Clinical Implementation of the CyberKnife

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Disclosure…

- *I have received honoraria from Accuray in the past.*
- *I have had travel expenses paid by Accuray in the past.*

Outline

- Machine Overview
- Site planning
- Commissioning
- Ongoing QA
- QA Equipment
  - User
  - Accuray
  - Other vendors

Machine Overview

Design features

- 6 MV linac (w/o flattener) mounted on an industrial robot with 6 degrees of freedom of motion and 0.2 mm precision
- 1200 to > 5000 possible angles of beam incidence around the patient – non-coplanar, non-isocentric
- Image guidance system that tracks, detects and corrects for patient motion and organ motion throughout treatment
- SRS and SBRT anywhere in the body

Tracking Modes

- Fiducial tracking
  - Lesion motion not affected by respiration
  - Lesion motion affected by respiration
- Density tracking
  - Skull tracking
  - Spine tracking
  - Lung nodule tracking

Collimators: fixed and motorized

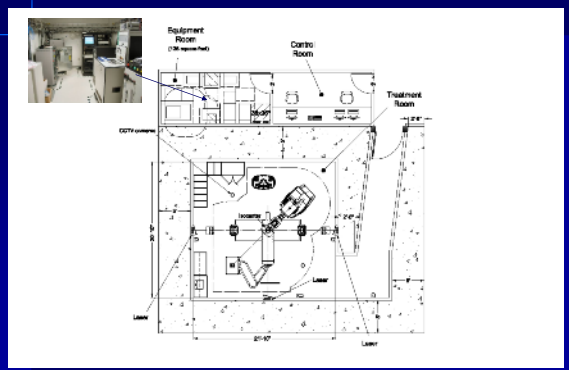
Iris has same 12 aperture sizes as the fixed collimators: 5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50, 60 mm diameter.

Site Planning

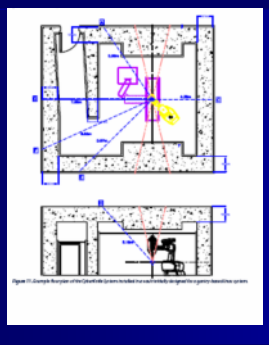
Shielding

- All walls are primary barriers
- Consider shielding entire roof same as the walls
- Don't use old workload numbers: output (mu/min) is going up and treatment times are going down every day; use newest data available

Typical CK Layout



CK in a Conventional Linac Vault



Commissioning

Commissioning Data Collection

Goal	Measurements	Estimated Time
Laser alignment	Verify coincidence of alignment of laser and center of radiation field	1 – 2 hours
Beam data collection for ray tracing algorithm	▪ TPR for each fixed and mobile collimator diameter ▪ OCR for each collimator size at depths = 15, 50, 100, 200, and 300 mm ▪ OF at three SAD's for each collimator size	▪ 30 hours for fixed collimators ▪ 36 hours for variable aperture collimator

Commissioning Data Collection

Goal	Measurements	Estimated Time
Additional beam data collection for Monte Carlo algorithm	▪ In-air OF at 800 mm SAD for all field sizes ▪ Beam profile with secondary collimator removed at 800 mm SSD at depth slightly greater than dmax ▪ PDD (d = 0 to 300 mm) for the 60 mm collimator at 800 mm SSD	4 hours for the fixed collimators 3 hour for the variable aperture collimator

Accuray provides cumulative data from all other centers with same model CyberKnife for comparison with your data.

Commissioning Data Collection

Goal	Measurements	Estimated Time
Scanner evaluation	▪ Scan appropriate phantom(s) on all CT scanners that will be used for treatment planning ▪ Determine CT number – density relationship ▪ Confirm geometric accuracy of scanners ▪ Confirm accuracy of MultiPlan fusion	8 hours per scanner

Commissioning MultiPlan TPS

Goal	Measurements	Estimated Time
Validate beam data	▪ Comparison of measured and reference beam data	2 hours
Ray tracing algorithm verification	▪ Many end-to-end tests (comprehensive system tests) to verify accuracy of absolute dose delivery and relative dose distribution in high and low dose regions ▪ Use all collimators, conformal and isocentric plans, all tracking modes.	1-2 weeks

Commissioning MultiPlan TPS (Monte Carlo)

Goal	Measurements	Estimated Time
Generate a source model	▪ Calculation of energy spectrum, source distribution, and fluence distribution.	5 minute calc time plus time to review and approve
Compare measured data	▪ Calculate and compare the measured and calculated TPR's and OCR's for each collimator	5 – 10 days calculation time (6 – 8 hours physicist interaction)
Generate normalization factor	▪ The NF converts deposited energy into absorbed dose. (Normalizes the calculated OF's at 800 mm to the measured OFs.)	2 days computation time

Commissioning MultiPlan TPS

Goal	Measurements	Estimated Time
Confirm consistency between independent mu calculation software and MultiPlan	▪ Compare results under idealized single beam geometry for every collimator setting. ▪ Compare results for plans for most common disease sites, including isocentric and conformal plans, small and large collimators, homogeneous and heterogeneous cases. ▪ Resolve all discrepancies.	3 days

Commissioning: it ain't over til …

- IMHO – you are not done until you have independent extra-mural confirmation of your system's accuracy.
- E.g. the MDACC SRS phantom (and other relevant MDACC/RPC phantom tests)
- Do not treat until you have an independent report that confirms that your system meets standard dosimetric criteria.

Routine Quality Assurance

Ongoing QA

	Daily	Monthly	Quarterly	Annual	Com/UG
Safety Interlocks Check	☑	☑	☑	☑	☑
System Status Check	☑	☑	☑	☑	☑
LINAC Output Constancy Test	☑	☑	☑	☑	☑
Robot Perch Position Laser Check	☑	☑	☑	☑	☑
X-ray Tube Warm-up	☑	☑	☑	☑	☑
AQA Test	☑	☑	☑	☑	☑
Beam Parameter Check Energy Symmetry		☑	☑	☑	☑
Robot Targeting Visual Check		☑	☑	☑	☑
Monthly End-to-end Targeting Tests		☑	☑	☑	☑
Imaging Alignment		☑	☑	☑	☑
Couch Position Accuracy Check			☑	☑	☑
LINAC laser Mechanical Alignment			☑	☑	☑
Target Locating System			☑	☑	☑
Quarterly Radiation Safety Report			☑	☑	☑
LINAC Annual				☑	☑
Robot Calibration				☑	☑
Safety System				☑	☑
CT Scanner Distance				☑	☑
Treatment Delivery Dose Verification					☑
TPS Single-Beam (PDD, OCR)					☑

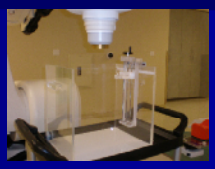
Patient Specific QA

Patient-Specific QA

- Ensure that treatment plan generated is delivered
- Objectives
  - Check dosimetry (absolute dose)
  - Verify spatial distribution of dose in region to be treated and in regions to be spared
- Dosimetry approaches
  - Amorphous silicon EPID is not an option for CK
  - Film-based dosimetry is one possible approach
  - Ion chamber measurement for absolute dose
  - Stereotactic diode array is another possible approach

Equipment

Equipment: user supplied



- Farmer chambers (2)
- Electrometer
- Diodes
- SRS ion chamber (TG-51 caveats)
- Water scanner
- Small water phantom
- CT-electron density phantom
- Patient specific QA phantom
- CT (MR) geometric accuracy phantom
- kV imaging QA phantom
- Phantom for physics output, symmetry, flatness checks
- Phantom for patient-specific QA
- Film scanner (professional quality)

Equipment: vendor supplied

Birdcage

AQA Phantom

- Adaptation of Winston-Lutz test
- Phantom contains spherical target and fiducials for tracking
- Orthogonal radio-chromic films inside phantom
- CT scan phantom, create a plan with 2 beams: AP and lateral
- Treat phantom every morning < 10 minutes
- Analyze films daily – spatial accuracy, robot calibration

Accuray also supplies film analysis software.

End to End Tests: Fiducial Tracking, Skull Tracking, Spine Tracking

Accuray also supplies film analysis software.

QA Respiratory Tracking

Other Accuray Supplied Equipment

- Pinhole laser collimator
- Isopost
- Mechanical distance indicator
- Software for analysis of radiochromic film tests
- Motion phantom with fiducials
- Motion phantom for 4-D planning and treatment

Valuable Equipment from Other Vendors

Note: The next slides are meant to serve as examples only. There are many vendors with test equipment that will do the job as well or better!

Valuable Equipment from Other Vendors

- CyberKnife QA equipment developed at the University of Miami
- Accepts many different detectors
- Efficient measurements of symmetry, flatness, output constancy, energy
- Commercially available from Ricardo Garcia*

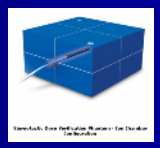
* address available upon request

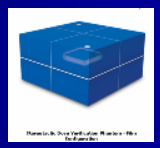
Valuable Equipment from Other Vendors

- Blue phantom from Standard Imaging
- Accepts many different detectors
- Can use film and i.c. simultaneously
- Includes inhomogeneities
- Patient specific QA

Simultaneous Film & IC

- Use commercially available water-equivalent phantom
- Achieve film and ion chamber dose measurements in one phantom with different slabs
  - Ion chamber slab has a cavity which accommodates inter-changeable ion chamber plugs for absolute dose measurements
  - Film slabs allow multiple films to be positioned for dose profile measurements

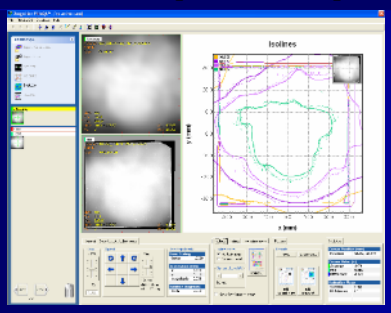




Patient-Specific Dosimetry: Example

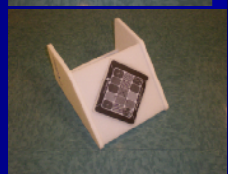
- Stereotactic Dose Verification Phantom from Standard Imaging
  - A16 ion chamber
  - EBT film
  - FilmQA analysis software
- Example results (prostate case):
  - Absolute dose error 1.9%
  - Dose distribution measured vs calculated excellent

Example: Dose Distribution (Isolines)



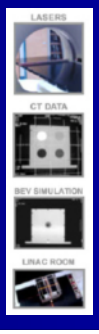
Valuable Equipment from Other Vendors

- kV imaging test module from Standard Imaging
- Angled at 45 degrees for CK geometry
- High contrast resolution constancy
- Relative density constancy
- Geometric distortion
- Artifacts



Valuable Equipment from Other Vendors

- ISIS phantom
- manufactured by TGM[2]
- geometric accuracy of CT/MR/PET-CT systems
- accuracy of MP fusion
- constancy of CT number-electron density relationship
- 4D CT and CK tracking?



Valuable Equipment from Other Vendors

- SRS Profiler
- manufactured by Sun Nuclear Corp.
- Uses MapCheck software
- Constancy of flatness symmetry, output calibration, laser-radiation field coincidence, commissioning???
- SNC cylindrical diode array being evaluated for CK patient-specific dosimetry

Coming soon…

Task Group 135
QA for Robotic Radiosurgery

Sonja Dieterich, Chair

estimated completion: 12/31/09

Conclusion

- The CyberKnife has unique features that affect site planning, acceptance testing, commissioning, and ongoing quality assurance.
- Specialized equipment is needed for some measurements.
- Adequate time is needed for physics work in order to assure that your system functions safely and accurately.
- Independent verification of absolute dose accuracy and relative dose distribution is essential before treating patients.

Epilogue: Don't Get Discouraged

- Gaining an in-depth understanding of – and confidence in - the unique CyberKnife hardware and software is necessary, challenging, rewarding, and fun.
- Investing time in site planning, commissioning, and clinical implementation is necessary, challenging, rewarding, and fun.
- When the novelty of the new technology begins to wear off after a year or two, the clinical outcomes you will see will keep the excitement going and going and going…..