The Journey of Cyberknife Commissioning

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X-ray Sources

Linear Accelerator

Manipulator

Image Detectors

Special Challenge

- Not most physicists trained with
  - Robot based system
  - Small field dosimetry
  - SRS/SBRT clinical application
- Less reference than conventional Linac
- Less likely to find an experienced mentor locally

Guidelines or References

- TG-51 (Absolute Dose)
- IAEA-398 Calibration Protocol
- TG-53 (Treatment planning)
- TG-142 (Linear accelerator and imaging Qa)
- TG- 104 (kV imaging)

- TG-135 (Cyberknife QA)
- Physics Essential Guide (Cyberknife Physics "Bible")

Anticipated Time Frame

- Shielding Design: 2 weeks elapse time (Physics time 24 hrs)
- Physics technical training, Dosimetry training : 1 week each
- Installation: 2~3 weeks
- Acceptance: 3 days
- Data collection: 2~4 weeks (Cone+Iris, MLC 50 hrs bm-on time each)
- Data Processing and Import : 8 hours
- TG 51, Independent Dose check: 4 hours
- Establish QA Baseline: 4~8 hours
- Imaging QA: 4 hours
- E2E verification, on-site physics training: 1 week
- On site clinical training: 1 week
- Paper work: Report, P&P, SOP etc.
- Monte Carlo Modeling: 2~4 weeks elapse time (Physics time 8 hours)

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Shielding Design

- Wide beam angle with small use factor
- Review & double check strongly recommended
- References:
  - NCRP Report No. 151, Chapter 7.2 Robotic Arm Stereotactic – Radiosurgery room
  - James Rodgers, CyberKnife Treatment Room Design and Radiation Protection, Chapter 5, Robotic Radiosurgery,
  - Anuj K. Purwar etc. Accuray White paper 2009, tenth value layer (unique)
  - Jun Yang. Radiation Shielding Evaluation Based on Five Years of Data from a Busy CyberKnife Center, RSS meeting 2012
- Additional resource:
  - Accuray support physics
  - Radiosurgery Society & AERO
  - Current user

Physics Training & Dosimetry Training

- One week each (Sunnyvale, California)
- Learn the principle and concept of technology
- Hands-on time with machine and planning system
- Review the manufacturer provided resources

Acceptance

- 3 Days
- Functionality Check and Performance Verification
  - Beam Characteristics
    - **Symmetry**, Penumbra and Energy
  - Beam and Head Laser alignment
    - Extra attention and try to go beyond manufacture specs
  - E2E tests
    - Will be repeated during physics training using commissioned data

Beam Data collection

CyberKnife TPS Requirements

- **Ray Trace Algorithm**
  - TPR table (1 file)
  - OCR tables (12 files, 12 field sizes, all commissioned data directly applied to planning)
  - Output Factors (1 file)
- **Monte Carlo Algorithm**
  - PDD 60mm cone
  - OCR – Primary collimator

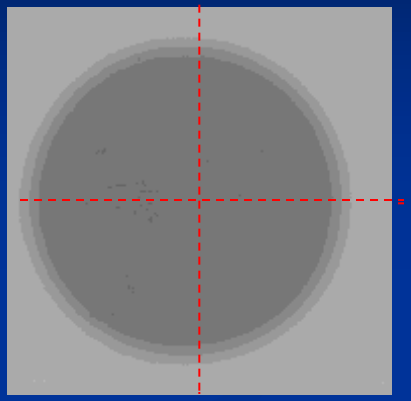
- One set of data for Fixed Cones, another set for the Iris Collimator
- **Get in touch with an Accuray support physicist for the commissioning spreadsheet with the latest composite data**

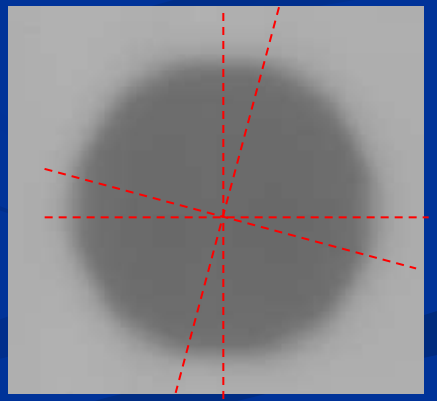
3D Scanner Setup

- 4 hours
- Level the water tank
- Machine Straight down
- Linac back plate parallel with water tank
- Place the diode at the center of the field

Beam Data collection

- Fixed Cone (12 field sizes): 20 Hours
  - TPR: 8 hrs manually, 4 hrs with TPR module
  - OCR: 8 hrs
    - 5 depths each field size
    - 2 profiles each depth
  - Output factor: 4 hrs
- Iris collimator (12 field sizes): 30 Hours
  - TPR: 8 hrs manually, 4 hrs with TPR module
  - OCR: 16 hrs
    - 5 depths each field size
    - 4 profiles each depth
  - Output factor: 4 hrs
- Monte Carlo required data: 1 Hour
- MLC: 50~60 hours





Data Processing and Review

- Transfer collected beam data to Cyberknife TPS required format
  - Great timer saver to have the TPS module to transfer
- Send formatted data to Accuray physicist for review and double check
  - Less than 1 day turn-around time
- Import to the planning system

Absolute Calibration and TG 51 issues

- 1.0 cGy / MU reference point is 1.5cm depth, 80cm SAD, 6cm Cone collimator

- TG 51 straightforward except for k_q and OCR

  k_q
  - %DD @ 100cm SSD for 10x10cm^2 vs. 6cm circle @ 80cm
  - BJR 25 yields a factor of 1.032 to convert
  - K_q is a slowly varying function -- .14% per 1.0% PDD

  OCR
  - OCR value over the length of the chamber may vary by 1-3% leading to approximately a 1.5% error

T. Kawachi et al, Reference Dosimetry condition and beam quality correction factor for CyberKnife beam, MedPhys, Vol. 35, No. 10 October 2008

E2E Tests, On-site Physics Visit

- E2E tests review
- Assist adjusting the system precision base on E2E tests
- Hands on physics training
- Review absolute dose calibration
- Review QA procedure and baseline

Physics Equipment List I

Item	Specifications	Use	Frequency					
			C	D	M	A	R	P
Water Tank	0.1 mm measurement accuracy capable of 0.2 mm step spacing, OCR inplane and crossplane as well as 15 deg angles, to scan up to 80 mm off axis and 300mm deep, diode compatible (For MLC need 120 mm off axis.)	OCR, TPR, Output Factors	X			X	X	
TMR Option	Accuray measures TPRs directly and does not convert from PDDs so this option will save data collection time	TMR	X			X	X	
Diodes with no buildup (2X)	Contact Physics Support as the specifications for individual diodes are continuously changing	OCR, TPR, Output Factors	X			X	X	
Computer	For running water tank software	Water Tank, Analysis Software	X	X	X	X		
Farmer Chamber (0.3cc)	While a 0.6cc Farmer chamber can be used, one smaller than 0.6 cc is recommended for absolute calibration to reduce OCR effects on the calibration	Absolute Dose Calibration	X		X	X	X	
Calibration for Farmer Chamber	May need build-up cap depending on country's calibration procedure.	Absolute Dose Calibration				X	X	
Digital Barometer	Calibrated	Absolute Dose Calibration	X		X	X	X	
Thermometer	Must be water compatible, Calibrated with 0.2 C scale	Absolute Dose Calibration	X		X	X	X	
Electrometer	Calibrated over the ion chamber and diode range used	Absolute Dose Calibration, Verifies Dose Delivery to Phantom Output Factor Measurements	X		X	X	X	X
Electrometer Calibration	Calibration for each scale used by the electrometer	Absolute Dose Calibration, Verifies Dose Delivery to Phantom	X		X	X	X	X
Daily QA Device	Meets local QA requirements	Daily Output Check, Flatness & Symmetry		X	X		X	
Flatbed Film Scanner	See current recommendations from ISP for scanning their Radiochromic Film.	Film analysis for targeting accuracy	X	X	X	X		X

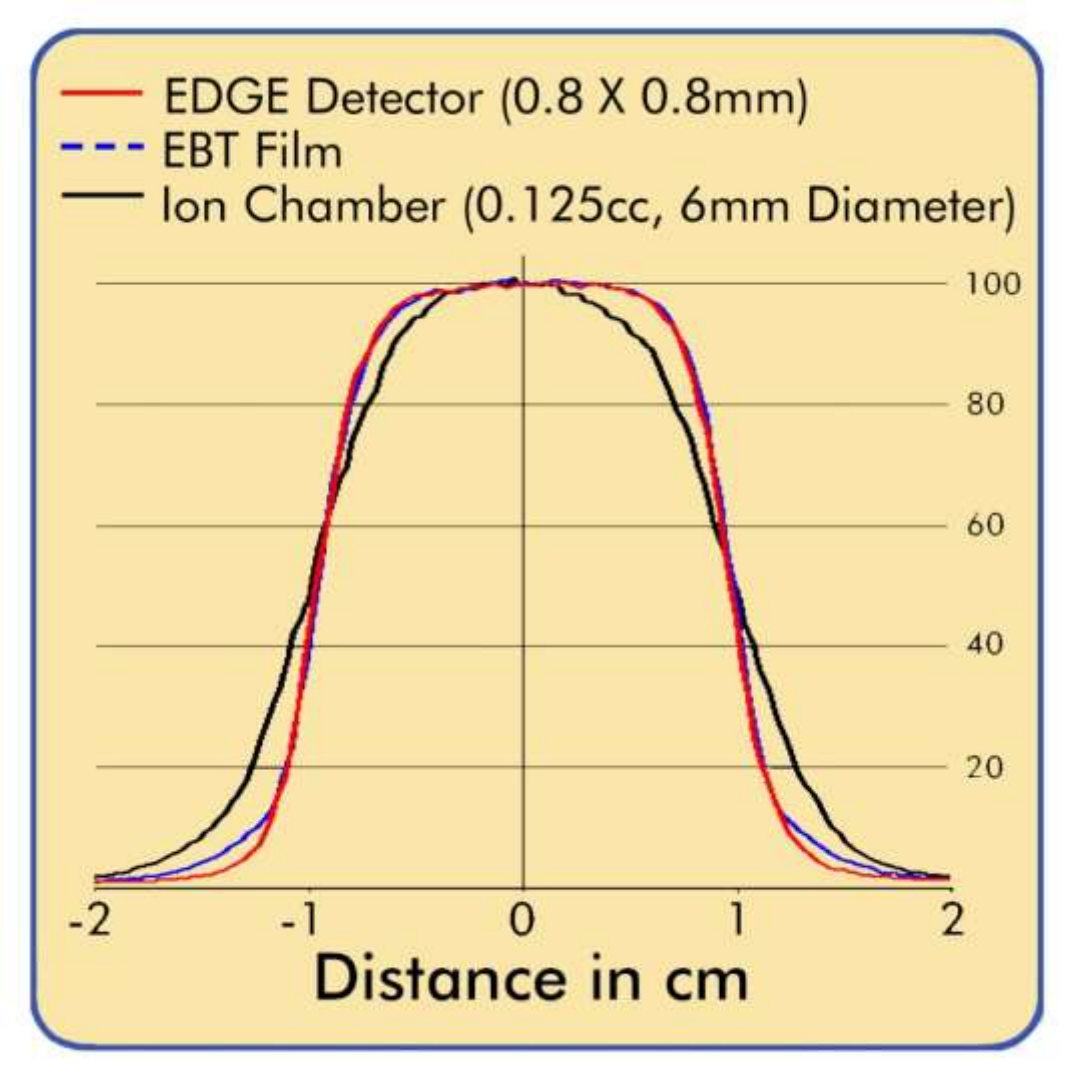
Physics Equipment List II

Item	Specifications	Use	Frequency					
			C	D	M	A	R	P
Slab Phantom with fiducials	At least 200x200 mm with enough depth to provide for sufficient backscatter at the depth of measurement. _ plugs and holes for ion chamber and/or film inserts and/or TLDs _ accurately known dimensions for structural features _ inhomogeneities	Verifies Point Dose Delivery to Phantom	X			X		X
Film & micro volume ion chamber slabs	Must be the same size (width & length) as the slab phantom	Verifies Dose Delivery to Phantom	X			X		X
Micro Volume Ion Chamber	Must be compatible with the above slab	Verifies Dose Delivery to Phantom	X			X		X
Isodose Comparison Software	Able to import film measurements and MultiPlan RT Dose files	Patient Specific QA Analysis				X		X
MLC QA Software	Able to analyze Garden Fence Test	To check MLC leaf alignment and centering	X		X	X	X	
kV Contrast & Resolution Phantom	Ability to mount at a 45 deg. angle to the floor. Analysis software very helpful but not required.	Verify Imaging System	X			X	X	
kVP Meter	80-120 kV range	Verify Imaging System	X			X	X	
Dynamic Thorax Phantom		Verification of XLT Imaging			X	X		
Lung Rod (Film)		Verification of XLT Treatments	X		X	X		
4D CT QA insert		Verification of 4D Treatment Planning	X		X	X		
Electron Density Phantom	Mass and electron densities provided over the clinical range of use	Convert CT numbers to density values for Treatment Planning	X			X	X	
Survey Meter	Standard vault survey meter for 6MV Linac	Radiation Surveys	*					

Small Field Dosimetry

- Profile
- Output Factor
- Absolute Dose Calibration

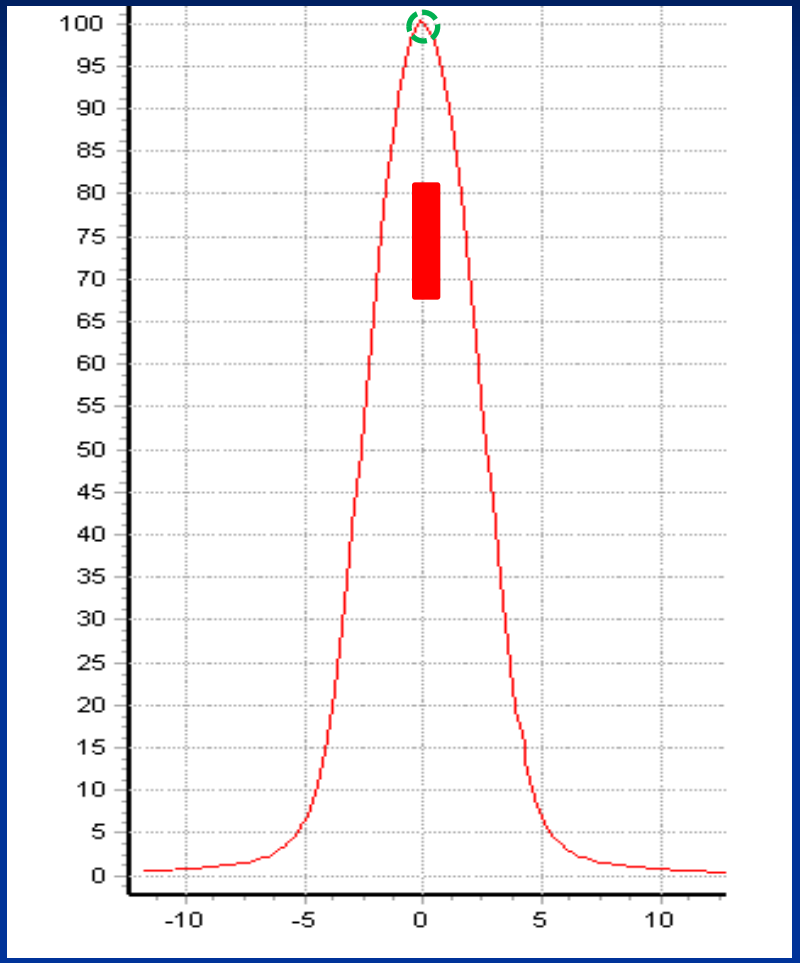
Small Field Dosimetry: Profile



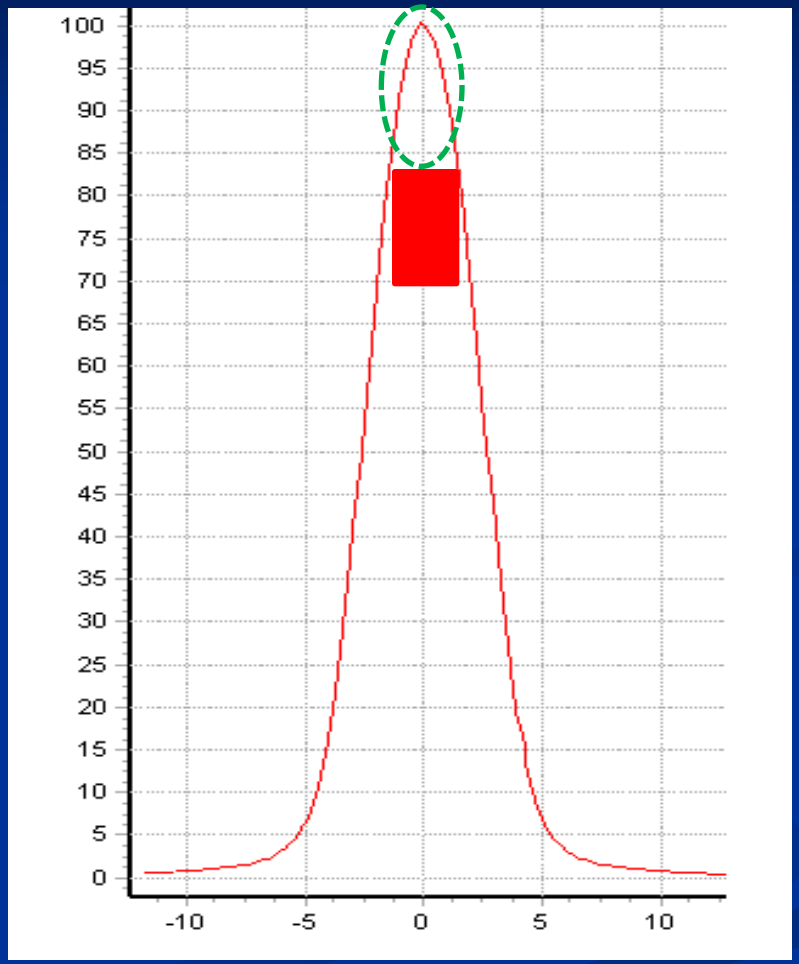
Detector response for a 2cm x 2cm field of 6 MV beam

* Courtesy from SunNuclear

Small Field Dosimetry: Output Factor



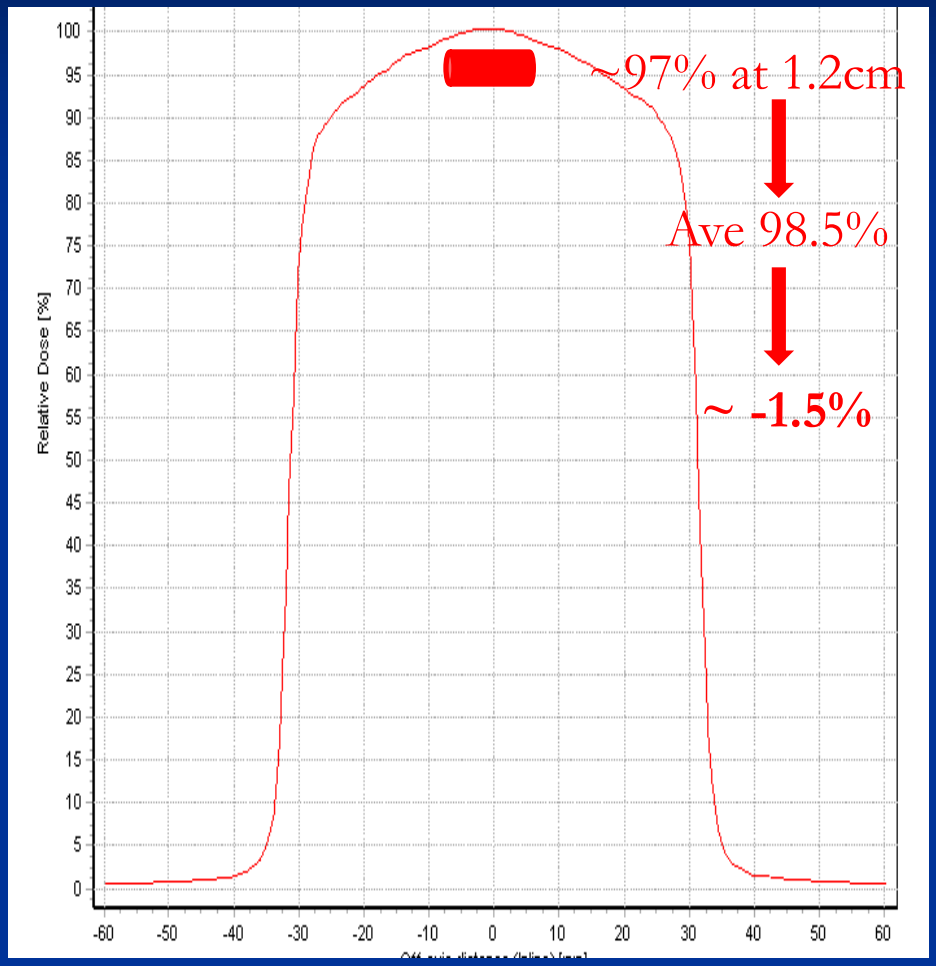
5 mm circular field using 1 mm detector for output factor



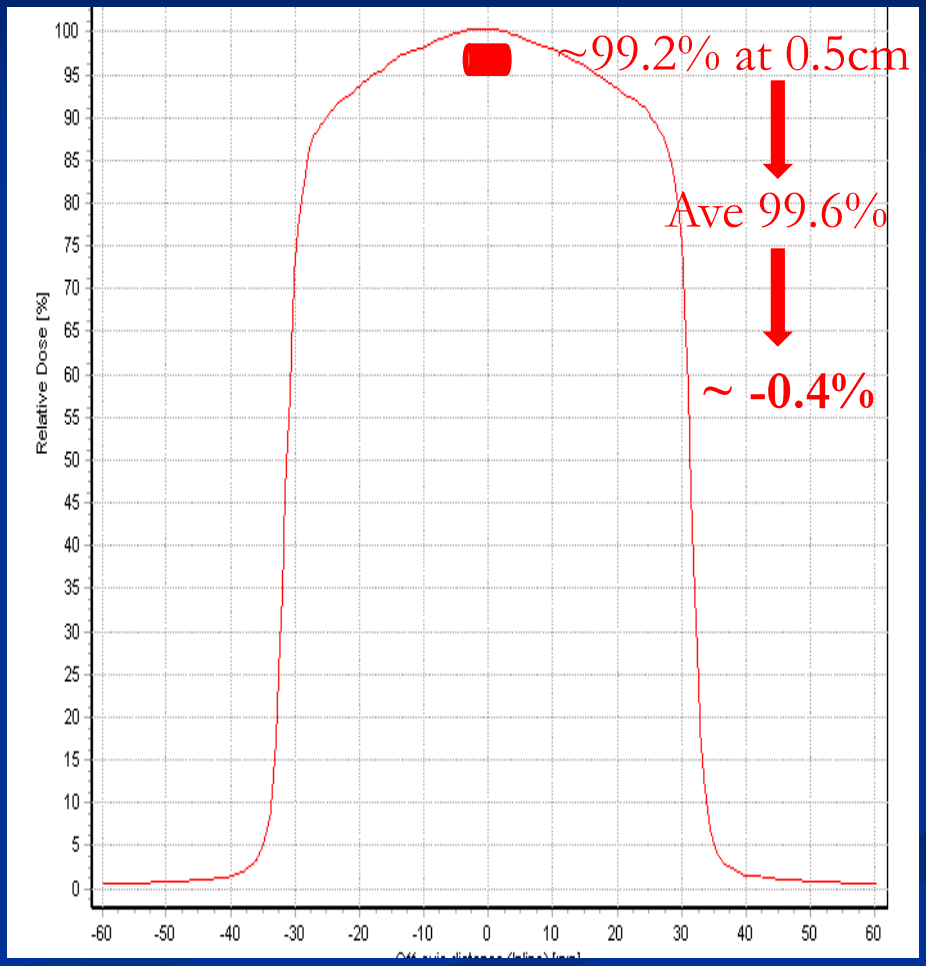
5 mm circular field using 3 mm detector for output factor

P Francescon et al, Monte Carlo simulated correction factors for machine specific reference field dose calibration and output factor measurement using fixed and iris collimators on the CyberKnife system, Phys.Med.Biol. 57(2012) 3741-3758

Small Field Dosimetry: Absolute Dose



0.6cc Farmer Chamber (**2.4cm** cavity)



0.24cc Farmer Chamber (**1cm** cavity)

Acknowledge

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- Charles Fuller Ph.D
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Thanks

- Question?