# Proton Therapy QA & Operations Loma Linda University Medical Center

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# **Facility Overview**

# **Operations**

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# James M. Slater, MD, Proton Therapy and Research Center

#### World's first hospital based proton treatment facility (1990)

- Accelerator: a synchrotron
- Passive beam scattering
- Four treatment rooms, Five treatment beam lines
  - three isocentric gantries
    - one with robotic patient positioner
  - one horizontal beam line
  - one fixed eye beam line
- One research room (3 horizontal beam lines)
- Variable energy capability with energies up to 250 MeV
- Accelerator runs 6 days a week, 24 hrs. a day
- One day per week for repair and preventive maintenance
- Active beam scanning (ABS) under development



### **Proton Treatment Facility Layout**





## **Typical Proton Facility Weekly Usage**

MODE	HOURS	PERCENTAGE
Treatment	94	56%
Calibration	24	14%
Maintenance	12	7%
Research	10	6%
Upgrades	16	10%
Operations	5	3%
Other	7	4%
TOTAL	168	100%



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# **Timeline of a Proton Treatment @LLUMC**

<u>Procedure</u>	Time Needed	<u>Time before Tx</u>
Patient orientation & education	1-2 hours	7-10 days
Patient immobilization & imaging	15-30 min	7-10 days
Treatment planning & plan QA	1- 3 days	5-8 days
Device manufacture & calibration	1 day	1-3 days
Treatment session	15-45 min	
Patient setup	5-10 min	
Alignment verification & approval	5-25 min	
Treatment	2-5 min	
Room reset	2-5 min	



# **Time Requirements for Routine QA Tasks**

<u>Task</u>	Time Needed	<u>Comments</u>
Simple calibration	10 min/field	5 min/additional field
Complex calibration	15-20 min/field	10 min/additional field
Problem fields	30-60 min/field	Small, odd shaped fields
Radio surgery fields	20-30 min/field	10-15 min/additional field
Eye-beam fields	45 min to 2 hours	Small mod-wheels, range
Model calibration	5-7min/field	Does not need beam
Device checks	5 min/device	Boluses and apertures
Daily QA	15 min/energy	
	20 min imaging sys lasers, table etc.	
Calibration checks	15-20 min/field	



# **Staffing**

- Staff cross-trained in both x-ray and proton therapy
- > 5 Ph.D. physicists, 5 M.S. physicists, 10 dosimetrists (9 physicians)
- 2 proton calibration physicists (night shift)
- 4 proton treatment rooms, 4 linear accelerators, one CT-Sim, 2 CT scanners and brachy service
- EMR: ARIA/Oncochart
- > Three academic programs
- Ongoing research & development (without treatment interruption)
- Physics workload: protons to x-rays: 65:35



### **Patient Mix by Diagnosis (since inception)**



# **Quality Assurance**



### **A Proton Treatment System**





#### **1** Accelerator

Beam position monitoring Beam energy monitoring Beam current monitoring Beam steering

2 Beam Transport System Beam routing to tx rooms Beam profile and centering

#### **3** Nozzle

Beam shaping/steering Beam monitoring Dose monitoring 4 Gantry

Beam rotation/aiming Imaging 5 Patient Positioner





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# **Daily QA Checks**

- Review beam delivery system logbook
- Verify integrity of the control system database for each beam-line
- Inspect treatment room (motion locks, snout extension, snout motion, range of table motions, hand pendent function etc.)
- Inspect treatment console area (indicator lamps, token key, backup monitor reset, audio-visual patient monitors
- Check localization lasers (2 mm)
- Verify modulator propeller interlock
- Verify functionality of barcode scanning system
- Check the functionality of the area radiation monitor within the room
- Run the daily DI tests
- Perform a daily QA for each energy
- Perform patient calibration for each new portal



# Daily Proton Beam

# QA

- A procedure to standardize operating conditions for each day, each room, each energy
- Daily beam calibration performed under standard conditions for each energy
  - Isocenter at Center of modulation (6 cm mod wheel)
  - Nozzle extension
  - Standard aperture
- Detector response compared with standard calibration (Pass/Fail)
- Calibration factor used for patient portal calibration
- Also includes verification of entrance and distal dose and range verification

	Daily Calibration su Portal ID:	ummary	AB	Run Nu	umber: 55653	
	Outcome:		Finisnea			
	Standard Calibration	n #:	103			
	Temperature (deg C.)	):	19.40			
	Pressure (mm Hg.):		735.40			
	Beam Energy (Mev.:		155			
	Counts:		1000000			
	Modulator Wheel:		060			
	Range Shifer ID:		0			
	Nozzle Extension:		48.29			
	Target Identifier:		WDC 88			
	Validation:		VALID			
	Comment:					
	Combo detector passe	ed daily calib	pration.TIC 3	detector		
L	passed daily calibra	ation.				
	Sequence Channel	Background	Raw	Corrected	Monitor	Calibration
	Number	Factor	Counts	Counts	Units	Factor
	Detector: Combo					
L	1 SEM	3.64	7294	6826.909	6826.91	48.4341
	1 TIC 1 SF	3.14	666510	666107.062	666107.06	4725.7578
	1 TIC 1 01	3.11	164528	164128.922	164128.92	1164.4277
	1 TIC 1 02	1.74	155416	155192.719	155192.72	1101.0289
	1 TIC 1 03	3.11	164893	164493.922	164493.92	1167.0172
	1 TIC 1 04	2.69	154578	154232.812	154232.81	1094.2189
	1 TIC 2 01	3.00	157415	157030.031	157030.03	1114.0640
L	1 TIC 2 02	3.16	158365	157959.500	157959.50	1120.6582
	1 TIC 2 03	3.11	153664	153264.922	153264.92	1087.3521
L	1 TIC 2 Q4	3.11	152639	152239.922	152239.92	1080.0801
	Detector: TIC 3					
L	1 TIC 3 CPP	3.04	3908	3517.896	3517.90	24.9580
L	1 Backup	0.32	19676	19634.936	19634.94	139.3018
	1 TIC 3 R1	3.15	1004275	1003870.750	1003870.75	7122.0532
	1 TIC 3 R2	3.25	623925	623507.938	623507.94	4423.5342
	Detector: Ion Chambe	er 0.00	0	1 233	140 95 11	4.3167
	1 0	0.00	U U	1.200	140.55 11	4.5107
	Ratios:	Nu	umerator	Denominator	Value	
	TIC 1 Up/Down		59487.50	638048.38	0.0932	3
	TIC 1 Left/Right	13	32487.50	638048.38	0.2076	4
	TIC 2 Up/Down	94	18468.75	620494.38	1.5285	7
1	TIC 2 Left/Right	19	95450.00	620494.38	0.3149	9
1	TIC 3 Up/Down	-2	23938.28	86053.50	-0.2781	8
L	TIC 3 Left/Right	-2	20031.64	86731.70	-0.2309	6
1	TIC 3 R1/SEM	100	3870.75	6826.91	147.0461	7
1	TIC 3 R1/TIC 3 CPP	100	3870.75	3517.90	285.3610	8
L	TIC 3 R1/TIC 1 SF	100	03870.75	666107.06	1.5070	7
1	TTC 1 SE/SEM	61	56107 06	6826 91	97.5708	2



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#### Daily beam calibration summary report

## Patient Specific QA: Each New Portal

- Check aperture for each new portal
- Check compensator bolus
  - Visual inspection
  - Probe plunge depths at select points against treatment planning data
- Correct barcodes for devices
- Perform patient specific calibration (model or physical)
- Do a second person check of patient calibration before the first treatment





### Patient Specific QA: Portal Calibration

#### **Physical Calibration**

- Performed with portal specific energy and patient devices
- Ion chamber placed at an equivalent depth in a solid phantom
- Prescribed dose delivered and output measured
- The counts, output and calibration factors generated for the detectors are stored in a patient file
- The beam calibration performed the day of treatment is used for portal calibration
- Model calibrations used when possible
- Small fields, large air gap, thick bolus: require physical calibration

a for patie	nt set-up file:		Data f	for physical calibratio	n:
hysical dose	(cGy)	163.6	Isot	to cal. pt. distance (cm)	0.0
nergy (MeV)	)	249.5	Cali	bration depth (cm)	20.61
dodulator wh	eel ID	80	Blo	cks used 35PMTA	20.653
canec shift		0		001110/1	120103
Nozzle extensi	ion	29.1 V	Addit	ional data:	
Table angle (d	eg)	-90	Sou	rce to aperture dist. (cm)	212.1
iffective f. s. a	at iso (cm)	5.52	Sou	rce to bolus dist. (cm)	218.5 /
Cone size (cm	)	15 1	Ape	rture pos. relative to bolus	upstrm
			Opt	irad MU prediction	1.114
oint bolus (	check:			Ov	erlay checks:
Point	Coordinates	WEQ.	Phys.	Meas. phys.	Bolus
location	(x : y)	thkness (cm)	thkness (cm)	thkness (cm)	AAHalaha
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Calibration	(0.25:0.39)	7.08	7.22	7.22	Aperiatre .
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		SMG	DETIM		77 -
ter of mod	lulation calcula	ation:	Beam	range check:	
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- modulation + 2 (cm)		0821/2	- 531	vy treatment death (cm)	24.83
	· 2 (cm)	00.2072 0	- 116	ix. treatment depth (cm)	
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## Monthly QA

- Review daily QA records
- Verify the room secure and other interlocks
- Verify the backup dose monitor functions properly
- Check snout extension accuracy at three extensions
- Beam pause and reset functions
- Verify the integrity and alignment of the scatterers
- Verify the patient calibration system
- Emergency off switches
- Beam flatness and symmetry
- X-ray and proton beam centering
- DI calibration tests



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# Annual QA...

#### **Safety Checks**

- Facility shutdown switches
- Area shutdown switches
- All beam safety interlocks
  - Beam energy interlock
  - Beam centering interlock
  - Backup counter interlock
  - Modulator wheel interlock
  - Door interlock
- Room secure
- Beam on indicator
- Beam pause and resume functions
- Calibrate area radiation monitors
- Audio-visual system function
- Radiation warning signs

#### Mechanical Checks

- Gantry angle readout accuracy
- Patient positioner readout accuracy
- Patient positioner sag
- Snout extension readout accuracy
- Laser alignment accuracy
- Modulator wheel visual inspection
- Inspection of block and bolus doors and latches in the nozzle
- Hand pendant operation (also daily)

#### X-rays & Imaging Checks

- Image magnification accuracy
- kVp and mAs accuracy
- Image quality



# Annual QA...

#### Proton Checks

- Proton vs. X-ray field centering
- Location of the effective source
- Location of the virtual source
- Linearity of dose per monitor unit for the primary channel

#### **Proton Dosimetry Checks**

- Field size dependent factors for all clinically used energies (±2%)
- Modulation factors (±2%)
- Depth dose profile
- Dose per monitor unit for the primary and all backup channels at selected gantry angles (±1%)
- Bolus gap factors
   Calibration protocol: IAEA-TRS-398 (ICRU 78)

### Proton Beam Quality Checks

- Lateral field symmetry
  - energy and gantry angle
- Lateral field flatness
  - energy and gantry angle
- Lateral penumbra widths
  - energy and gantry angle
- Range uniformity (picket fence)

### **QA Equipment Tests**

- Standard ion chambers and electrometers calibration factors
  - Current ADCL calibrations
- In house ion chambers and electrometers calibration factors
  - Periodic inter-comparisons



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### **Summary**

- Quality begins at the top! Institution leadership has to show tangible commitment to quality
- To maintain quality and to improve quality, a Quality Management Program; a written document of quality expectations, of procedures and policies, and roles and responsibilities should be developed
- To implement quality programs, the institution should make available the needed resources: personnel, tools and time
- The main purpose of a hospital based proton center is to treat patients. But to treat patients right, a thorough QA program is essential. Don't squeeze out QA time to accommodate more patients
- QA procedures and policies should be strictly followed

