Communication of Uncertainties in Radiation Therapy

Ben Mijnheer

NETHERLANDS CANCER INSTITUTE ANTONI VAN LEEUWENHOEK

Disclosure

The Netherlands Cancer Institute – Antoni van Leeuwenhoek Hospital has a research cooperation with Elekta concerning the development of cone-beam CT and EPID dosimetry software

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Learning objective: To describe methods of uncertainty communication and display

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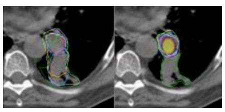
- in target volume delineation



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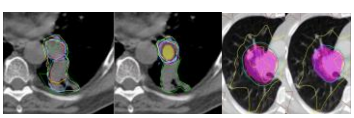
- in treatment planning



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Learning objective: To describe methods of uncertainty communication and display

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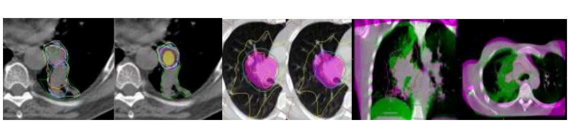

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Radiation oncologist to physicist: What dose will this patient receive?

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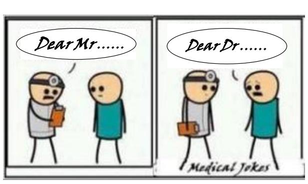

Radiation oncologist to physicist: What dose will this patient receive?

Physicist: 60 Gy with an uncertainty of ±3.5%

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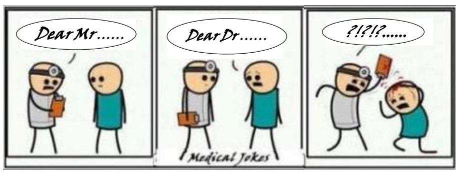

Radiation oncologist to physicist: What dose will this patient receive?

Physicist: 60 Gy with an uncertainty of ±3.5%

Radiation oncologist: I don't want any uncertainty, just 60 Gy to the target volume

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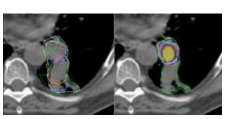
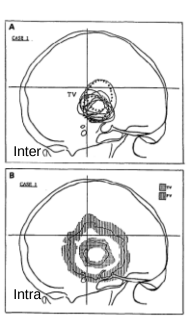
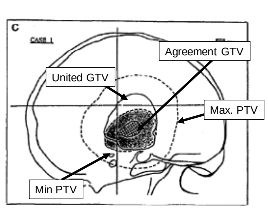
- in target volume delineation



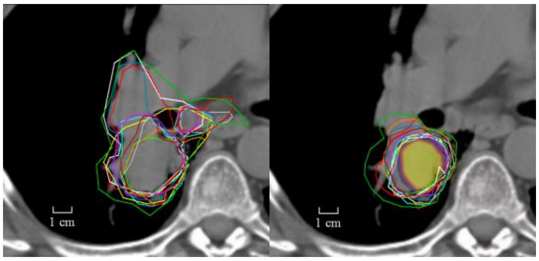
Intra- and inter-observer variability in contouring on CT





(Leunens *et al.*, Radiother Oncol 29: 169, 1993)

Delineation variation: CT versus CT + PET



CT (T_2N_2) — SD 7.5 mm

CT + PET (T_2N_1) — SD 3.5 mm

(Steenbakkers *et al*., IJROBP, 64, 435-448, 2006)

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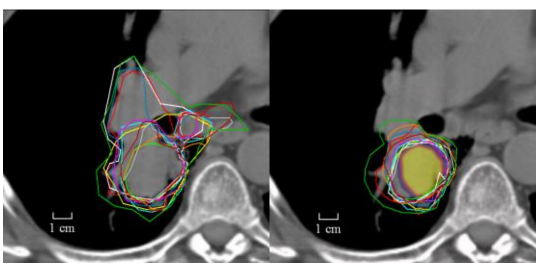

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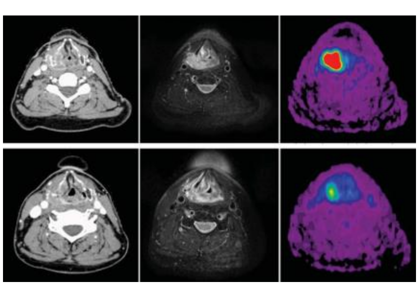
Delineation variation: CT versus MRI and PET

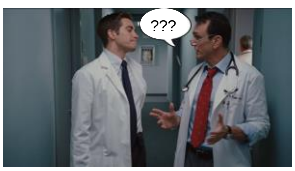


Delineation of a GTV can vary according to
the diagnostic modality (From ICRU Report 83)

What can be done to reduce target delineation variation?

- A correct identification of the macroscopic extension of a tumour requires a long training of a radiation oncologist, and an awareness of the specific abilities of a given imaging method

What can be done to reduce target delineation variation?



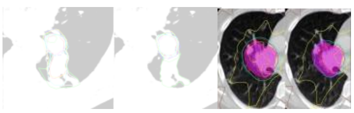
- A correct identification of the macroscopic extension of a tumour requires a long training of a radiation oncologist, and an awareness of the specific abilities of a given imaging method
- Image quality plays also an important role (slice thickness, patient motion during acquisition, equipment characteristics…)

What can be done to reduce target delineation variation?

- A correct identification of the macroscopic extension of a tumour requires a long training of a radiation oncologist, and an awareness of the specific abilities of a given imaging method
- Image quality plays also an important role (slice thickness, patient motion during acquisition, equipment characteristics…)
- Medical physicists and radiation oncologists should communicate about the possibilities and limitations of the various imaging tools available in their department

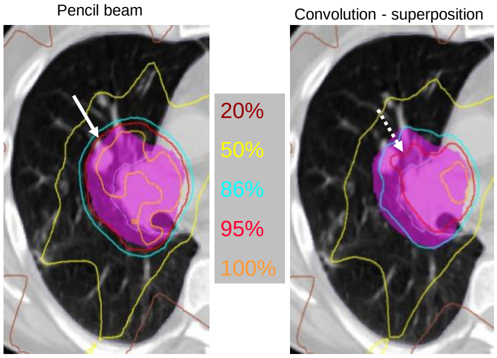
Communication of Uncertainties in Radiation Therapy

- in target volume delineation
- in treatment planning



Comparison of isodose distributions

Pencil beam Convolution - superposition



Clinical implementation of a more advanced dose calculation algorithm

- When introducing a more advanced (type b) dose calculation algorithm, e.g. convolution-superposition, instead of a (type a), e.g. pencil-beam algorithm, considerable lower dose in the PTV and a somewhat higher dose in most of the lung becomes visible for the same beam setup and number of MUs

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- Recalculate some old plans with the new algorithm for various approaches; e.g. coverage of the PTV by 95% (i.e. using larger field sizes) or by 90% at the lung side

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- Optimize plans for the same constraints on PTV and/or OAR (lung) using the new approaches

Clinical implementation of a more advanced dose calculation algorithm

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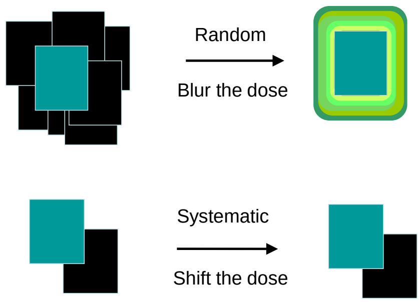
Discussion is needed between physicists and radiation oncologists to fully understand the differences and clinical consequences of the various approaches when introducing a more advanced dose calculation algorithm

Effect of type of geometric uncertainty on dose in the CTV



CTV to PTV margin recipes

To cover 99% of the CTV with 90% of the specified dose:

PTV margin = 2.0 Σ + 0.7 σ (Stroom *et al.*, 1999)

To cover the CTV for 90% of the patients within the 95% isodose surface:

PTV margin = 2.5 Σ + 0.7 σ (van Herk *et al.*, 2000)

Σ = SD of all systematic uncertainties combined quadratically

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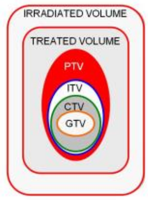

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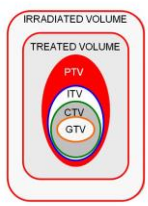

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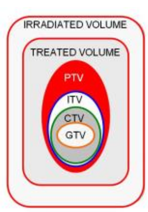
- When using a GTV-CTV margin, there still is a finite chance that some patients of a population of "identical" patients have a microscopic extension outside this margin



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- When [illegible] a fini[illegible] popu[illegible] a microscopic ex[illegible] outside this margin
- Reducing margins after introducing IGRT may therefore lead to poorer outcome and should be done with utmost care

Discuss margins with the whole team!

Probabilistic treatment planning

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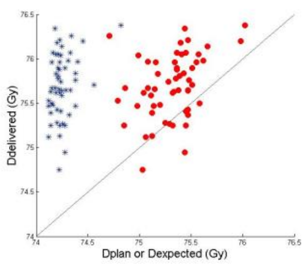
- A (Monte Carlo) mathematical model is often employed to simulate and evaluate many possible treatments

Results of probabilistic treatment planning of 56 prostate VMAT treatments



Stars: Minimum dose in PTV from TPS (Dplan)

Circles: Minimum dose in CTV) from probabilistic planning (Dexpected)

Delivered dose: Actual dose recalculated from CBCT data

Probabilistic treatment planning leads to a better prediction of the delivered dose compared to conventional planning

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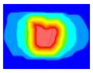

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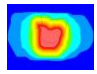

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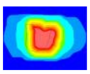
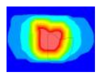
- *Patient-specific* evaluation is performed, but based on *population-based* Σ and σ values





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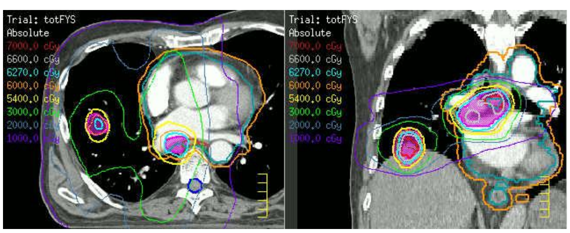
- Example:
  - lung cancer treatment using 24x 2.75Gy on the lymph nodes and 3x18Gy on the tumor in the second week
  - measure the first week with CBCT the change in relative position of the tumor and the lymph nodes
  - generate a worst case plan

Hybrid plan of a lung cancer treatment 3x18Gy on tumor and 24x2.75Gy on lymph nodes



No shift

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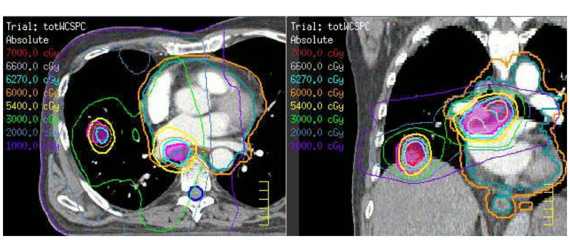

5 mm shift of tumor relative to lymph nodes

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  - measure the first week with CBCT the change in relative position of the tumor and the lymph nodes
  - generate a worst case plan
  - the dosimetrist and/or physicist should discuss with the radiation oncologist if the dose in the OAR(s) is still acceptable

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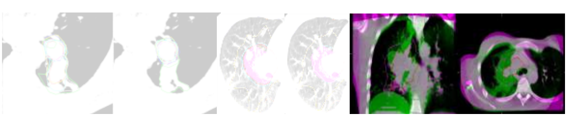
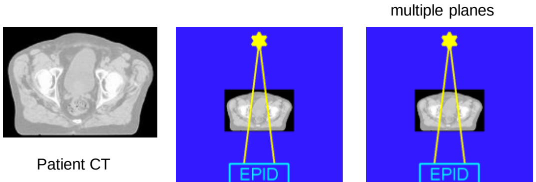


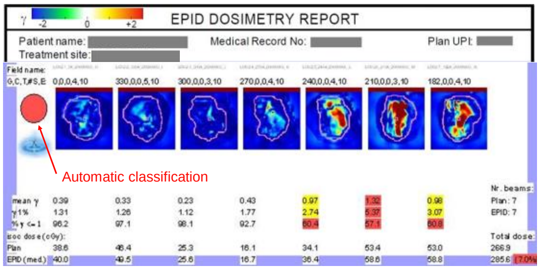
EPID-based *in vivo* 3D dose verification using a back-projection model

1) Calculate plan
2) Measure EPID dose
3) Reconstruct dose in multiple planes



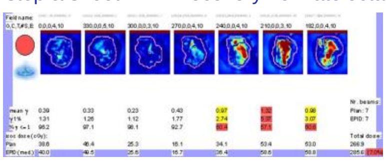
4) Compare planned and reconstructed 3D dose distribution

Lung step & shoot IMRT:



Fully automated dosimetry report generation showing results of 3D gamma evaluation and the dose at the isocenter

Lung step & shoot IMRT: recovery from atelectasis



Based on the *in vivo* dosimetry and CBCT result the physicist and radiation oncologist should discuss if replanning is neccesary

Anatomical changes during a series of patient treatments: the traffic light protocol

- Uncertainties in dose delivery arise when anatomical changes, such as contour variation, tumor shrinkage or tumor growth, occur during the course of a treatment

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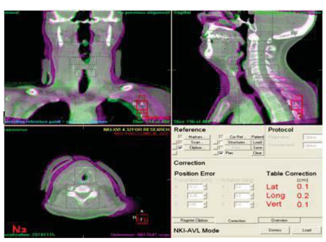
(red)	Action level 1	Action before next fraction	Communication by telephone
(orange)	Action level 2	No immediate action	Communication by email
(green)	Action level 3	No action	Communication by email

Anatomical changes during a series of patient treatments: the traffic light protocol

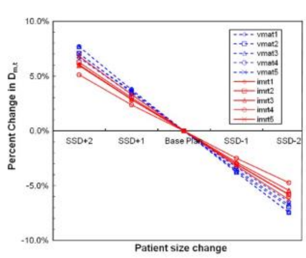
Purple: planning CT

Green: CBCT



(red)	Action level 1	Contour change > 1.5 cm
(orange)	Action level 2	Contour change 1.0 – 1.5 cm
(green)	Action level 3	Contour change 0.5 – 1.0 cm

Dosimetric effects of weight loss or gain during IMRT and VMAT for prostate cancer



The target mean dose, decreased or increased by 2.9% per 1-cm SSD decrease or increase in IMRT and by 3.6% in VMAT.

(Pair *et al.*, Medical Dosimetry 38, 251–254, 2013)

Final remarks

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- Reducing uncertainties in radiation therapy needs the expertise from radiation oncologists, physicists, dosimetrists and therapists
- Talk to each other and discuss all (difficult) cases
- Be pragmatic: the vast majority of our treatments are “correctly” delivered if a comprehensive QA program is performed
- The challenge is to select those cases where knowledge of the uncertainty is of paramount importance for the optimal treatment of that particular patient

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