

# Imaging Quality and Dose of IGRT: Our Institutional Practice



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# Introduction



- Image guided radiation therapy (IGRT) used to guide the radiation therapist
  - ❖ To localize the tumour position very precisely
  - ❖ To confirm the setup uncertainty with sub mm accuracy
  - ❖ Then radiation beam delivers its prescribed dose
- As the same time imaging dose to the normal tissues out side the tumour area increases during the course of the treatment which induces the potential risk of secondary cancers.
- Our aim is to **reduce the imaging dose.**



# Our Institution Facility



## TrueBeam 2.7 with OBI with iCBCT

- ❖ 2D Imaging with KV & MV
- ❖ 3D CBCT with KV & 4D CBCT for MM
- ❖ Millennium 120 MLC Leaves -5 mm

## Halcyon Elite 3.1 with OBI with iCBCT

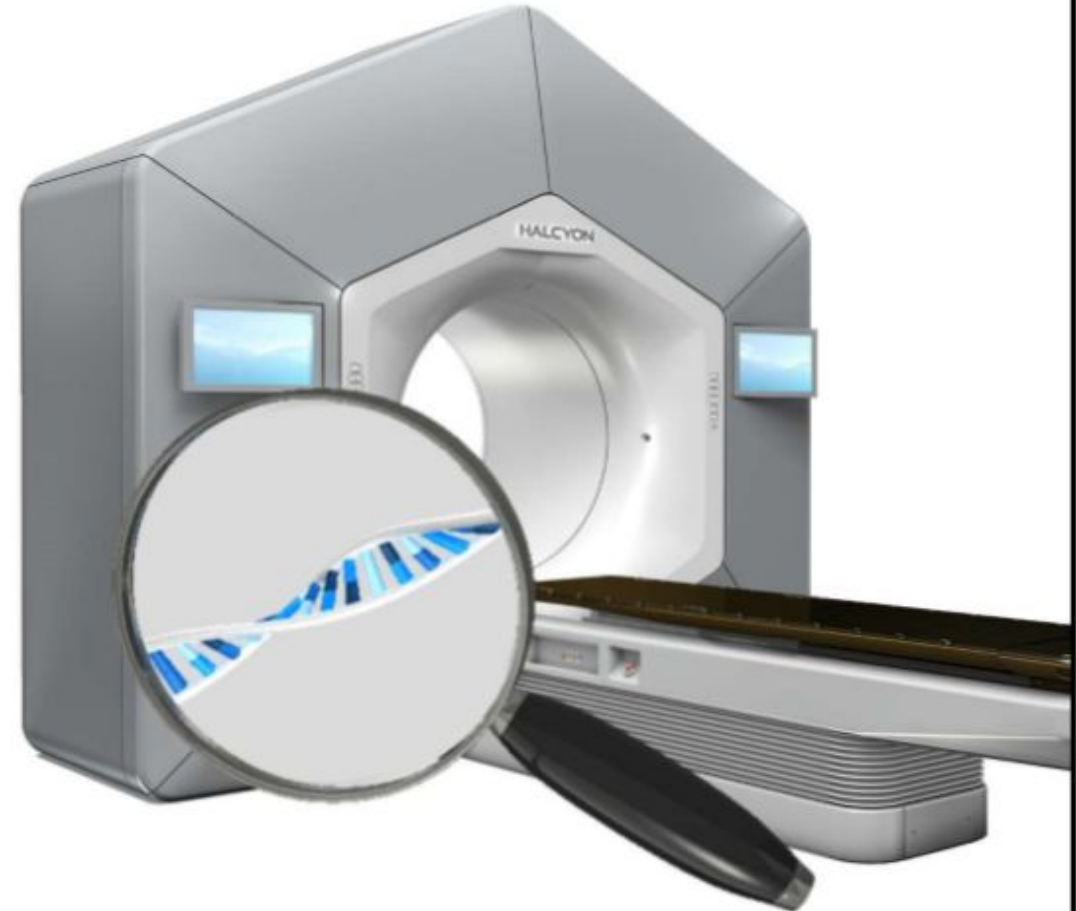
- ❖ 2D Imaging with MV
- ❖ 3D CBCT with MV and KV
- ❖ SX2-Dual Layer MLC – 5mm Resolution



**Installed and Commissioned – 2 IGRT Machines (Since April 2023)**

## Halcyon TrueBeam

- TrueBeam experience
  - Won't go to waste on Halcyon
- Halcyon is built on the TrueBeam platform
  - Exactly the same control hierarchy
  - But the linac components are a little different
- Items not found on Halcyon:
  - ODI
  - Field light
  - Lasers marking treatment isocenter
  - Pendants
  - Couch side panel controls





# Our Institutional Protocol



- Our Institution – Common Protocol
  - ❖ Daily KV CBCT
  - ❖ Produces additional dose to OARs
  - ❖ Could not be avoided
- But the imaging dose can be minimized
- Optimal image parameters
  - ❖ kVp,
  - ❖ mAs,
  - ❖ FOV,
  - ❖ Scan Length
  - ❖ iCBCT without affecting the image quality.



# Imaging Default Protocol



## True Beam

## Halcyon

CBCT Protocol	KVp	mAs	CTDI (mGy)
Head	100	150	1.06
Image Gently	80	100	0.94
Thorax	125	270	4.0
Pelvis	125	1080	15.98
Pelvis Large	140	1687.5	36.79

CBCT Protocol	KVp	mAs	CTDI (mGy)
Head	100	138.9	3.67
Head Low Dose	80	46.30	1.22
Thorax	125	300.65	6.01
Thorax Fast	125	294.6	5.89
Breast	125	49.10	0.98
Pelvis	125	1074	21.48
Pelvis Fast	125	592	11.84
Pelvis Large	140	1456	38.44
Pelvis Large Fast	140	698	18.43



# Imaging Protocol



## True Beam

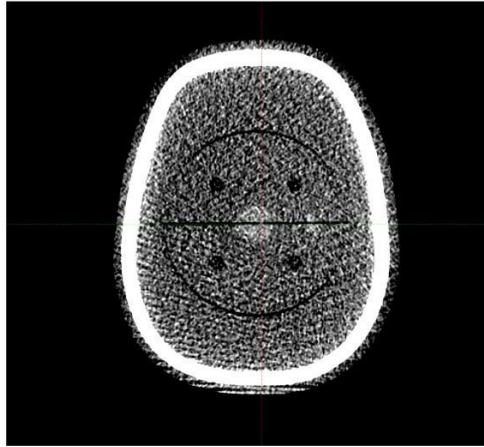
CBCT Protocol	KVp	mAs	CTDI (mGy)
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Image Gently	80	100	0.94
Thorax	125	270	4.0
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Pelvis Large	140	1687.5	36.79

## Halcyon

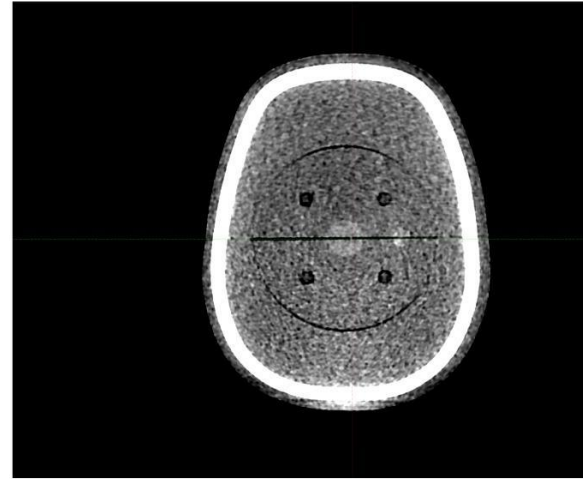
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With the use of **iCBCT** and **decreasing mAs**, **Image dose can be reduced** without affecting the beam quality.

# Image Quality CBCT vs iCBCT



HEAD PROTOCOL- STANDARD



HEAD PROTOCOL- iCBCT

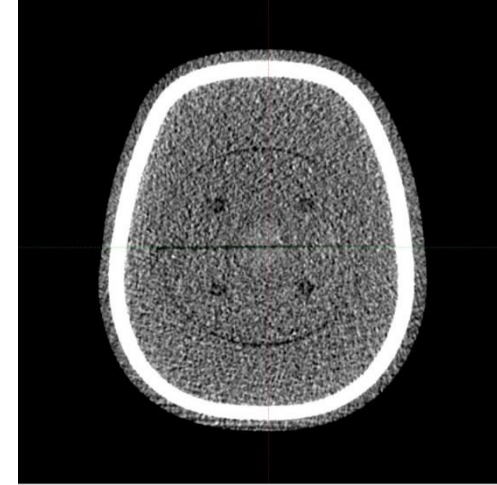


IMAGE GENTLY PROTOCOL- STANDARD

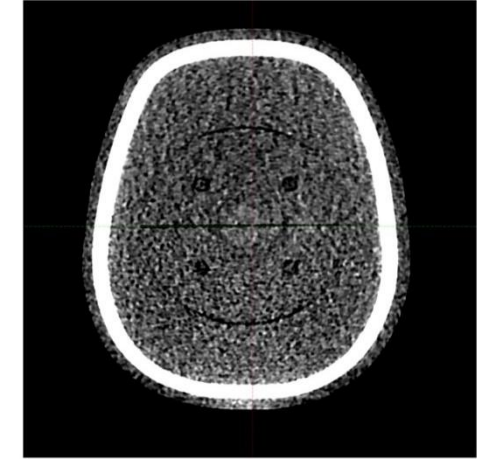
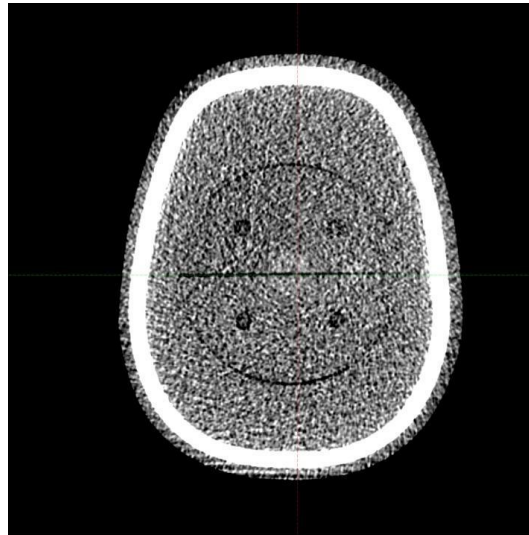
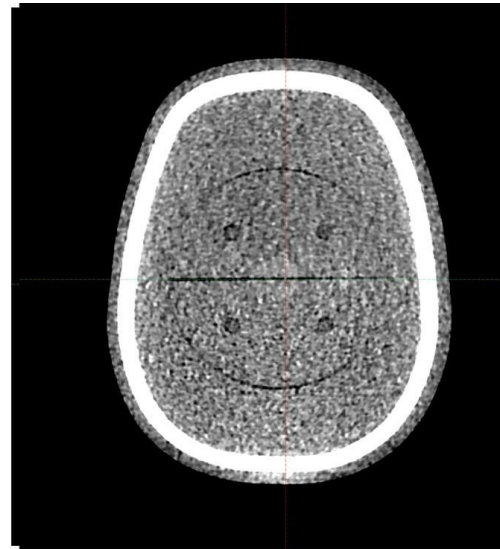


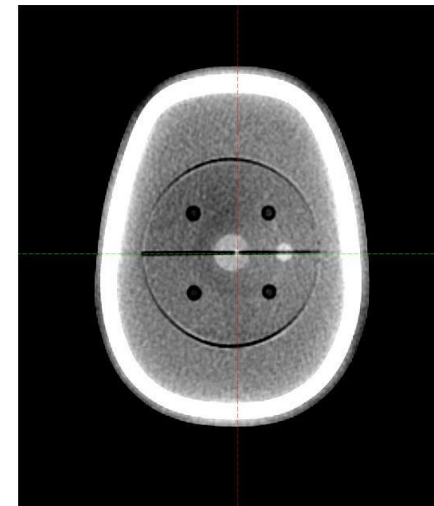
IMAGE GENTLY PROTOCOL- iCBCT



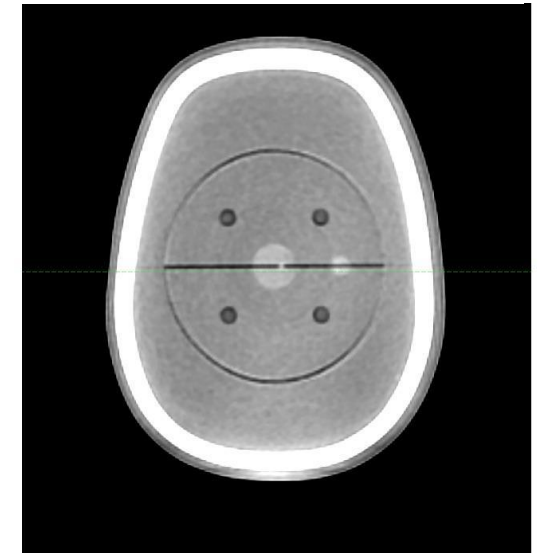
HEAD LOW DOSE PROTOCOL- STANDARD



HEAD LOW DOSE PROTOCOL- iCBCT



PELVIS PROTOCOL- STANDARD

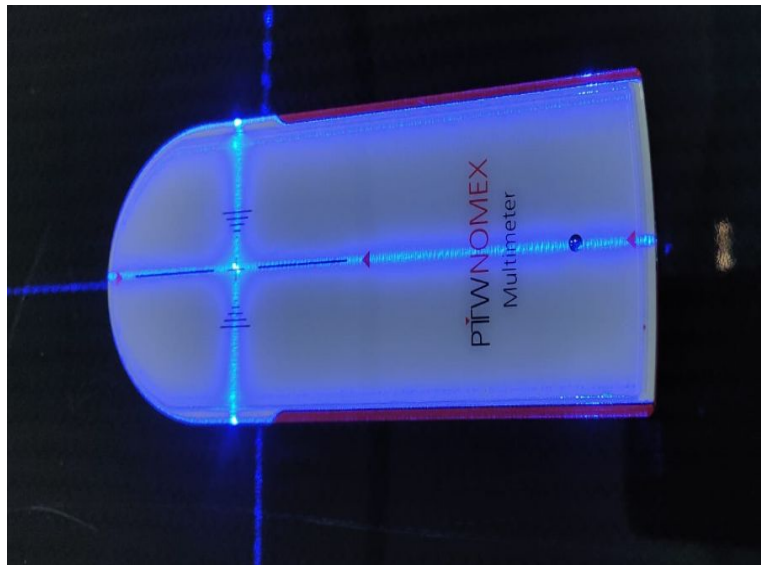


PELVIS PROTOCOL- iCBCT



# Imaging System QA

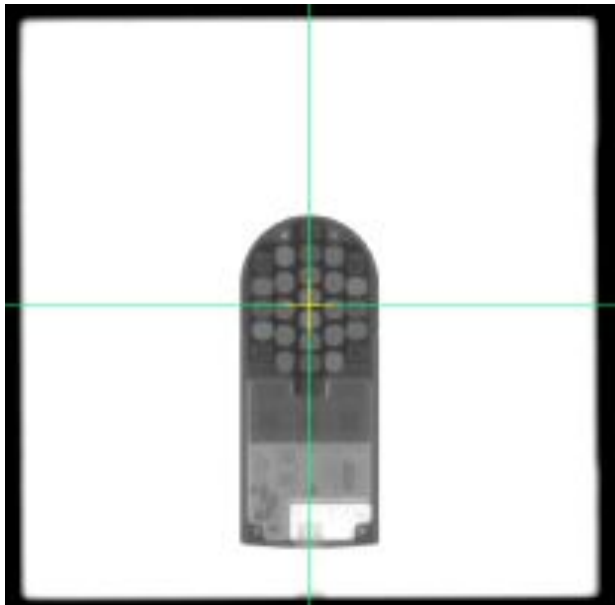
Accuracy of kVp					
Sr.No.	Applied KVp	Measured KVp 50 mA	Measured KVp 80 mA	AverageKVp	Max Diff in kVp
1	50	50.4	50.2	50.3	-0.3
2	60	60.4	60.7	60.55	-0.55
3	70	70.6	70.4	70.5	-0.5
4	80	81	81.1	81.05	-1.05
5	90	91	91	91	-1
6	100	100.9	101.3	101.1	-1.1
7	120	120.5	120.6	120.55	-0.55
8	140	139.9	140	139.95	0.05



Accuracy of Timer					
Sr.No.	Applied mS	Measured mS	Average mS	% Diff	
1	30	31.500	31.500	31.5	4.76
2	50	51.500	51.500	51.5	2.91
3	100	101.500	101.500	101.5	1.48
4	200	201.500	201.000	201.25	0.62
5	400	401.000	401.500	401.25	0.31
6	500	501.500	501.500	501.5	0.30
7	800	801.500	801.000	801.25	0.16
				Average %Diff	1.51

# Imaging System QA

Linearity of mA					
	kVp=100, mS=50				
Sr.No	mA	Dose in $\mu\text{Gy}$		Average $\mu\text{Gy}$	S= $\mu\text{Gy}/\text{mA}$
1	25	46.57	46.41	46.49	1.860
2	50	92.28	92.45	92.365	1.847
3	75	138.5	138.7	138.6	1.848
4	100	184.5	184.6	184.55	1.846
5	125	230.8	230.3	230.55	1.844
6	150	276.2	276	276.1	1.840
				X max	1.859
				X min	1.840
		Co L= (X max- X min)/(X max + X min)			0.00512



Linearity of Timer					
	KVp = 120, mA = 100				
Sr.No	Time in mS	Dose in $\mu\text{Gy}$		Average $\mu\text{Gy}$	S= $\mu\text{Gy}/\text{mS}$
1	30	179.2	179.1	179.15	5.971
2	50	299.8	299.3	299.55	5.991
3	75	448.1	447.8	447.95	5.973
4	100	597.1	596.7	596.9	5.969
5	300	1789	1789	1789	5.963
6	500	2981	2980	2980.5	5.961
7	800	4768	4769	4768.5	5.961
8	1000	5958	5958	5958	5.958
				X max	5.991
				X min	5.958
		Co L= (X max- X min)/(X max + X min)			0.00276



# Optimize Scan Length



The screenshot displays a medical imaging software interface with the following sections:

- Imaging Systems:**
  - MV Imaging [cm]: Mid
  - KV Imaging [cm]: -50.0, 0.0, 0.0
  - Filter/Blades: At plan
- KV CBCT Parameters:**
  - Acquisition Type: 3D CBCT
  - CBCT Mode: Head
  - Reconstruction: Standard
  - Fan Type: Full
  - Trajectory: Half
  - kV: 100
  - mAs: 150.00
  - CTDivol: 3.17 mGy
  - DLP: 67.7 mGy \* cm
- Acquisition:**
  - Projections: 500
  - Velocity [°/s]: 6.0
- Scan:**
  - Diameter [cm]: 26.2
  - Range [cm]: 18.5
- Gantry Angle:**
  - Start [°]: Auto
  - Stop [°]: Auto
- Reconstruction:**
  - Matrix Size: 512
  - Filter: Auto
  - Ring Suppression: Medium
  - Slice Thickness [mm]: 2.0

The main display area shows a 3D model of a head with a red bounding box indicating the scan field of view (FOV). The FOV is labeled as "FOV (Scan Diameter: 26.2 cm) Scan Range: 18.5 cm". The scan range is further defined by "X1=-14.0 cm", "X2=14.0 cm", and "Y2=10.7 cm". A "Couch Lng Shift: 0.00 cm" is also indicated. At the bottom, there are buttons for "Stop Scan Early" and "Discard Volume", along with a progress bar showing 0% to 100% completion.



# Optimize Scan Length

Imaging Systems

	Vrt	Lng	Lat
MV Imaging [cm]	Mid		
KV Imaging [cm]	-50.0	0.0	0.0

Filter/Blades At plan

---

KV CBCT Parameters

Acquisition Type: **3D CBCT**

CBCT Mode: **Head**

Reconstruction: **Standard**

Fan Type: **Full**

Trajectory: **Half**

kV: **100**

mAs: **150.00**

CTDIvol: **3.17 mGy**

DLP: **36.0 mGy \* cm**

Persistent parameters loaded

Loading Reference CT:

**CT and structures created.**

None

Acquisition

Projections: **500**

Velocity [°/s]: **6.0**

Scan

Diameter [cm]: **26.2**

Range [cm]: **9.1**

Gantry Angle

Start [°]: **Auto**

Stop [°]: **Auto**

Reconstruction

Matrix Size: **512**

Filter: **Auto**

Ring Suppression: **Medium**

Slice Thickness [mm]: **2.0**

Imaging Limited

KV\_Topo\_AP\_1a - 10/10/2024 7:37 PM - 0°

X1=-14.0 cm

X2=14.0 cm

Y1=-5.7 cm

Y2=5.7 cm

FOV (Scan Diameter: 26.2 cm, Scan Range: 9.1 cm)

Couch/Lng Shift: 0.00 cm

Stop Scan Early

Discard Volume

0  100%



# Optimize Scan Length



The screenshot displays the software interface for configuring a kV CBCT scan. The 'kV CBCT Parameters' panel on the left includes settings for Acquisition Type (3D CBCT), CBCT Mode (Head), Reconstruction (Standard), Fan Type (Full), Trajectory (Half), kV (100), mAs (150.00), CTDIvol (3.17 mGy), and DLP (67.7 mGy \* cm). The 'kV Acquisition Parameters' panel in the center shows kV set to 85, mAs set to 5.00, Anatomy set to Head, and Size set to Medium. The 'Imaging Acquisition Settings' panel at the bottom shows 'Topogram' selected. Two red circles highlight the 'Loading Reference CT' dropdown menus, which are set to 'kV Topogram'. The status bar at the bottom shows 'Total kV Dose [mGy] 0.00', 'Timer [min] 0.0', 'HU%:', 'Anode 53', and 'Housing 24'.



# Optimize Scan Length



**kV CBCT Parameters**

Acquisition

CBCT Mode: Head

Energy [kV]: 100.00

Exposure [mAs]: 138.90

CTDIvol [mGy]: 3.67

DLP [mGy \* cm]: 91.7

Scan time [s]: 16.6

Scan

Diameter [cm]: 28.2

Range [cm]: 21.9

Extended CBCT:

Reconstruction

Matrix [pixel]: 512

Thickness [mm]: 2.0

iCBCT Enhance:

KVCBCT-DRR - 10/11/2024 10:49 AM - 0°

Y2=14.0 cm

R

L

Y1=11.0 cm

0 Idle 100%



# Optimize Scan Length



kV CBCT Parameters

Acquisition

CBCT Mode: Head

Energy [kV]: 100.00

Exposure [mAs]: 138.90

CTDIvol [mGy]: 3.67

DLP [mGy \* cm]: 4.4

Scan time [s]: 16.6

Scan

Diameter [cm]: 28.2

Range [cm]: 1.0

Extended CBCT:

Reconstruction

Matrix [pixel]: 512

Thickness [mm]: 2.0

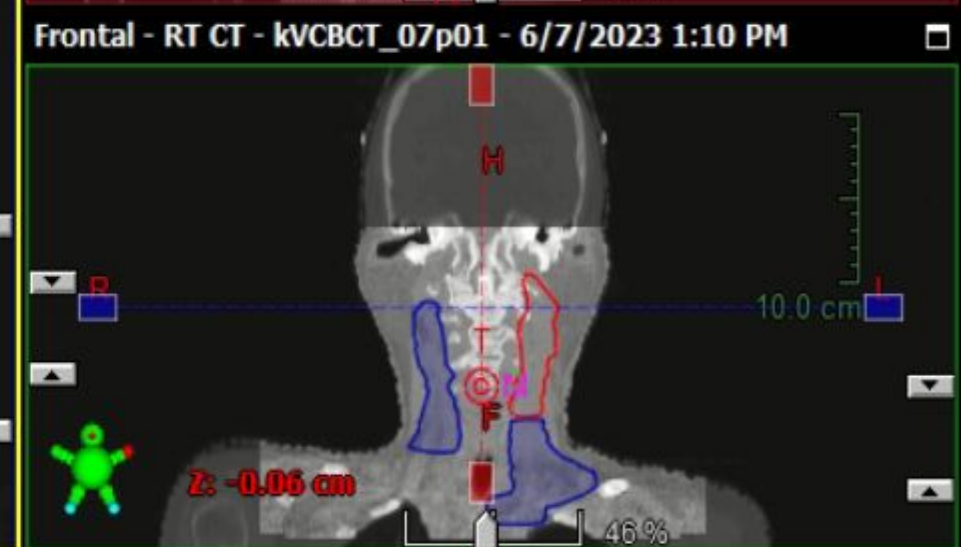
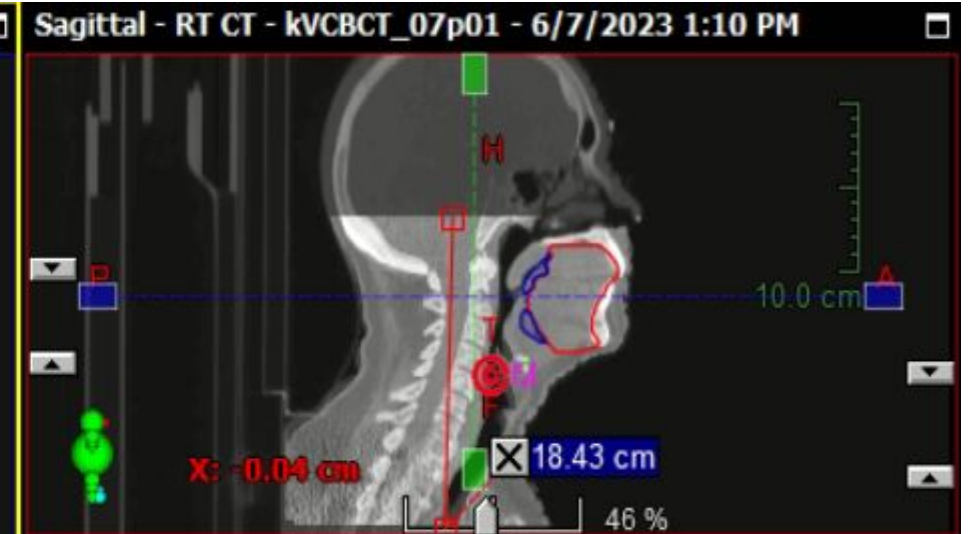
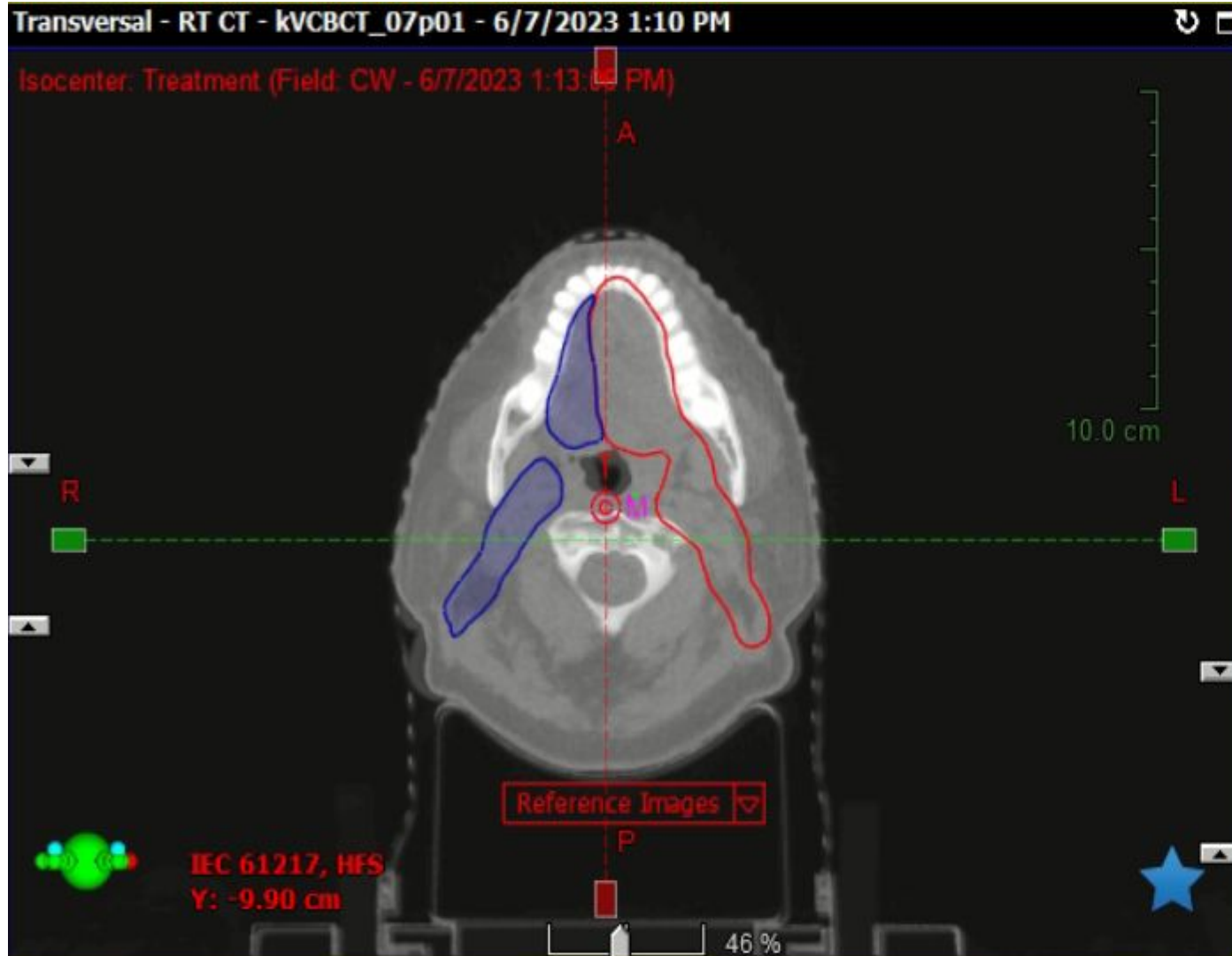
iCBCT Enhance:

Y2=0.0 cm

Y1=1.2 cm

0 Idle 100%

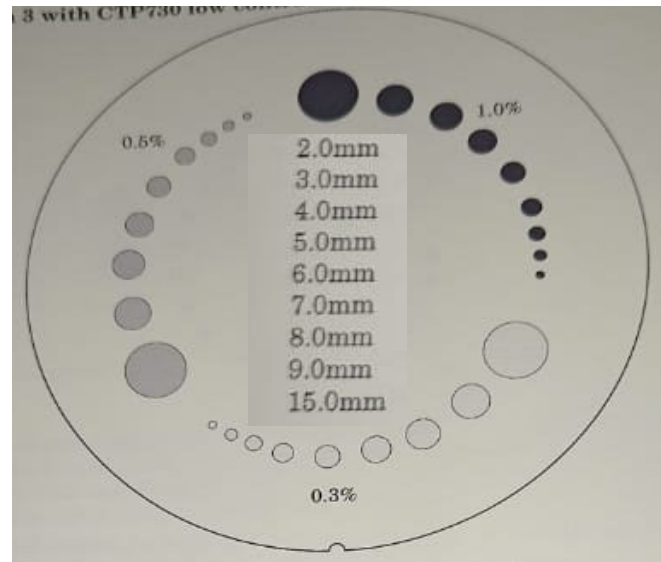
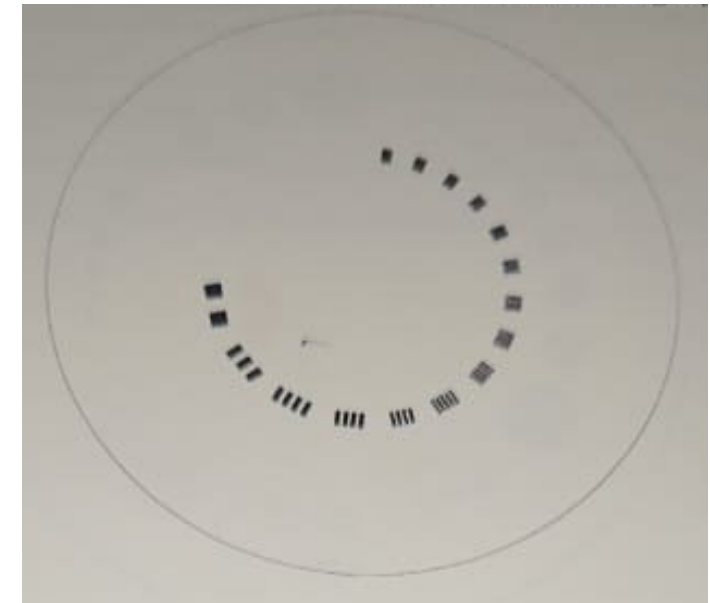
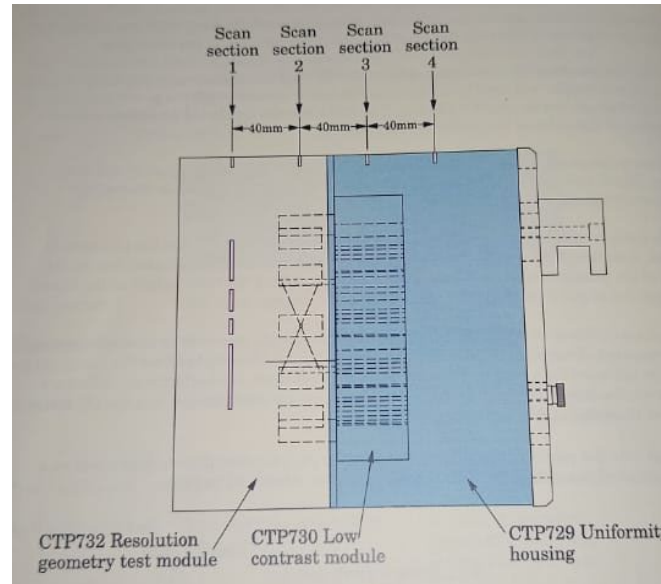
# Optimize Scan Length





# CatPhan 604

Tests	Catphan@ 504	Catphan@ 604
Slice geometry	23° wire ramps	23° wire ramps
Alignment light verification	Exterior alignment dots require offset	Exterior alignment dots relate to wire ramps
Sensitometry	7 materials including air	9 materials including 2 calcium bone formulations and air
Pixel verification	X and Y targets 5cm spacing	X and Y targets 5cm spacing
High resolution test	1-21 line pair gauge and .28mm MTF bead	1-15 line pair gauge, .18mm MTF bead and .05mm steel MTF wire
Low contrast	1%, 0.5% and 0.3% contrast targets and 1% sub-slice targets	1%, 0.5% and 0.3% contrast targets
Uniformity	Solid cast 15cm diameter	Solid cast 20cm diameter



Line Pair/cm	Gap Size	Line Pair/cm	Gap Size
1	0.500 cm	9	0.056 cm
2	0.250 cm	10	0.050 cm
3	0.167 cm	11	0.045 cm
4	0.125 cm	12	0.042 cm
5	0.100 cm	13	0.038 cm
6	0.083 cm	14	0.036 cm
7	0.071 cm	15	0.033 cm
8	0.063 cm		



# Imaging Protocol



## True Beam

CBCT Protocol	High Contrast (Line Pair/cm) CBCT & iCBCT	Low Contrast (CBCT)	Low Contrast (iCBCT)
Head	7	1%/15mm	1%/8mm
Image Gently	7	Nil	1%/15mm
Thorax	4	1%/6mm .5%/9mm	1%/4mm .5%/7mm
Pelvis	4	1%/4mm .5%/7mm .3%/9mm	1%/3mm .5%/7mm .3%/9mm
Pelvis Large	4	1%/4mm .5%/7mm .3%/9mm	1%/2mm .5%/6mm .3%/8mm

## Halcyon

CBCT Protocol	High Contrast (Line Pair/cm) CBCT & iCBCT	Low Contrast (CBCT)	Low Contrast (iCBCT)
Head	6	Nil	Nil
Head Low Dose	6	Nil	Nil
Thorax	6	Nil	Nil
Thorax Fast	6	Nil	Nil
Breast	4	Nil	Nil
Pelvis	4	1%/4mm .5%/9mm	1%/3mm .5%/9mm
Pelvis Large	4	1%/4mm .5%/8mm. 3%/9mm	1%/2mm .5%/7mm .3%/9mm

Image resolution Tests Performed with the CAT Phan (CTP604)



# Imaging Protocol



## True Beam

CBCT Protocol	KVp	mAs	Optimized mAs
Head	100	150	100
Image Gently	80	100	75
Thorax	125	270	180
Pelvis	125	1080	920
Pelvis Large	140	1687.5	1080

## Halcyon

CBCT Protocol	KVp	mAs	Optimized mAs
Head	100	138.9	-
Head Low Dose	80	46.30	-
Thorax	125	300.65	-
Thorax Fast	125	294.6	-
Breast	125	49.10	-
Pelvis	125	1074	984.5
Pelvis Fast	125	592	Not Done
Pelvis Large	140	1456	1051.7
Pelvis Large Fast	140	698	Not Done

With the use of **iCBCT** and **decreasing mAs**, **Image dose can be reduced** without affecting the beam quality.



# Summary



- iCBCT with lowering the mAs – Produced the same Imaging Quality of Standard CBCT
- Observed 25%-30% mAs can reduced to match with standard protocol
- Decreasing Scan length & mAs produces significant reducing in the Imaging dose.
- Future scope of work
  - Dosimetry study needs to be evaluated for these protocols
  - Imaging dose to Organs at risks for various site location



## Kind Acknowledgements to Our Medical Physics Team

- Mrs. Sivasankari K
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