New insights in IGRT for prostate cancer

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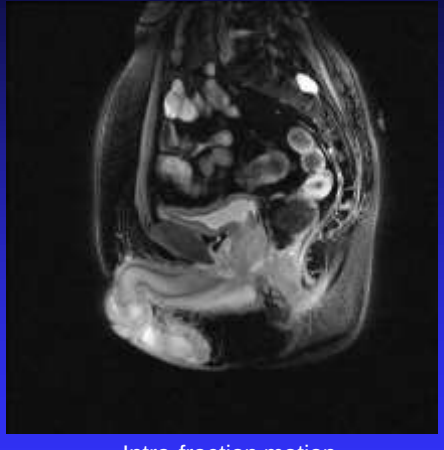
Prostate and bladder motion



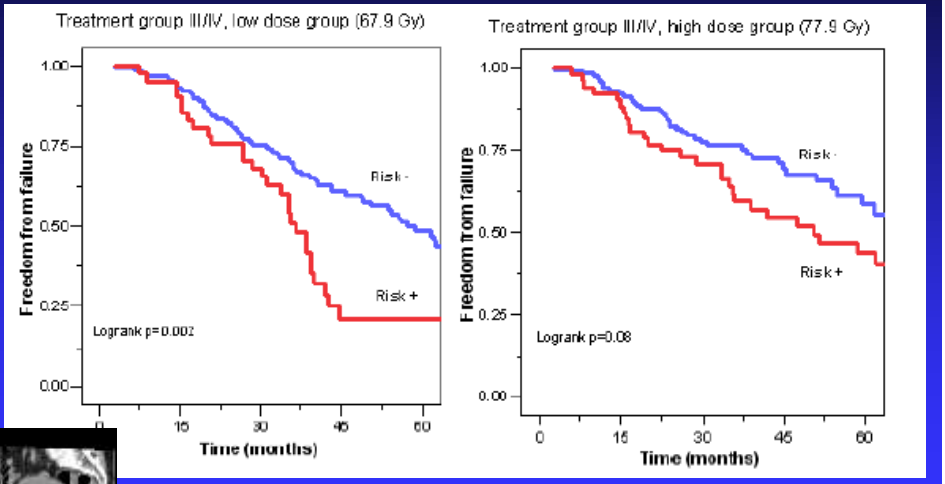
Intra-fraction motion
Scan time: 1 hour

Inter-fraction motion
Scan time: days

Courtesy of Jaffray and Ghilezhan
(WBH, Royal Oak, MI)

Motion counts? Prostate trial data (1996)

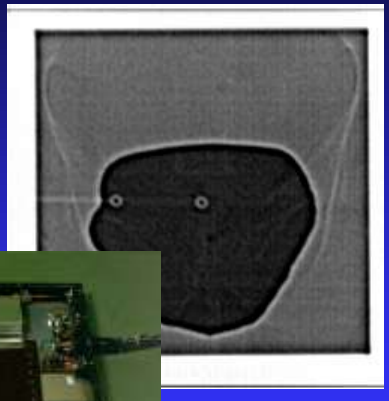
N=185 (42 risk+) N=168 (52 risk+)



Risk+: initial full rectum, later diarrhea

Heemsbergen et al, IJROBP 2007

My first task as a hospital physicist: develop a megavoltage detector: image guidance 'avant la lettre'



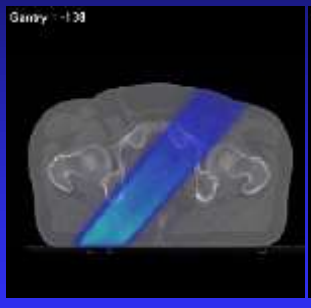
With Harm Meertens, Joost Weeda, Jan de Gans, Albert van Dalen

EPID dosimetry QA to catch gross errors: currently used for all curative patients at NKI

EPID movie

-140° 140°

Reconstructed EPID dose (VMAT case)



per frame

cumulative

Precision: within few %, enough to catch gross errors

Mans et al, 2010

Gross errors detected in NKI

TABLE I. Errors detected by means of EPID dosimetry from the clinical introduction to July 2009, grouped by (a) treatment site and (b) error type.

(a) Site	Clinical introduction	No. of patients	No. of errors
Prostate	02–2005	1018	2
Rectum	07–2006	602	4
Head-and-neck	06–2007	543	4
Breast	01–2008	1319	2
Lung	01–2008	454	2
Others	01–2008	401	3
	Total	4337	17

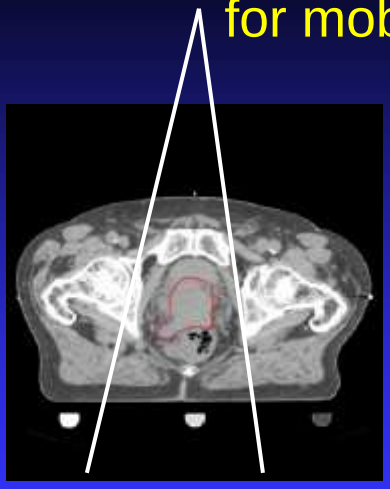
(b) Error type	No. of errors
Patient anatomy	7
Plan transfer	4
Suboptimally tuned TPS parameter	2
Accidental plan modification	2
Failed delivery	1
Dosimetrically undeliverable plan	1
Total	17

0.4% of treatments show a gross error (>10% dose)

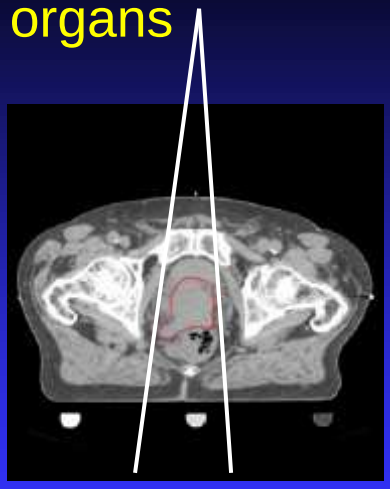
9 out of 17 errors would not have been detected pre-treatment !!

Mans et al, 2010

Soft tissue image guidance needed for mobile organs



1. Use large margins, irradiating too much healthy tissues



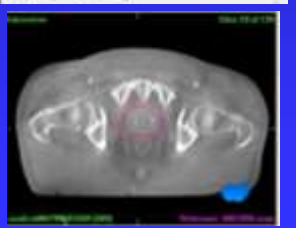
2. Use small margins, and risk missing the target

3) Use image guided radiotherapy

Cone beam CT works allright

2 min

3 cGy



Typical patient dose for prostate imaging:
3 cGy in isocenter, 3 cGy at the skin (with bowtie filter)

Number of image frames: 651
130 kV 32 mA 40 ms Half offset field of view

Are prostate markers perfect ?

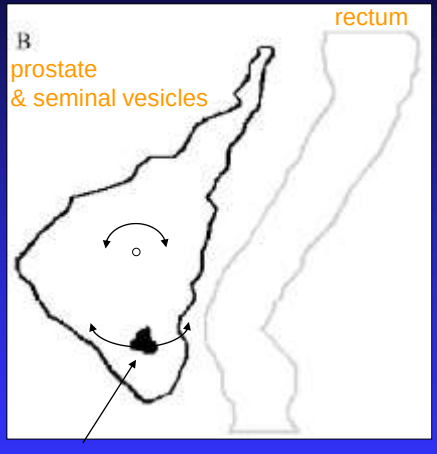
Apex | Base | Sem. Vesicles

→ +/-1 cm margin required

Best: combine markers with low dose CBCT

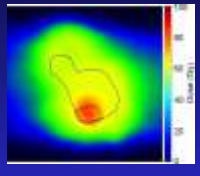
van der Wielen, IJROBP 2008
Smitsmans, IJROBP 2010

Different target regions in prostate cancer



dominant lesion (GTV)

Prostate & focal lesion: use markers



Prostate + SV: use CBCT
Setup on markers
Adaptive RT for large motion of SV

Prostate + SV + lymph nodes: use CBCT
Setup on bone
Measure prostate & SV location with markers
Adaptive RT for large motion of prostate or SV

Use of animation for validation of CBCT prostate registration (for Adaptive Radiotherapy)

Automatic bone match

First week scans (10 mm margin)

Automatic prostate match

help line (GTV+3.6 mm)

$\overline{T}$, R mean prostate position (7 mm margin)

Smitsmans *et al.*, Nijkamp et al, Nuver et al, IJROBP

Weekly scans to monitor ART treatment

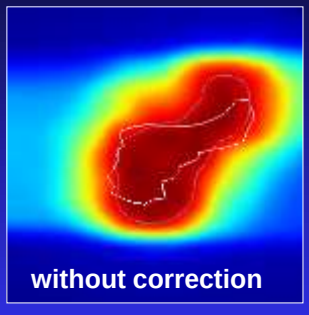
average CTV + 7 mm margin

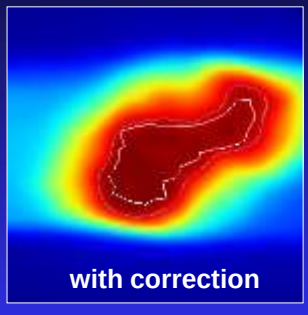
Is it possible to adapt without replanning

- Simple modification to RTPLAN
- Adjust collimator angle
  - IMRT
  - VMAT

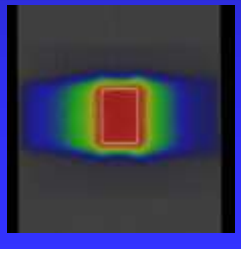
correct large rotations with collimator angle adjustments (IMRT & VMAT)

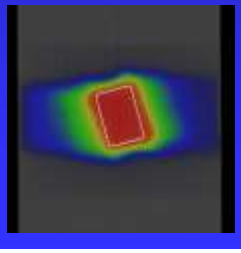
IMRT

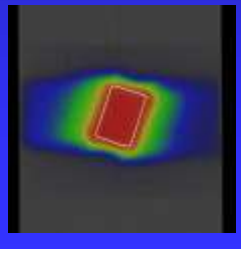




VMAT



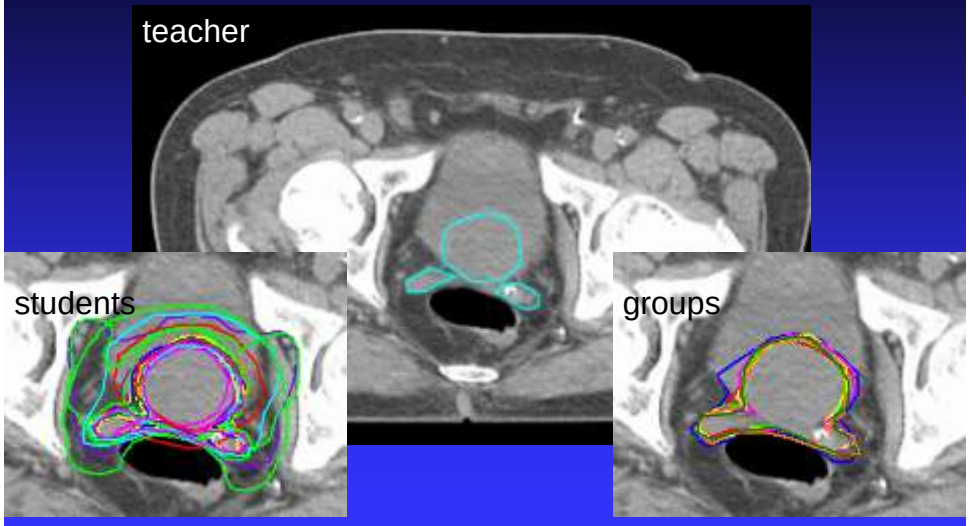




IGRT – The good, the bad, and the ugly

- Good: IGRT gives unprecedented precision of hitting any *clearly defined* point in the body
- Bad: This precision may give us overconfidence in the total chain accuracy: *tumors are rarely clear*
- Ugly: we may have to find this out from our clinical mistakes

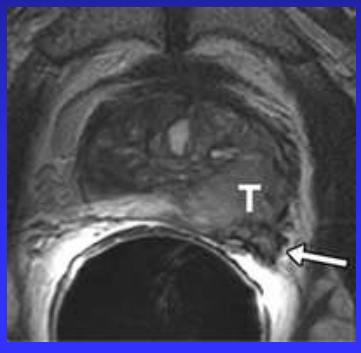
Effect of training and peer collaboration on target volume definition



Material collected during ESTRO teaching course on target volume delineation

Target definition

With smaller PTV margins, CTV definition becomes more critical



Make sure the CTV covers extra-prostatic spread

How well can we delineate prostate tumors?

UZ LEUVEN

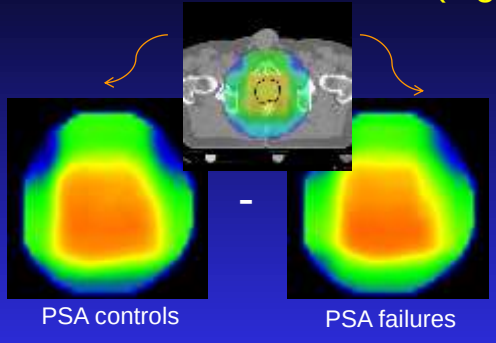
NETHERLANDS CANCER INSTITUTE

- Location of tumors and volume were validated with histopathology

But what about the CTV outside the prostate ?

- By definition disease between the GTV and the CTV cannot be detected
- Instead, the CTV is defined by means of margin expansion of the GTV and/or anatomical boundaries
- Very little is known of margins in relation to the CTV
  - Very little clinical / pathology data
  - Models to be developed

Estimate pattern of spread from response to incidental dose in clinical trial data (high risk prostate patients)



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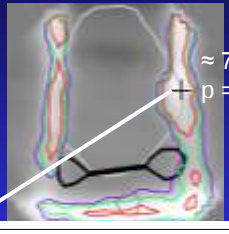
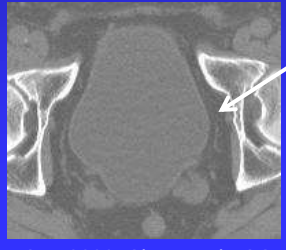
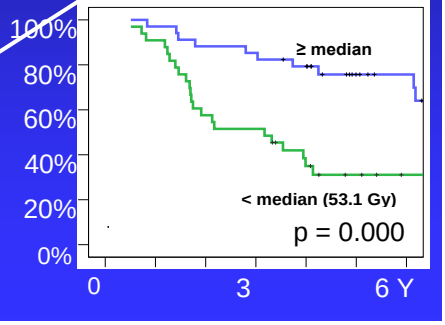
Average dose no failures – average dose failures







Witte et al, IJROBP2009; Chen et al, ICCR2010

Prostate margin with full IGRT
2.5 Σ + 0.7 σ

all in cm	systematic errors	squared	random errors	squared			
delineation	**0.25**	0.0625	**0**	0	Rasch et al, Sem. RO 2005		
organ motion	**0**	0	**0**	0	van Herk et al, IJROBP 1995		
setup error	**0**	0	**0**	0	Bel et al,IJROBP 1995		
intrafraction motion			**0.1**	0.01			
total error	**0.25**	0.06	**0.10**	0.01			
	times 2.5		**times 0.7**				
error margin	**0.63**		**0.07**				
total error margin		**0.70**					

Risky small margins

IJROBP 2009; 74: 388-391

CONFORMAL ARC RADIOTHERAPY FOR PROSTATE CANCER: INCREASED BIOCHEMICAL FAILURE IN PATIENTS WITH DISTENDED RECTUM ON THE PLANNING COMPUTED TOMOGRAM DESPITE IMAGE GUIDANCE BY IMPLANTED MARKERS

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238 T1-T3N0M0 patients

- Margins for
- Bony anatomy correction, 6 mm LR, 10 mm AP & CC (n = 213)
- Marker correction, 3 mm LR, 5 mm AP & CC (n = 25)

Freedom from biochemical failure

- Bony anatomy correction: 91 %
- Marker correction: 58%

Conclusions

- In spite of IGRT there are still uncertainties that need to be covered by safety margins
  - Margins for intrafraction motion can often be small
- Important uncertainties relate to imaging and biology that are not corrected by IGRT
  - For many sites we have indeed reached the limits of accuracy because IGRT is much better than the doctor's uncertainty
- Even though PTV margins are designed to cover geometrical uncertainties, they also cover microscopic disease. Reducing margins after introducing IGRT may therefore lead to poorer outcome and should be done with utmost care (especially in higher stage disease)
- Accurate radiotherapy requires teamwork between radiation oncologists, technologists, physicists and radiologists