

# Planar radiographic imaging for prostate fiducial tracking

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# Disclosure

- Research support from Varian Medical Systems

# Scope

Survey clinical methods of intrafraction prostate motion monitoring using kV and MV planar imaging of implanted markers

# Rationale

- Clinical goals of high-precision RT, esp. hypofractionated
- Knowledge of intrafraction motion from beacon studies

Table 2. Patient-Specific Percentage of Over-3 mm Time Using NI Strategy With Different Setup Delays.

Setup Delay (sec)		30	60	120	180
Percentage of overthreshold time, mean (standard deviation), max, (%)	IMRT	6.9 (7.1), 33.1	8.2 (8.5), 44.0	9.3 (10.4), 66.3	19.0 (22.3), 70.0
	VMAT	7.1 (7.2), 31.1	8.5 (8.7), 42.9	11.3 (12.0), 66.8	17.0 (19.3), 77.3

Abbreviations: IMRT, intensity-modulated radiation therapy; NI, no intervention; VMAT, volumetric-modulated arc therapy.

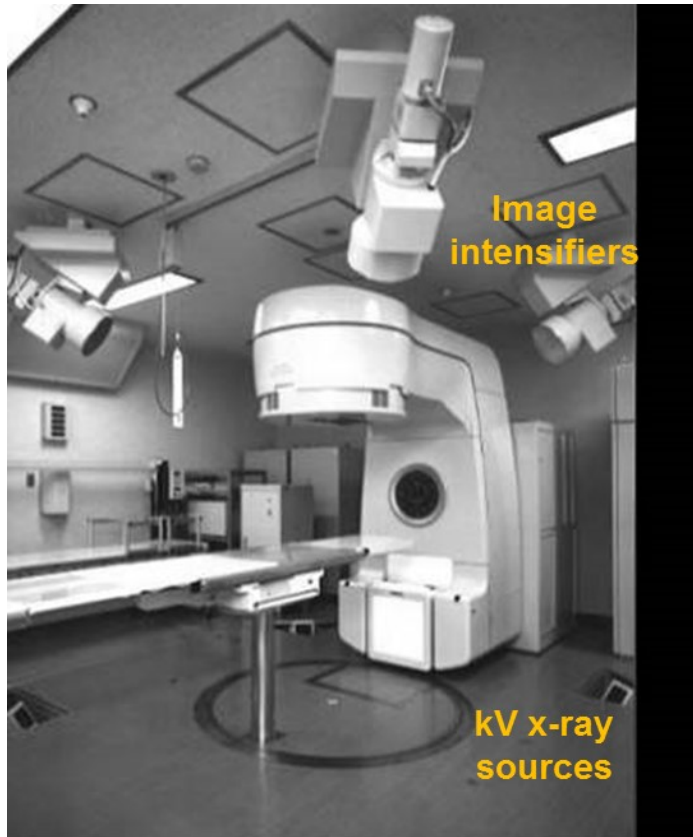
(Ma et al TCRT 2019; 18:1)

# Outline

- Room-mounted systems
- Gantry-mounted systems
- Intrafraction acquisition modes
- Strategies for obtaining 3D information
- Quality assurance

# Room-mounted imaging systems

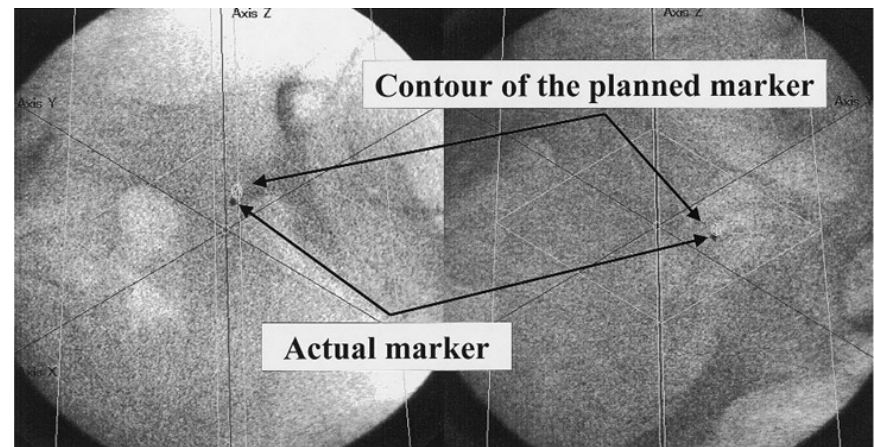
# Real-Time Tumor-Tracking (RTRT) system



Shirato et al, UROBP 2000; 48:1187

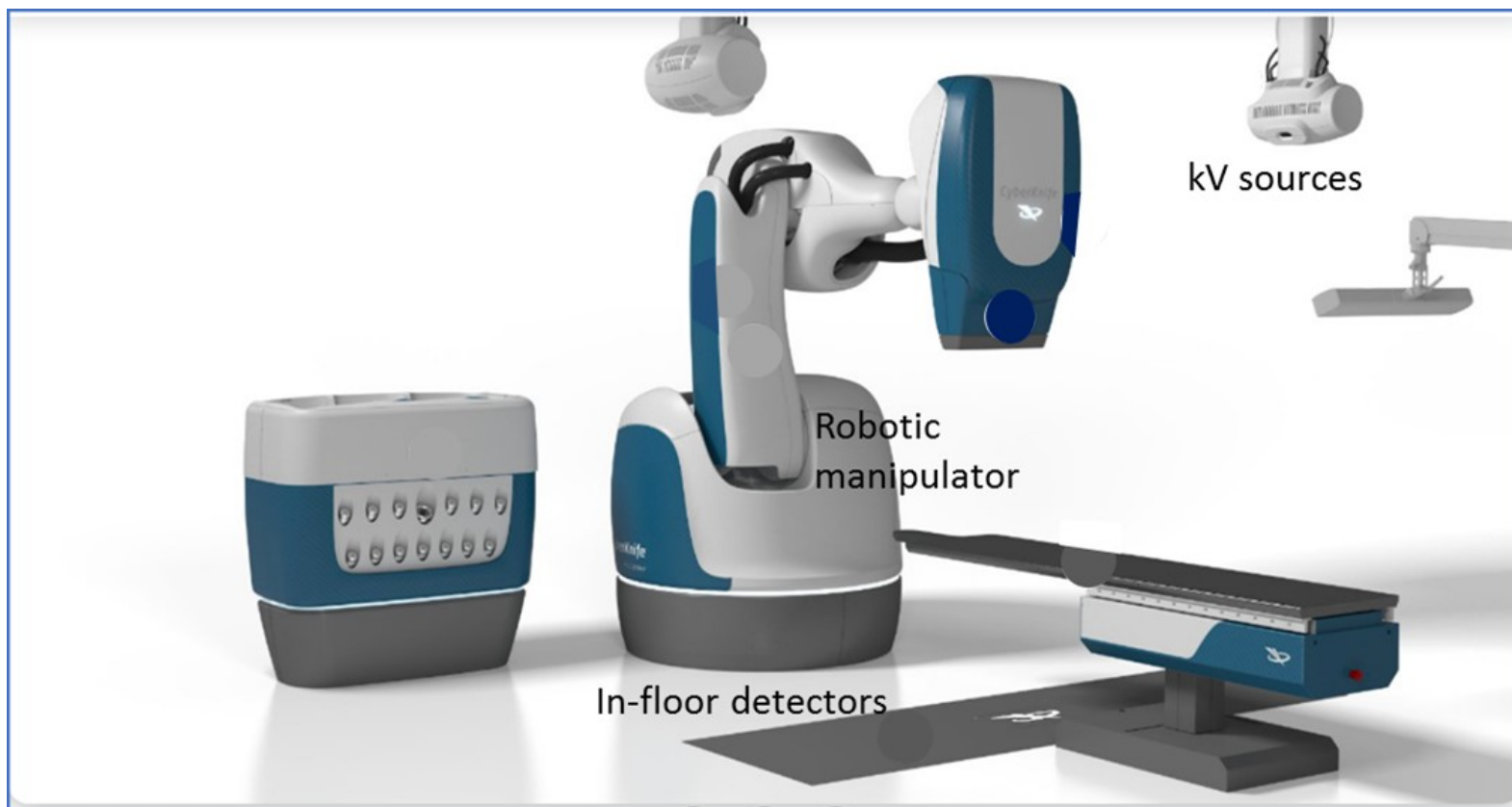
Shimizu et al Radiat Oncol 2014; 9:118

- 110-patient study prostate IMRT
- Mean # kV localizations: 7.5/fx
- Median couch corrections: 19/30fx



Shimizu et al, UROBP 2000; 48:1591

# CyberKnife Robotic SRS/SBRT



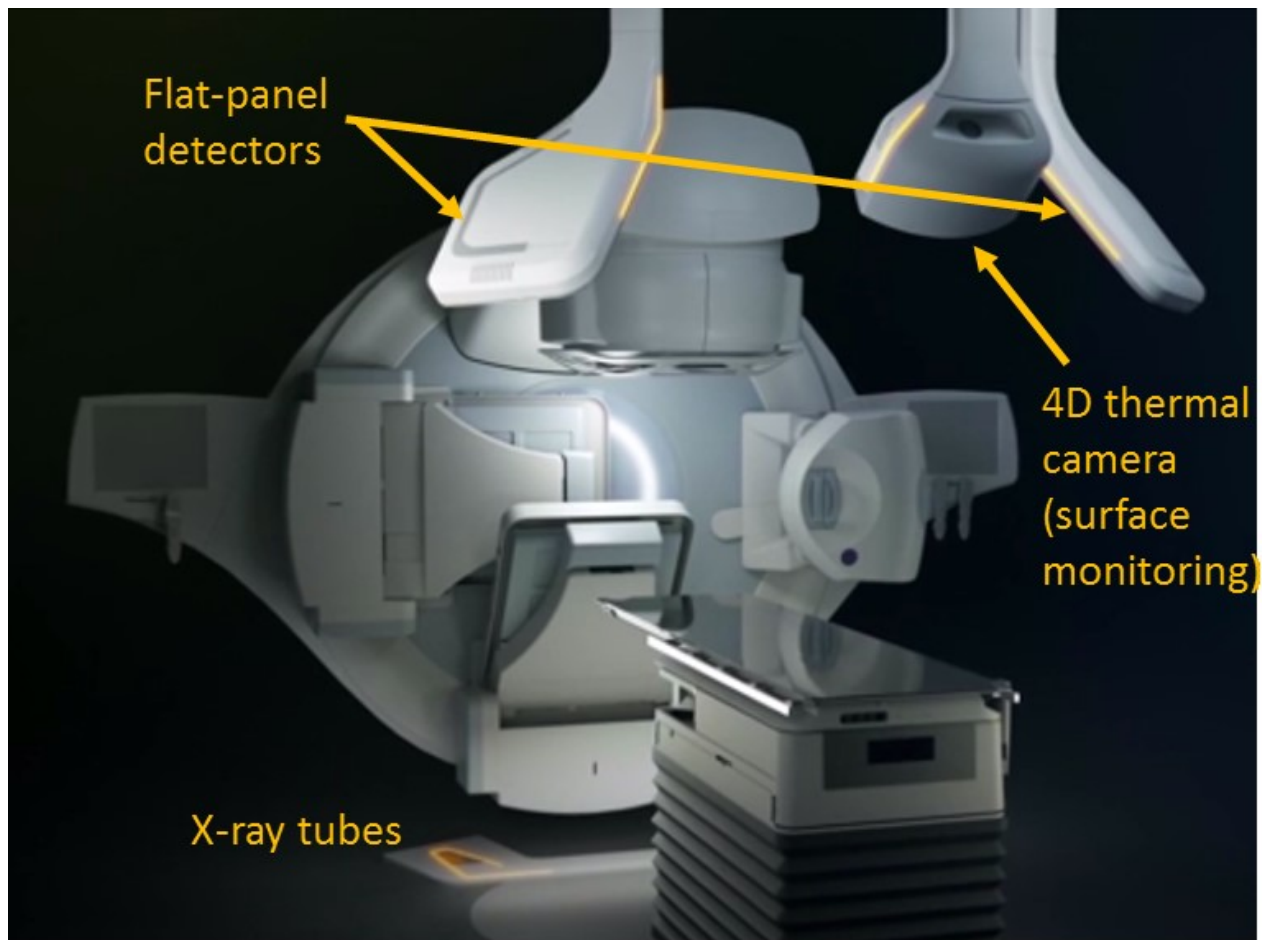
Prostate SBRT trials:

- King et al IJROBP 2009; 73:1043
- Friedland et al TCRT 2009; 8:387

**([www.accuray.com/cyberknife](http://www.accuray.com/cyberknife))**



# ExacTrac X-ray

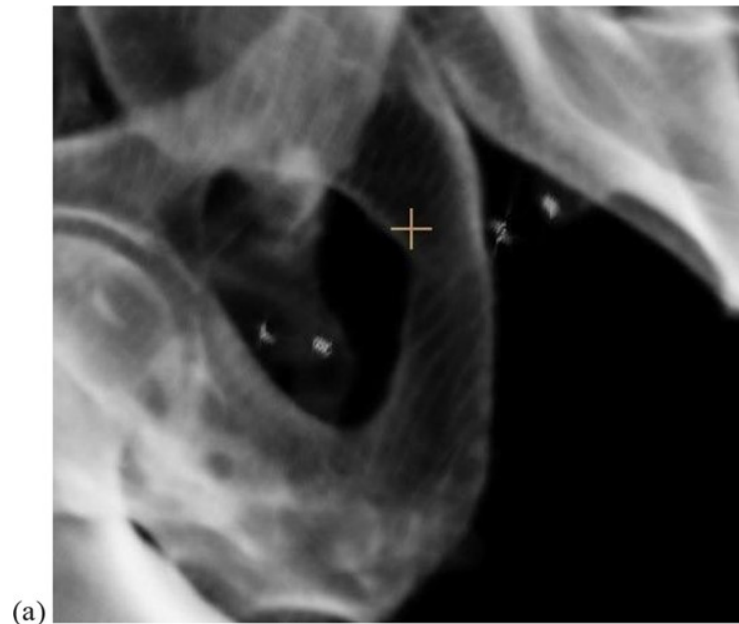


(Brainlab.com)

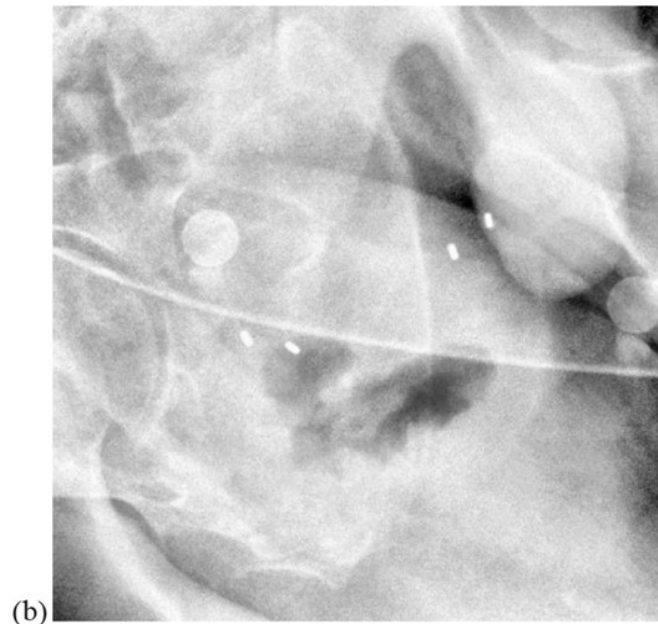
# Study of ExacTrac X-ray 6D IGRT setup uncertainty for marker-based prostate IMRT treatment

- 43 patients, 1200 fx, 3500 corrections
- Visicoil or cylindrical markers
- Average 3 corrections/fx

DRR



Setup kV radiograph



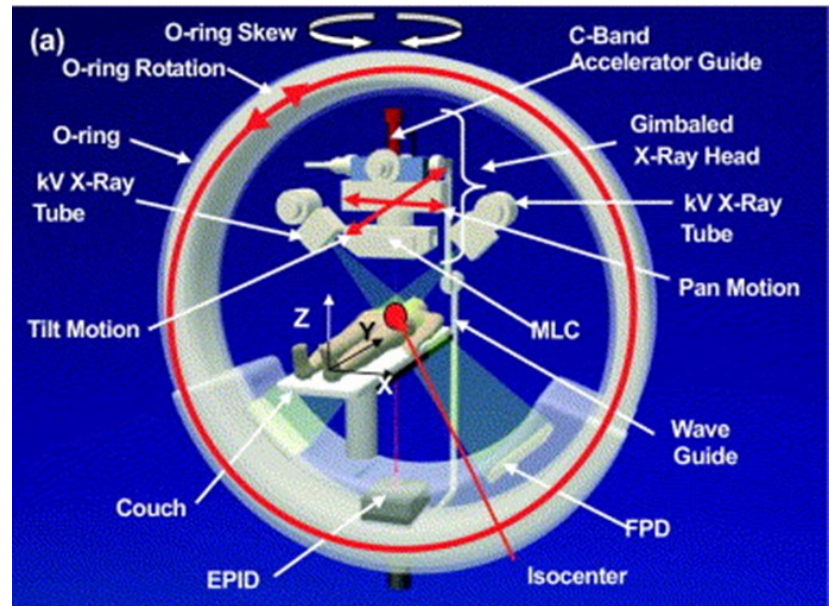
(Shi et al JACMP 2012; 13: 35)

# Gantry-mounted imaging systems

# Vero System

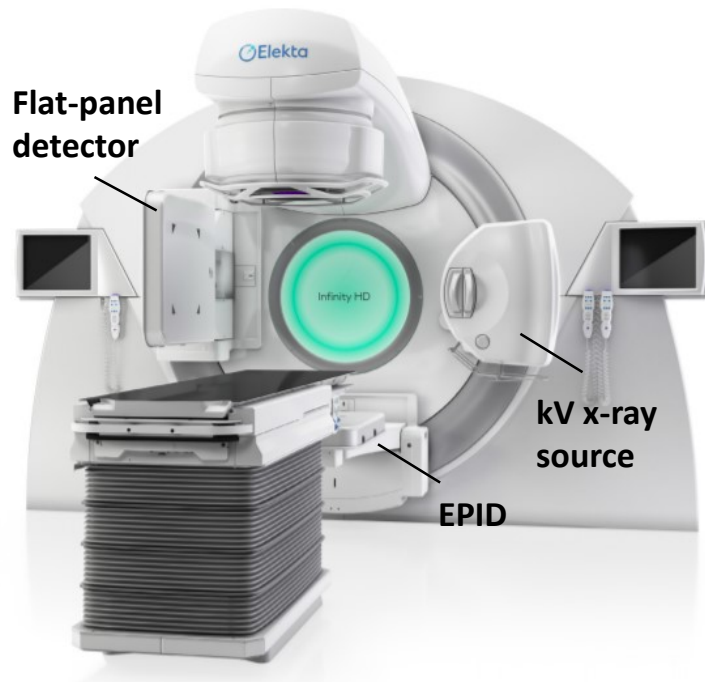


[www.Brainlab.com](http://www.Brainlab.com)



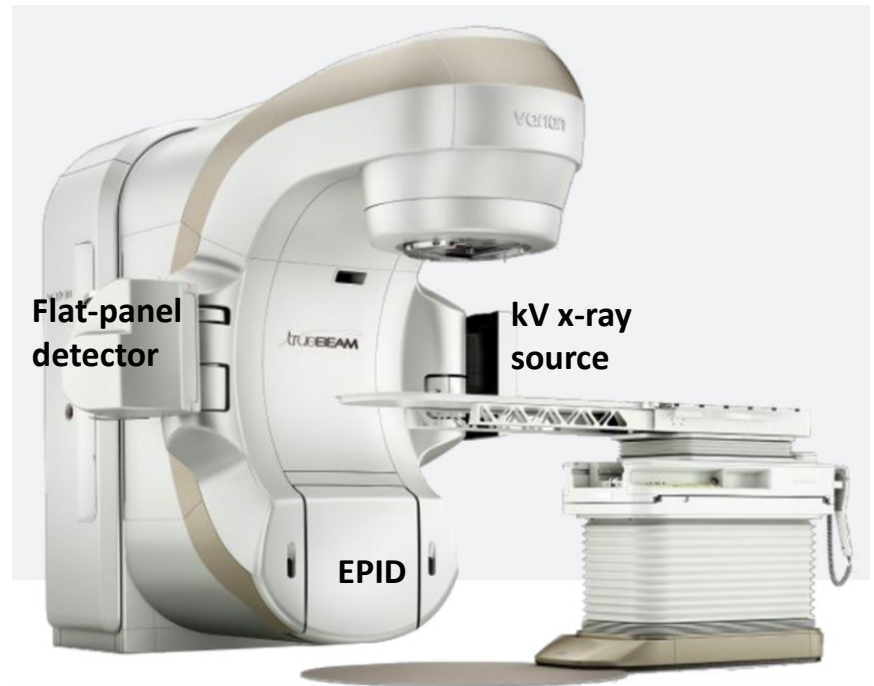
Kamino et al UROBP 2006; 66:271

Elekta Infinity

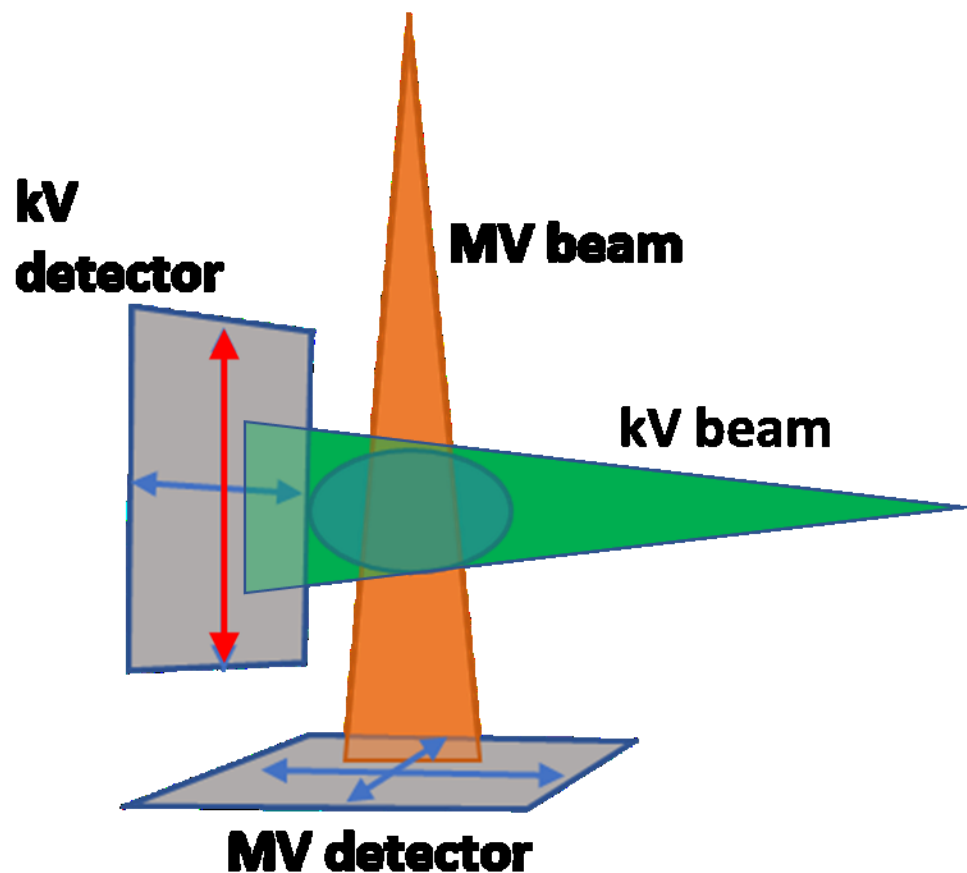


(elekta.com)

Varian TrueBeam



(varian.com)



Considerations  
in localization  
with gantry-  
mounted  
planar images

# Intrafraction acquisition modes

# Intrafraction acquisition

## Snapshot (Ad-hoc imaging):

- Interrupt beam, acquire/correct, resume

## Fluoroscopic

- Continuous kV, ~3-30 Hz
- Imaging dose a consideration, hybrid mitigation methods

## Triggered kV

- Trigger on time, MU, gantry angle, respiratory gating
- $\leq 0.5$  Hz



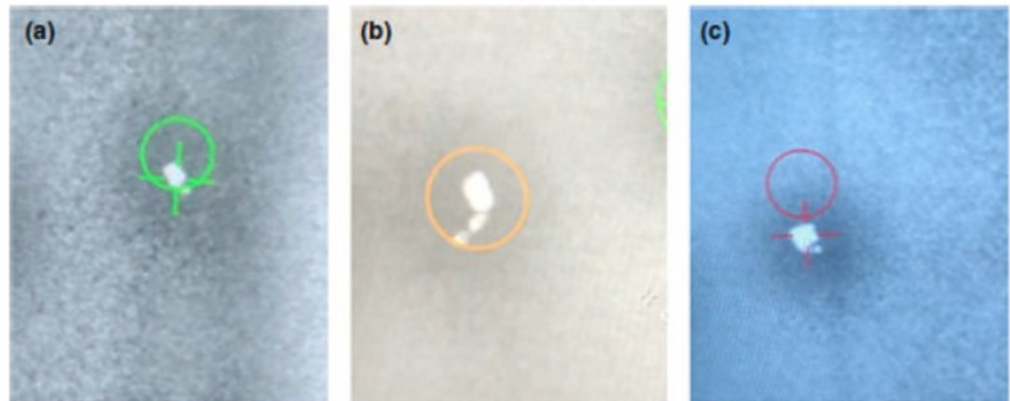
# Intrafraction Motion Review (IMR, Varian Truebeam v2.5+)

## Auto-detection of markers:

Circle = planned marker position + tolerance

Crosshairs = detected marker

- Green = within tolerance
- Yellow = marker not detected
- Red = outside tolerance



(Korpics et al JACMP 21:3:184)

# Strategies for obtaining 3D information (1)

Kilovoltage intrafraction monitoring (KIM)

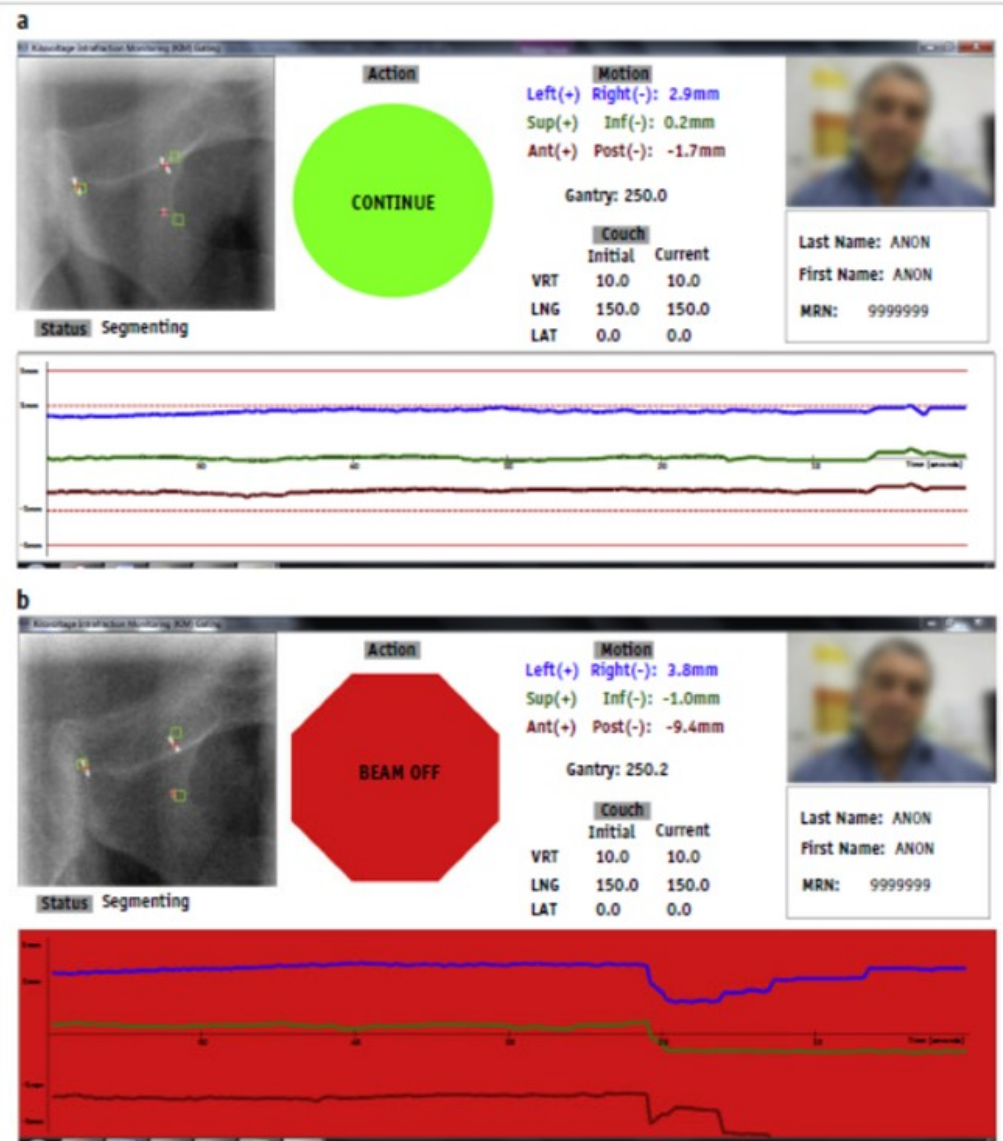
# Kilovoltage intrafraction monitoring (KIM)

KIM-guided gated RT in prostate:

- 1) kV fluoroscopy during MV treatment
- 2) Auto-detection of markers in 2D images
- 3) 2D-to-3D reconstruction from model of estim. motion correlations
- 4) Display of real-time positions

Example at right:

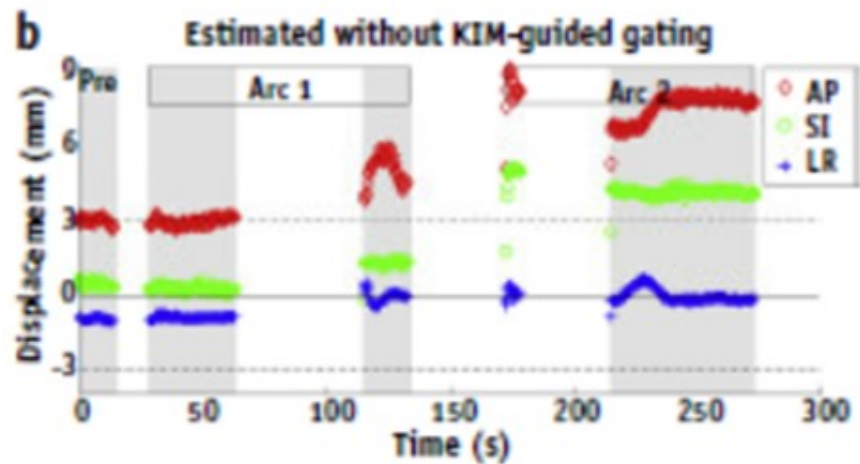
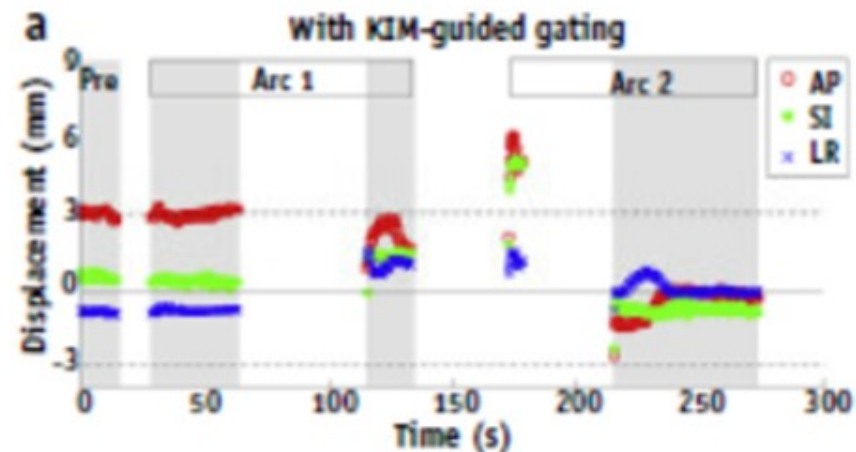
- (a) Motion within tolerance
- (b) Outside tolerance: needs couch shift



(Keall et al IJROBP 2016; 94:1015)

# KIM-guided gating example

- (a) With gating: Couch corrections at 60s and 170s
- (b) Without gating (estimate)



(Keall et al IJROBP 2016; 94:1015)

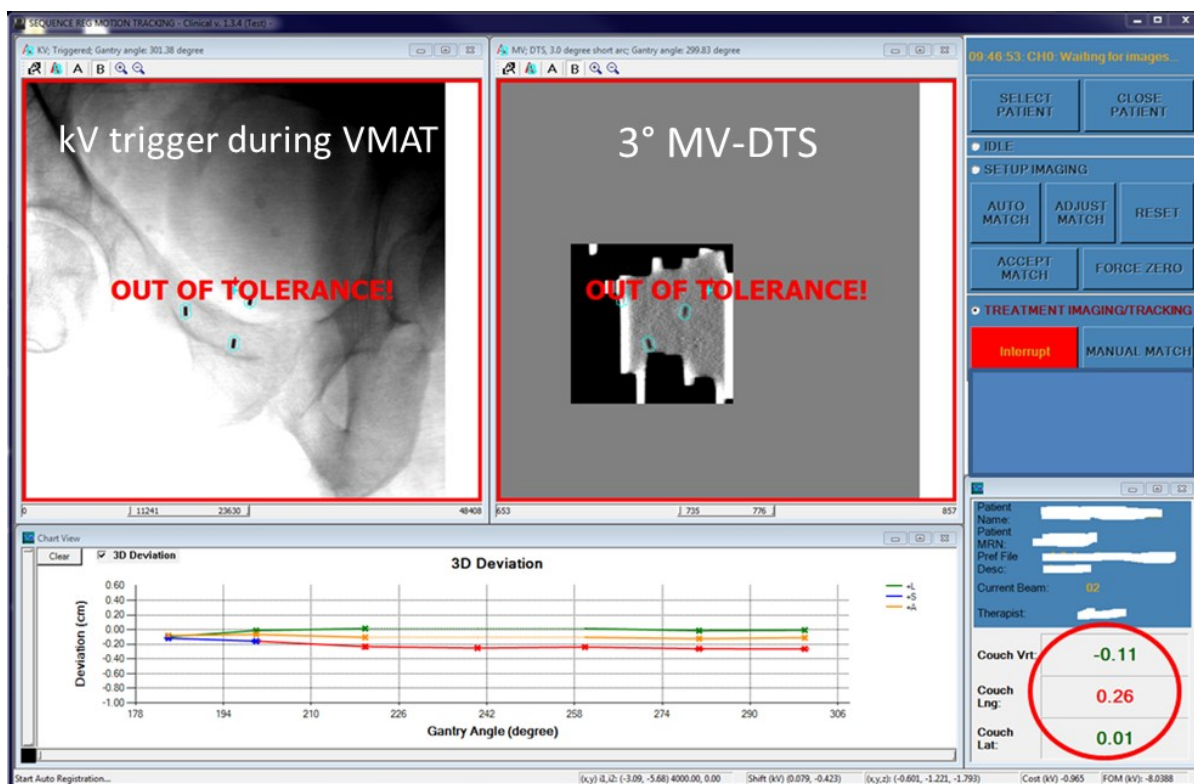
# Strategies for obtaining 3D information (2)

MV/kV Intratreatment monitoring of Prostate SBRT

# MV/kV clinical process – VMAT

Hunt et al. J Appl Clin Med Phys 2016;17:473

- Triggered kV + MV short-arc digital tomosynthesis @ 20° intervals
- Audio/visual alert if 2 mm tolerance is exceeded
- Manual beam interruption and correction of position if needed
- Modification of control-point sequence to increase fiducial visibility



# Quality Assurance (1/3)

Gantry-mounted MV & kV systems

- AAPM TG-104, TG-142

Gantry- & room-mounted MV & kV systems

- AAPM MPPG 2.a

Robotic radiosurgery

- AAPM TG-135

# Quality Assurance (2/3)

KIM-specific (Ng et al Med Phys 2014; 41:111712)

- 1) Stationary localization accuracy
- 2) Dynamic localization
- 3) Treatment interruption
- 4) Latency measurement
- 5) Clinical conditions

Tests 1-4: Anthro phantom + markers, 3D motion platform, prostate motion trajectories

Test 5: Comparison to MV/kV triangulation from RT



# Quality Assurance (3/3)

MV/kV-specific (Hunt et al J Appl Clin Med Phys 2016;17:473)

- 1) Stationary localization accuracy
- 2) Dynamic localization
- 3) Clinical conditions

Test methods:

- 1) Anthro phantom + markers, scripted VMAT + MV/kV image control points (Developer Mode, TrueBeam)
- 2) Same as Test 1 + scripted couch motion w/ clinical prostate trajectory
- 3) Patient study (n=3), VMAT+MV/kV, comparison to manual localization