Clinical Applications of Surface Imaging

Frameless (Maskless, Bite-blockless) Intracranial Radiosurgery

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Disclosure

- Work partially supported by VisionRT

Objectives

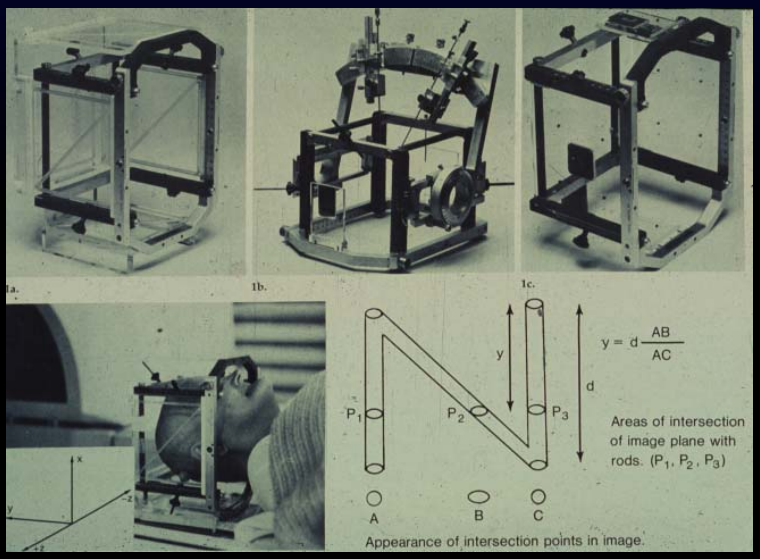
- Background of frameless intracranial stereotactic radiosurgery
- UCSD SRS/SRT procedure
- Clinical Results
- Summary

Background :
Intracranial Stereotactic Radiosurgery

- Total prescribed doses : order of **10 - 50 Gy**
- Planning targets are small : from **1 to 35 cm^3**.
- Positional and numerical accuracy in dose delivery are **±1mm** and **±5%**, respectively.
- Accurate determination of the target volume and its location with stereotactic techniques.
- Conformal Dose distributions : **sharp dose fall-off** outside the target volume.
- Accurate knowledge of the total dose and **fractionation scheme** required for treatment of a particular disease.

Background :

SRS Frame and fiducial markers



Goals of frameless SRS/SRT

- Patient comfort
- Ease of treatment
- Similar or better accuracy of positioning
- Potential for hypofractionated treatments

Advanced Techniques

- IGRT techniques for accurate patient positioning / monitoring
  - Radiographic localization
  - Non-radiographic localization
- Better precision of hardware in treatment machine
  - High precision mechanics (Couch, Gantry, MLC etc.)
  - Full automatic 6DOF couch
  - Manual Head Adjuster for 3D rotation

Frameless (Maskless, Bite-blockless) SRS

- Real-time setup and monitoring
  - VisionRT surface imaging
- Immobilization approaches

Passive

Minimally Active

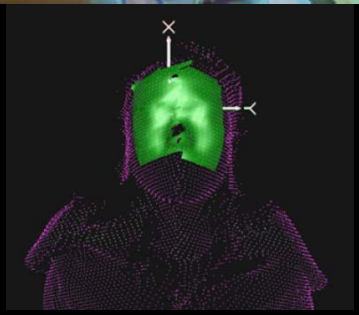
AlignRT System

- Stereo photography
  - 3 cameras & visible light projector
  - Reference image = Contours from DICOMRT, Previous AlignRT image

- Registration algorithm
  - Minimize distance between reference image and real-time surface
  - Rotations & translations

Initial System Testing

- Compare
  - AlignRT monitoring
  - Zmed monitoring
- Observe motion due to couch movements
  - Use calibration SRS phantom with ZMed
  - Use Rando head phantom with AlignRT



Cervino et al. Phys Med Biol. 2010

Initial System Testing

Results: Translations

Test no	Vertical motion (mm)	Long. motion (mm)	Lateral motion (mm)	Vert. difference (mm)	Long. difference (mm)	Lateral difference (mm)	Vector difference (mm)
1	−0.1	36	0.7	0.8	0.2	0.4	1.18
2	−20.7	36	0.5	0.2	0.2	0.6	1.00
3	−20.5	36	19.1	0.1	0.2	1.0	1.14
4	−20.7	36	−21.1	0.2	0.4	0.8	1.18
5	0.1	−0.1	−18.9	0.0	0.0	0.4	0.63
6	−0.1	−0.1	−19.5	0.0	0.1	0.4	0.71
7	−0.2	−0.3	0.6	0.2	0.1	0.3	0.77
8	0.1	−0.4	20.9	0.2	0.1	0.4	0.84
9	−20.7	36.7	21.1	0.1	0.2	0.6	0.95

Difference in motions detected by Zmed and AlignRT
(Average = 0.93mm)

Cervino et al. Phys Med Biol. 2010

Initial System Testing

Results: Rotations

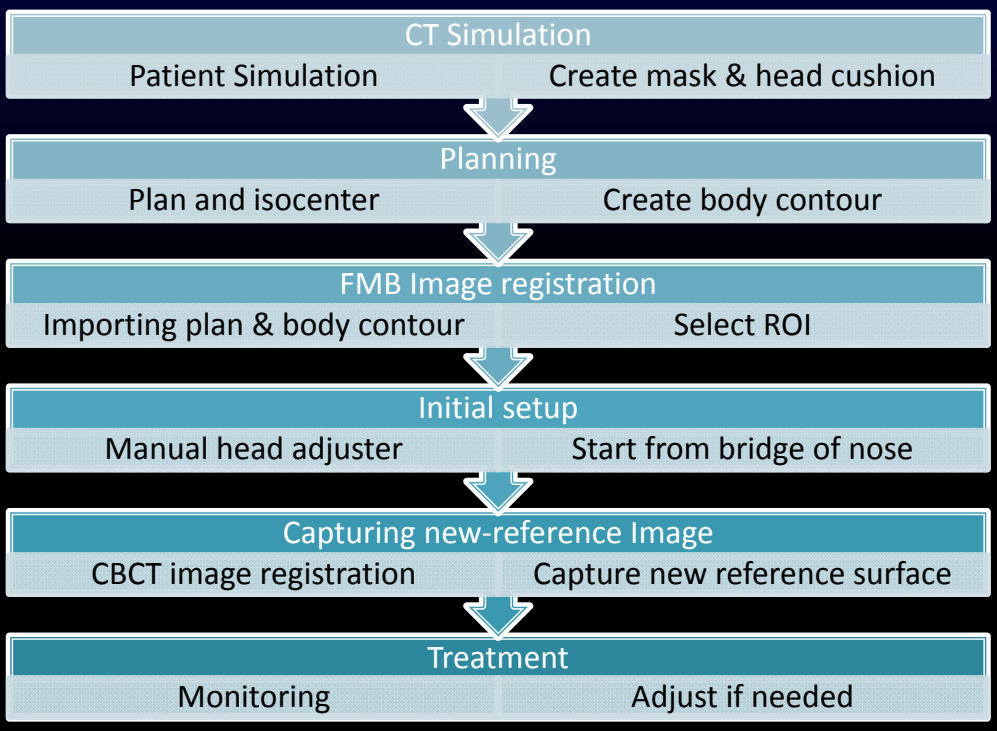
Couch angle	90 deg.	45 deg.	315 deg.	270 deg.
Vert. (mm)	0.4	0.2	0.2	0.4
Lat. (mm)	0.6	0.3	0.4	0.6
Lng. (mm)	0.8	0.8	0.3	0.1
Head yaw (°)	0.2	0.1	0.2	0.2
Head pitch (°)	0.1	0.0	0.3	0.7
Head roll (°)	1.0	0.3	0.1	0.3

Cervino et al. Phys Med Biol. 2010

Other publications

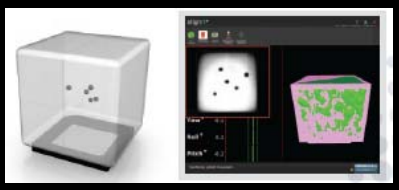
- Detecting shifts with a torso phantom
  - Sub-millimeter accuracy (0.75 mm) for the 3 translational degrees of freedom and less than 0.1° for each rotation
  - Bert et al. Med Phys. 2005
- Detecting shifts with a head phantom
  - 1D motion detection was 0.1 mm±0.1 mm, dependent on the CT skin definition with ~0.4 mm variation
  - Li et al. Med Phys. 2011

UCSD FMB Procedure



Equipment

- Varian TrueBeam
- Varian Eclipse V10
- AlignRT V 5.0.517 with HD Camera
- Manual Head Adjuster
- Daily QA phantom
- Monthly QA phantom



CT Simulation

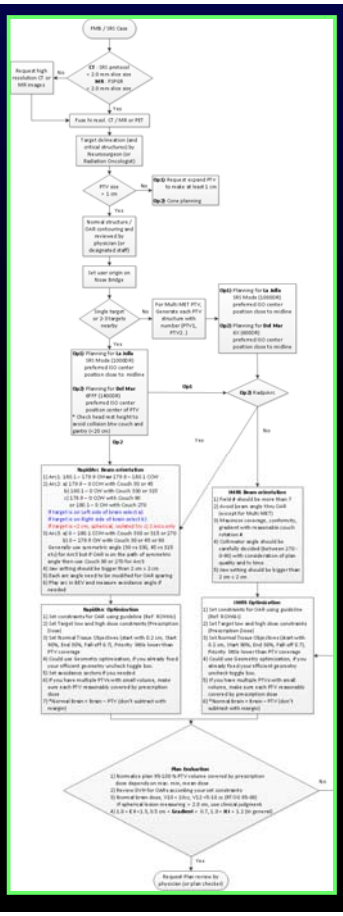
Not a real patient

Table 1. UCSD CT simulation policy for CNS

Tx Site / Technique	Mask Type	Immobilizers	Setup
Brain / FMB	Open Mask with S-frame	- "B" Headrest - Custom head cushion - Pad on the table - Kneefix w/ 1 insert - Hands on abd. with ring	Patient to keep their chin down Align at Midline on the Brain Scan Protocol: SRS (Slice size: 1.25 mm)

FMB Planning

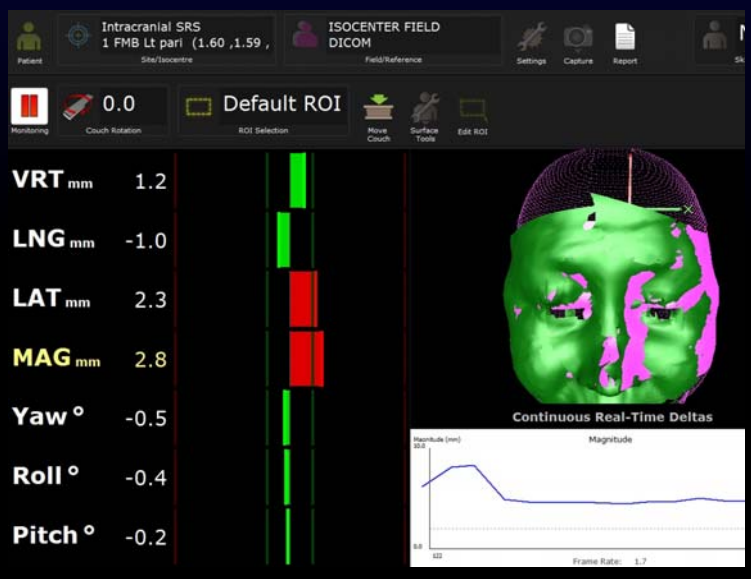
- Body contour
- Resolution of target structure
- Smaller calculation grid size
- Origin @ bridge of nose (shift information to isocenter)
- PTV margin info @ setup note
- Documenting AP/LAT BEV (Body contour) with graticule
- Plan evaluation



Treatment: Initial Positioning

Patient setup

Patient setup

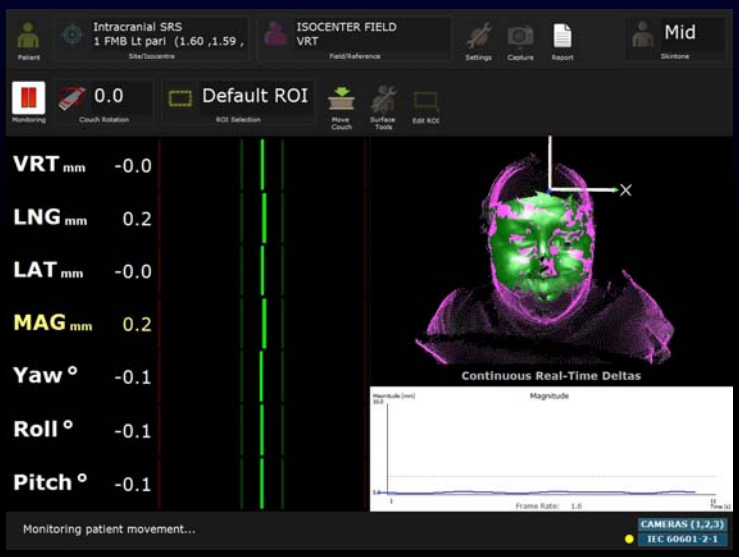


- Initial setup: moves from the bridge of nose with given shift numbers
- Two therapists: one looks after rotations another after shifts

Patient setup

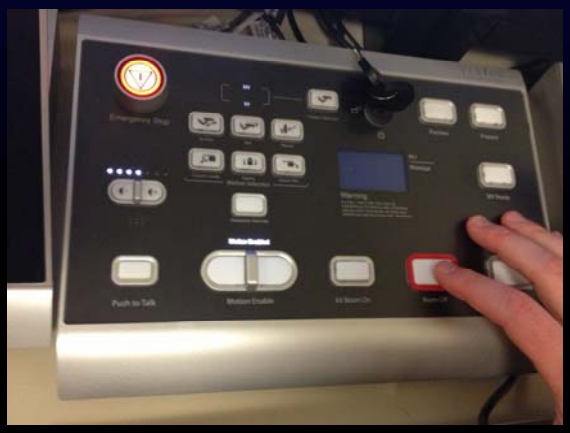
Target: < 0.5 mm, < 0.5 °

Capture new reference



- Co-registration to CBCT approved by a radiation oncologist
- New reference surface after CBCT-based shifts
- Expect small deviations

Treatment, Real time monitoring



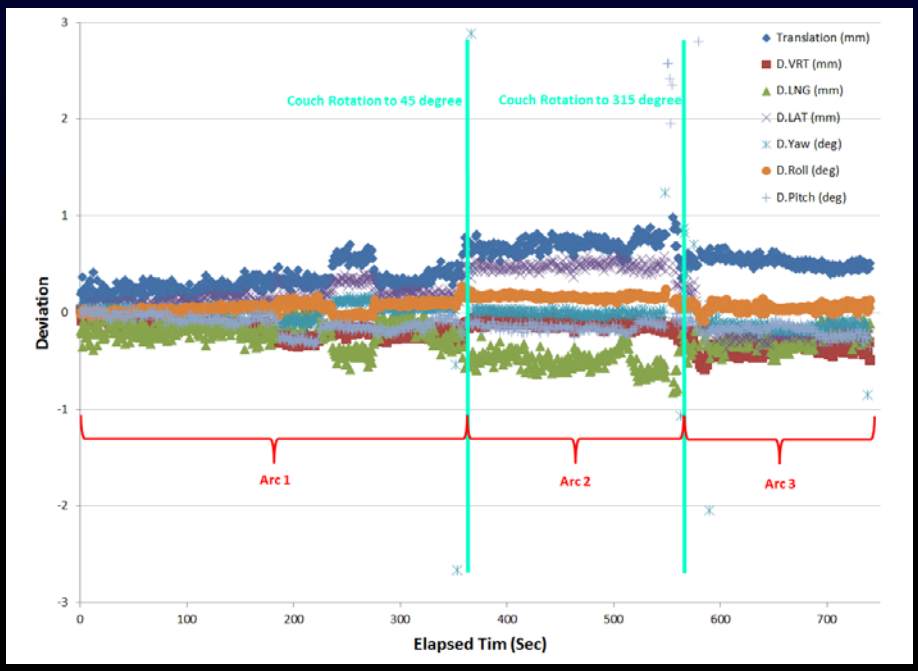
- Beam-off if out of tolerance (depends on setup margin)
- General Tolerance
  - Any translational < 1mm
  - Any rotations < 1°
  - 3D MAG < 1.0 mm

Treatment, Couch rotation

Treatment, Couch rotation

Example Case

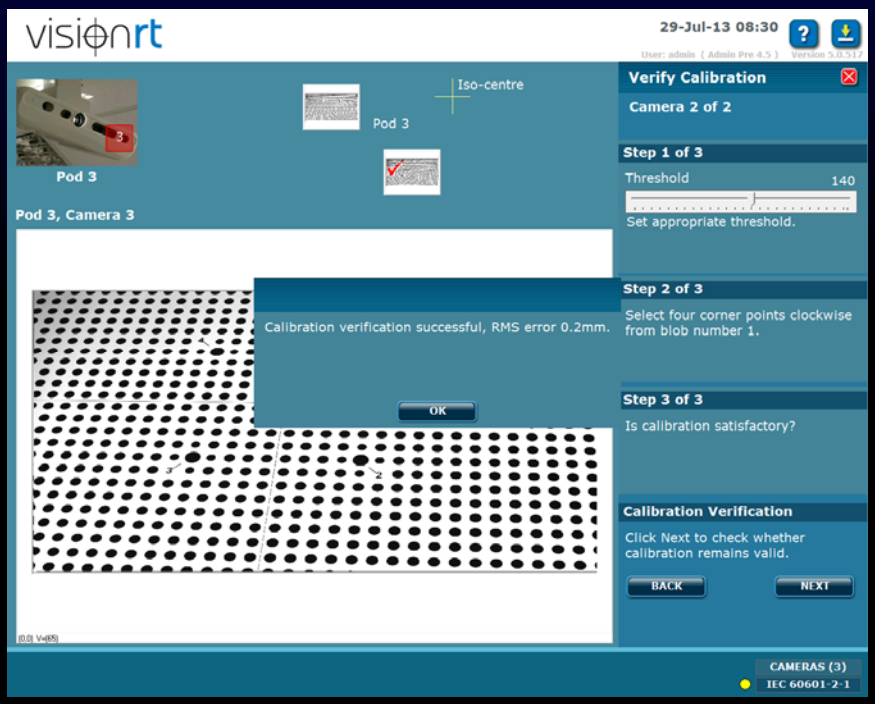
Example Case



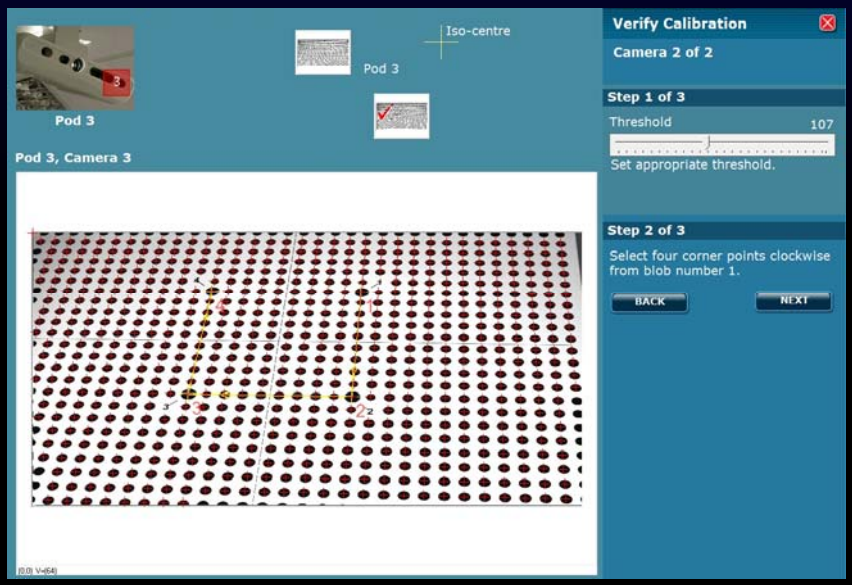
Daily QA, Cal. Board

- Board with distinct pattern
- 100 cm SSD, Align with cross-hair
- Verification of camera calibration

Daily QA, Cal. Board



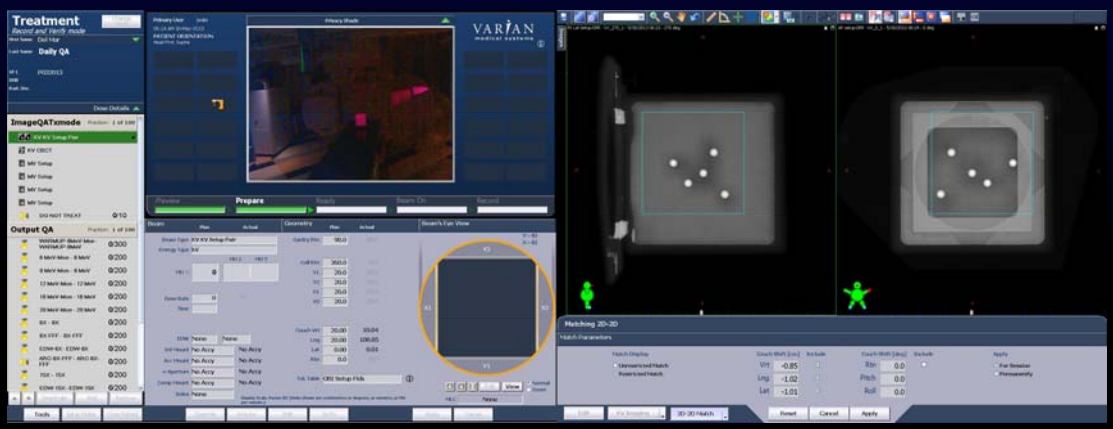
Daily QA,
Cal. Board – recalibration if needed



Daily QA, QA Phantom

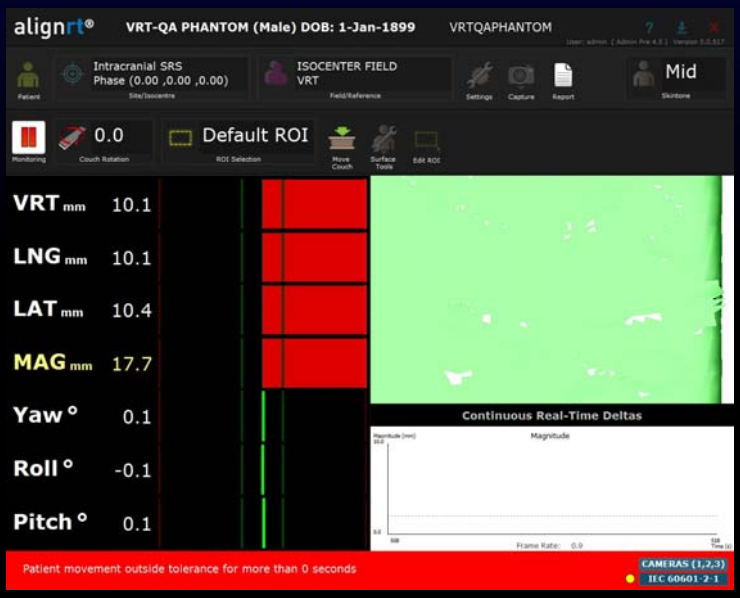
- Level and set to lasers
- Precisely setup with AlignRT
- Test plan with deliberate shift 1 cm in each direction
- Verify with kV/kV, CBCT and MV

Daily QA, QA phantom



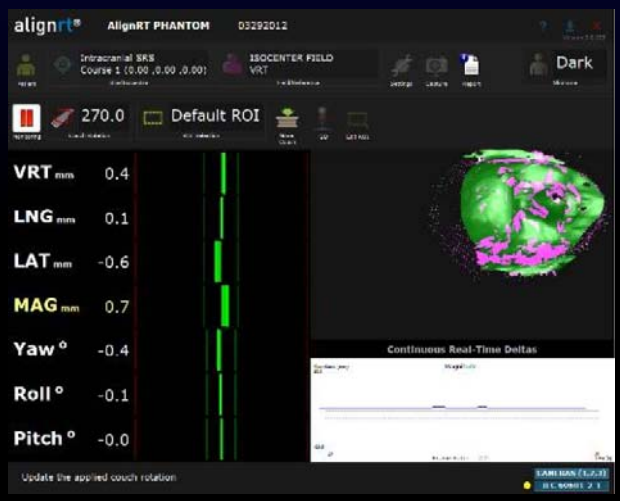
- Matching to fiducials has to show 10 mm shifts in each direction
- End-to-End test tolerance +/- 1.5 mm
- kV/kV + CBCT, move couch from CBCT, MV orthogonal pair

Daily QA, QA Phantom

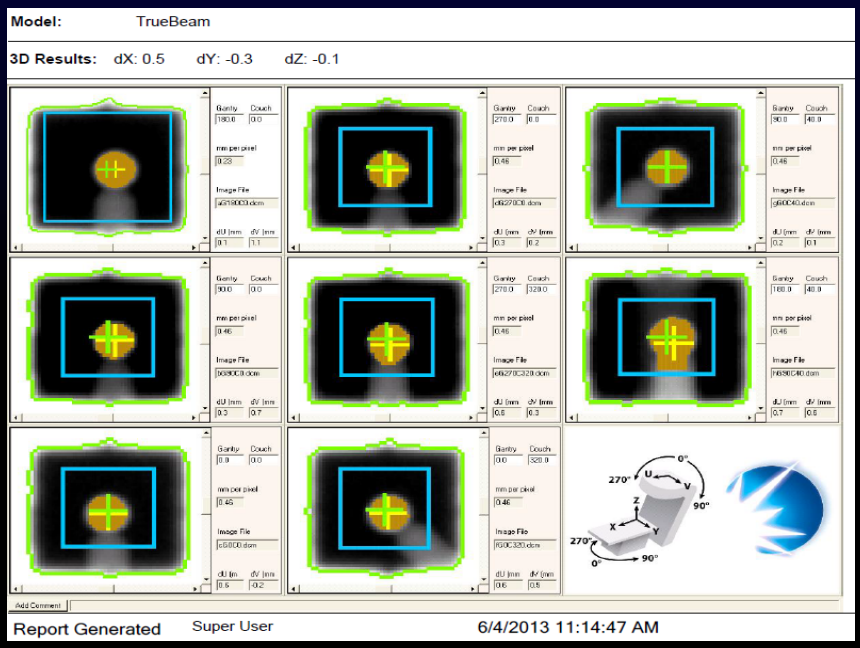


- After couch moves Align RT report required shifts
- Have to match 10 mm shifts made
- This completes the loop including shifts seen by Align RT

Monthly QA, Hidden target



Monthly QA, Hidden target



Tolerance < 1 mm

Clinical Results

- 44 patients
  - 115 intracranial metastases
- Median follow-up of 4.7 months
  - 1 year actuarial local control rate was 84%
    - 95% confidence interval: 69-99%

Pan et al. Neurosurgery, 2012, 71 (4) : 844-852

Clinical Results

Comparison of local control & survival for retrospective studies of brain metastases treated with radiosurgery

Treatment System	Pts (n)	Actuarial 1y LC* (%)	Actuarial 1y Survival (%)
Frame-based linac	80	89	33
Frame-based Gamma Knife	205	71	37††
Frameless linac	53	80	44
Frameless linac	65	76	40
Frameless, surface-imaging guided linac	**44**	**84**	**37**

*LC: local control; † -: not reported; ††estimated from Kaplan-Meier curve

Summary

- Frameless SRS treatments with surface imaging are able to achieve the required level of accuracy
- Accuracy and precision of the system could be improved and verified with updated hardware (HD camera, 6D couch etc.) and an optimized QA program
- UCSD has established FMB intracranial stereotactic radiosurgery as its sole SRS/SRT technique

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