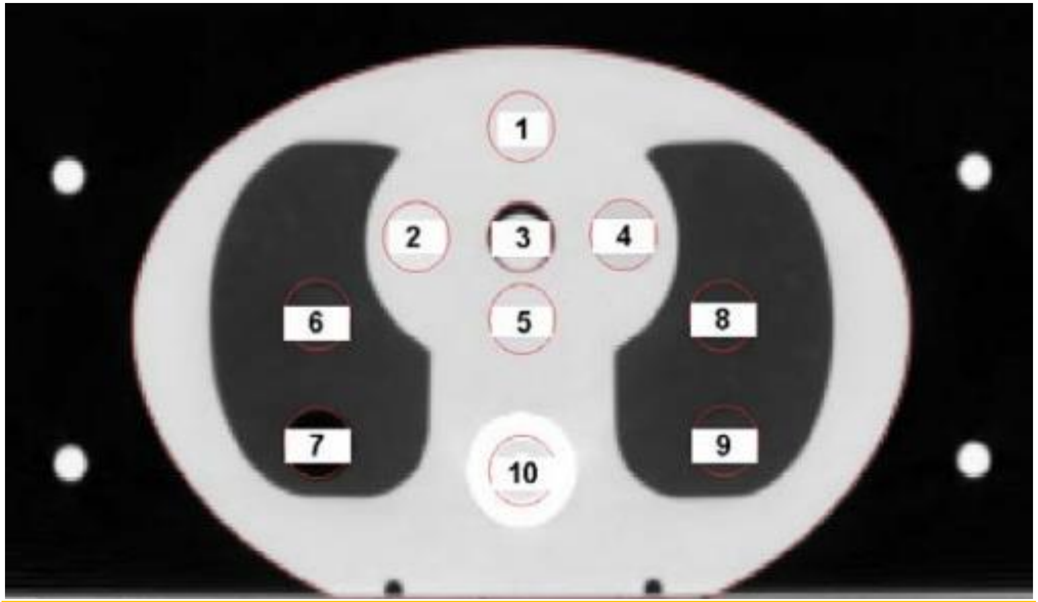




Methodology

- The phantom was scanned twice in each hospital using CT and treatment plans were made for seven different test cases according to IAEA TECDOC 1583 on local TPS.
- For the first scan the relative electron densities reference plugs were inserted to obtain CT numbers (HU) to the RED conversion curve.
- The second scan was used for the planning of clinical test cases as defined in the TPS.
- The phantom was irradiated according to the treatment plans and doses were measured.
- The differences between the measured and calculated doses were noted.
- The scanning parameters for both cases were kept the same.

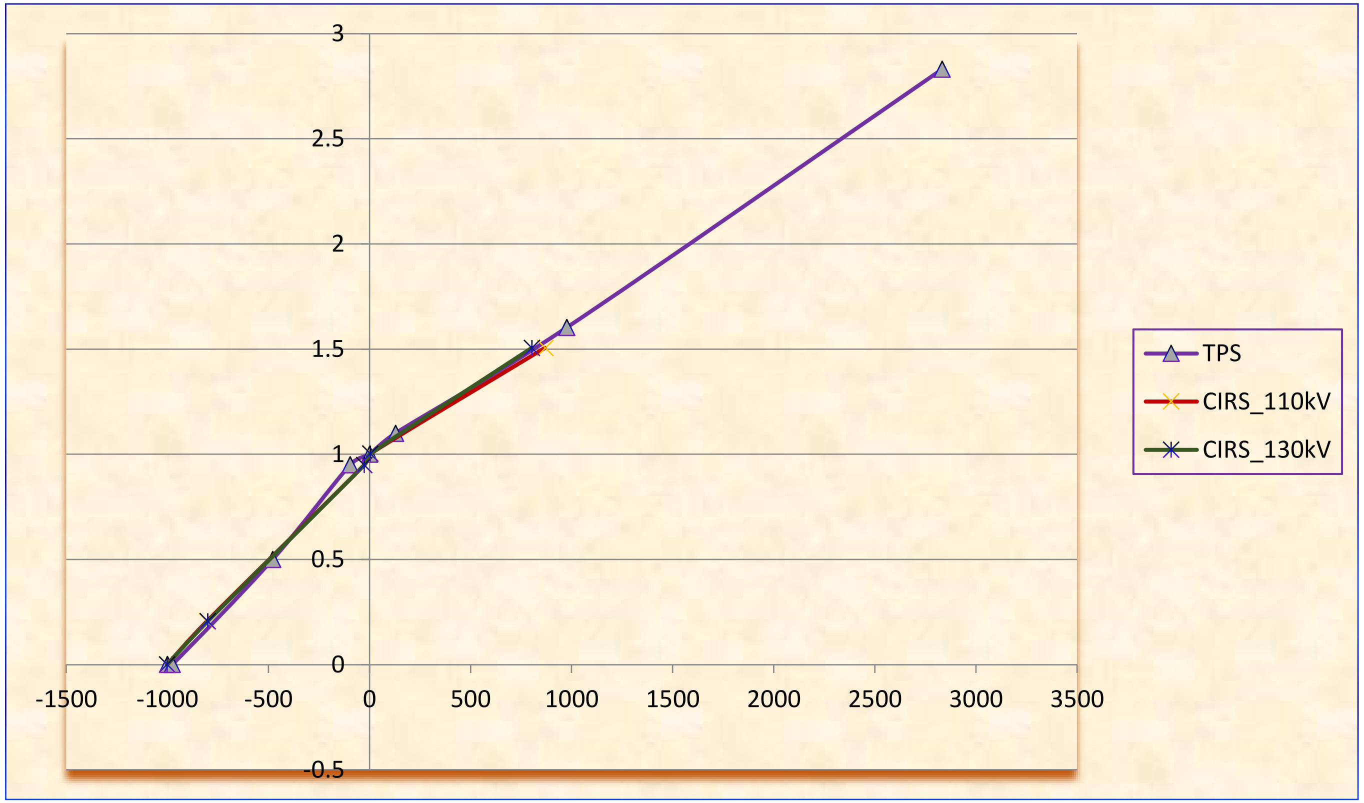
Verification of CT Nos. to RED Conversion used by TPS



Labelling of holes & the recommended arrangements of the certified electron density reference plugs for the CT scan

- ✓Plug 1: water equivalent
- ✓Plug 2: muscle substitute
- ✓Plug 3: syringe filled with water
- ✓Plug 4: adipose substitute
- ✓Plug 5: water equivalent
- ✓Plug 6: lung substitute
- ✓Plug 7: empty to represent air
- ✓Plug 8 & 9: lung substitutes
- ✓Plug 10: bone substitute

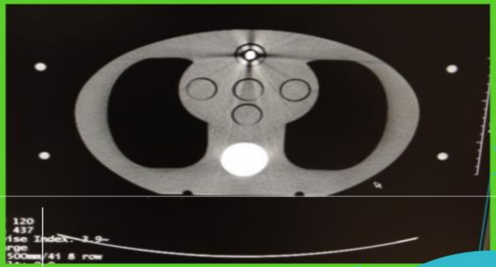
CT Calibration Curve



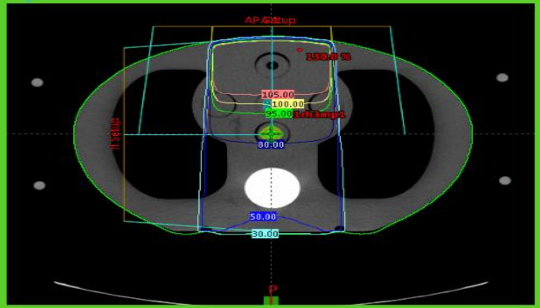
Materials and Methods

Methods

CT images imported to Treatment Planning System(TPS)



All Parameters for dose delivery determined by TPS



All parameters sent to Treatment machine for dose delivery

Methods

Dosimetric test cases

Case 1: Testing for reference conditions based on CT data

Case 2: Oblique incidence, lack of scattering and tangential fields

Case 3: Significant blocking of the field corners

Case 4: Four field box

Case 5: Automatic expansion and customized blocking

Case 6: Oblique incidence with irregular field and blocking the centre of the field

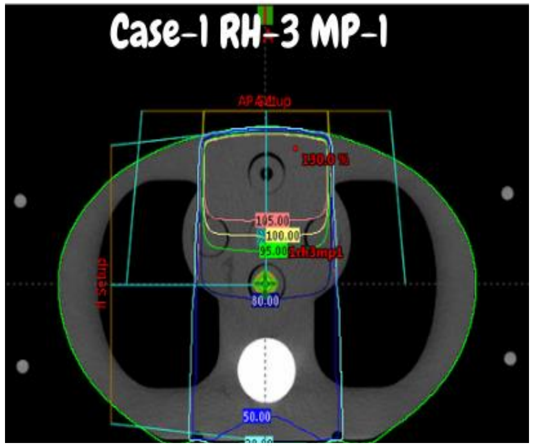
Case 7: Non coplanar beams with couch and collimator rotation

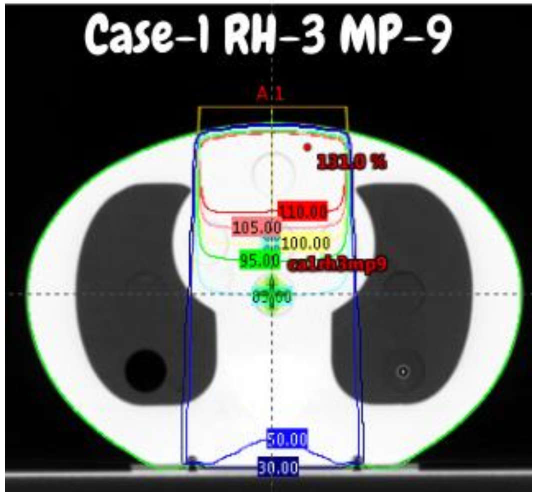
Methods

Case 1: Testing for reference conditions based on CT data

Table-1: Geometry for case -1

Number of beams	Set-up	Reference point	Measure ment point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SSD 100cm	Hole-3	Hole-1	10×10	0°	0°	None
1	SSD 100cm	Hole-3	Hole-3	10×10	0°	0°	None
1	SSD 100cm	Hole-3	Hole-5	10×10	0°	0°	None
1	SSD 100cm	Hole-3	Hole-9	10×10	0°	0°	None
1	SSD 100cm	Hole-3	Hole-10	10×10	0°	0°	None



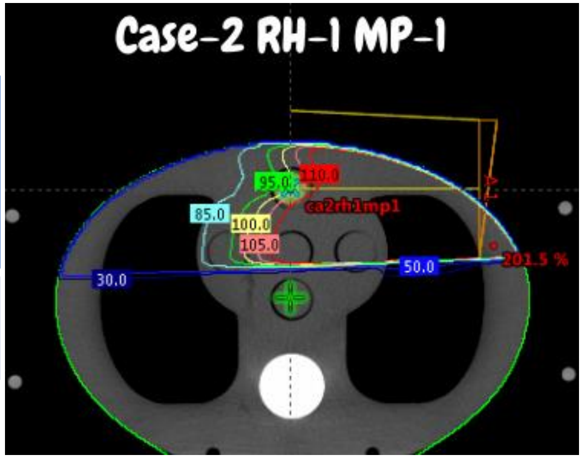


Methods

Case 2: Oblique incidence, lack of scattering and tangential fields

Table-2: Geometry for case -2

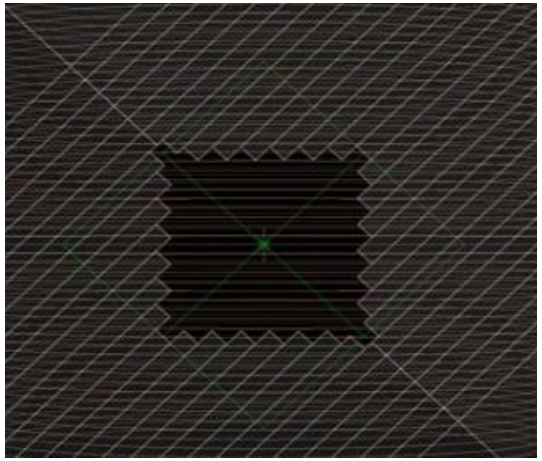
Number of beams	Set-up	Reference point	Measurement point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SAD 100cm	Hole-1	Hole-1	15×10	90^o	0^o	45^o Wedge



Case 3: Significant blocking of the field corners

Table-3: Geometry for case -3

Number of beams	Set-up	Reference point	Measurement point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SSD 100cm	Hole-3	Hole-3	14×14 10×10	0^o	45^o	MLC

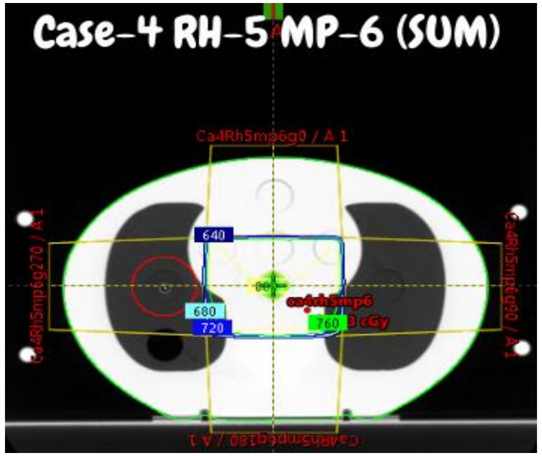


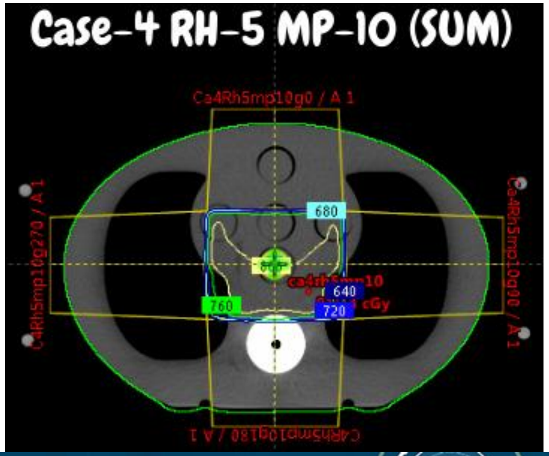
Methods

Case 4: Four field box

Table-4: Geometry for case -4

Number of beams	Set-up	Reference point	Measurement point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SSD 100cm	Hole-5	Hole-5	15×10	0⁰	0⁰	None
				15×10	180⁰		
				15×8	270⁰		
				15×8	90⁰		
1	SSD 100cm	Hole-5	Hole-6	15×10	0⁰	0⁰	None
				15×10	180⁰		
				15×8	270⁰		
				15×8	90⁰		
1	SSD 100cm	Hole-5	Hole-10	15×10	0⁰	0⁰	None
				15×10	180⁰		
				15×8	270⁰		
				15×8	90⁰		



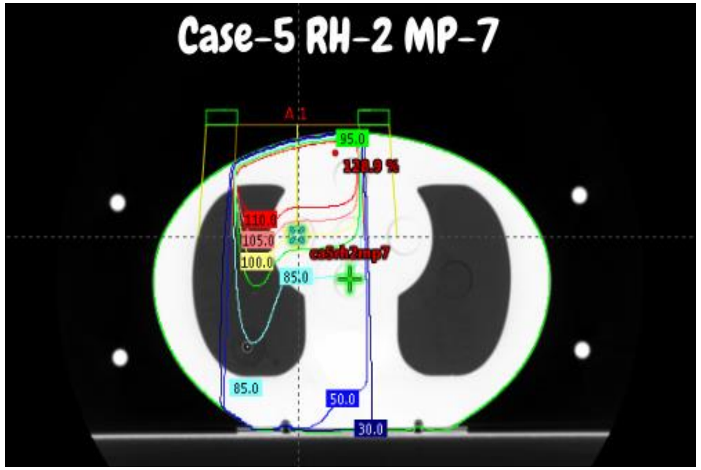


Methods

Case 5: Automatic expansion and customized blocking

Table-5: Geometry for case -5

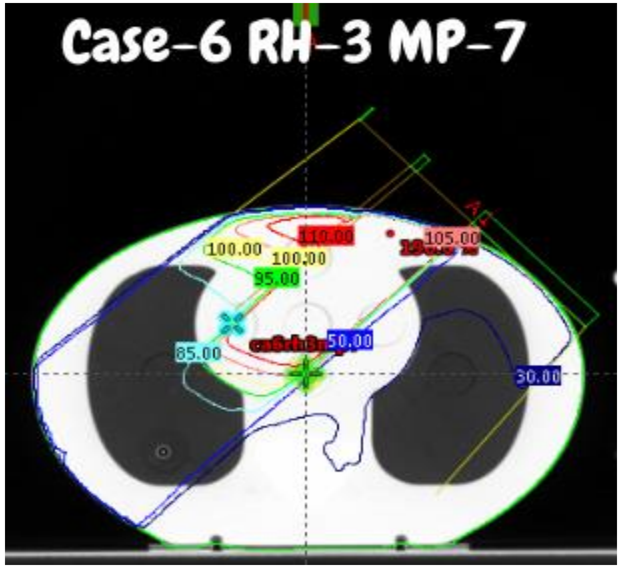
Number of beams	Set-up	Reference point	Measurement point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SAD	Hole-2	Hole-2	15×15 12×12	0^o	0^o	MLC
1	SAD	Hole-2	Hole-7	15×15 12×12	0^o	0^o	MLC



Case 6: Oblique incidence with irregular field and blocking the centre of the field

Table-6: Geometry for case -6

Number of beams	Set-up	Reference point	Measurement point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SAD	Hole-3	Hole-3	L-shaped 10x20	45^o	90^o	MLC
1	SAD	Hole-3	Hole-7	L-shaped 10x20	45^o	90^o	MLC
1	SAD	Hole-3	Hole-10	L-shaped 10x20	45^o	90^o	MLC

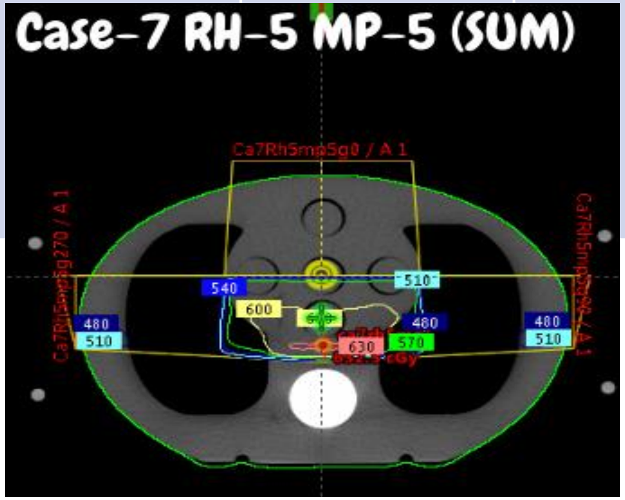


Methods

Case 7: Three fields, two wedge-paired, asymmetric collimation

Table-7: Geometry for case -7

Number of beams	Set-up	Reference point	Measurement point	Field Size (cm) L × W	Gantry angle	Collimator angle	Beam modifiers
1	SAD	Hole-5	Hole-5	10x12	0^{o}	0^{o}	None
				10x6	90^{o}	According to wedge orientation	Physical wedge 30°
				10x6	270^{o}		Soft wedge 30°



Formula of Dose Calculation & Deviation

❖ $D_{w,Q} = M_Q \, N_{D,w,Qo} \; k_{Q,Qo}$ Gy/MU………………..(1) [IAEA TRS 398]

$M_Q = M_1 \, k_{TP} \, k_{elec} \, k_{pol} \, k_s$ nC/MU

❖ $D_{w,Q} = M_1 \, k_{TP} \, k_{elec} \, k_{pol} \, k_s \, N_{D,w,Qo} \; k_{Q,Qo}$ Gy/MU….(2)

Where

- M_1 = Ratio of dosimeter reading and monitor unit
- k_{TP} = Temp. & Pressure correction factor
- k_{elec} = Electrometer calibration factor
- k_{pol} = Polarity correction factor
- k_s = Ion recombination factor
- $N_{D,w,Qo}$ = Absorbed dose to water calibration factor
- $k_{Q,Qo}$ = Beam quality factor

$$\delta(\%) = \frac{(Dcal - Dmeas)}{Dmeas, ref} \times 100$$

Where

D_{cal} = Calculated Dose

D_{meas} = Measured Dose

$D_{meas,\, ref}$ = Dose value measured at the reference point

Results

Case	Ref. point	Location of measuring point	Calculated dose (cGy)	Measured dose (cGy)	Deviation (%)	Agreement criteria (%)
1	Hole-3	Hole-1	239.6	243.7	✓1.6	2
		Hole-3	201.4	201.7	✓0.14	2
		Hole-5	169.2	168.2	✓0.59	2
		Hole-9	13.9	12.13	14.59 ✖	4
		Hole-10	120.6	120.7	✓0.08	3
2	Hole-1	Hole-1	201.4	203.7	✓1.14	3
3	Hole-3	Hole-3	201.3	201.1	✓0.09	3
4	Hole-1	Hole-5	200.7	201.1	✓0.24	2
			200.7	197.8	✓1.47	3
			201.6	200.2	✓0.69	3
			201.1	197.2	✓1.97	3
		Hole-6	19.0	13.31	42.74 ✖	4
			124.4	130.7	✓4.82	3
			22.5	17.27	30.28 ✖	3
			258.8	265.6	✓2.5	4

Result

Case	Ref. point	Location of measuring point	Calculated dose (cGy)	Measured dose (cGy)	Deviation (%)	Agreement criteria (%)
4	Hole-1	Hole-10	141.4	143.2	✓1.25	3
			15	14.51	✓3.37	4
			270.6	278	✓2.66	4
			15	14.51	3.37 ✗	3
5	Hole-2	Hole-2	201.0	202.5	✓0.74	2
		Hole-7	168.5	169.5	✓0.59	4
6	Hole-3	Hole-3	201.5	204.6	✓1.5	3
		Hole-7	142.2	147.5	✓3.59	4
		Hole-10	136.2	143.0	✓4.7	5
7	Hole-5	Hole-5	200.4	199.1	✓0.65	2
			201	198	✓1.51	4
			200.3	197.8	✓1.26	4

Discussions

- Most of the cases, dose deviations have been found within the acceptance limit; but in few cases deviations have been found to be more than the acceptable level.
- The large deviations have been observed, may be due to the exact positioning of ionization chamber in the phantom or air gap outside the chamber, scattered dose, field converse or field size, effective point of measurement of ionization chamber in the phantom.
- In the CT calibration curve, we found some differences in the region with densities above that for water, which also conforms other studies.
- The acceptance criteria for the difference between the stored and measured values of CT numbers for the same RED was ±20HU [TRS 430].

Conclusion

- The dosimetric verification of our computerized treatment planning system is well defined except some cases.
- However, few cases have shown discrepancy with the agreement criterion. Further study should be needed to overcome this limitation.
- The magnitude of the error in calculated dose due to this difference of HU affects ~ 3% (2-3%).
- Finally, this study will help the users to better understand the operational features and limitations of their TPSs i.e. to perform **complete QA from CT imaging to dose verification.**

Future Plan

- To verify the TPS and dosimetry system of all radiotherapy centers in Bangladesh for audit purpose to ensure quality cancer treatment.

Thank you All for Patience Hearing

Acknowledgements

Thanks to Delta Hospital Ltd. Authority to allow me to do the experiment. Special thanks to S. M. Enamul Kabir, Principal Medical Physicist & Coordinator, Dept. of Medical Physics, DHL. for his kind cooperation.