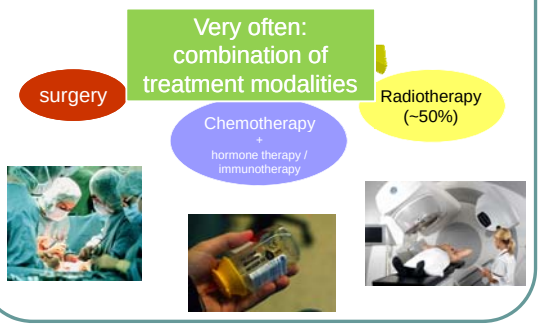
External Beam Radiotherapy

OOA Course 2010
Bas Gobets (AMC)
May 31, 2010

Outline

- Radiotherapy: intro
- The RT dilemma
- Radiation sources
- Radiotherapy workflow
  - Scan
    - Pre-treatment imaging
    - Contouring
  - Plan
    - Treatment planning
  - Treat
    - Position verification
    - Dosimetry

About 38% of women and 44% of men will develop cancer at some point in their lives (Netherlands) (NtvG 2008)

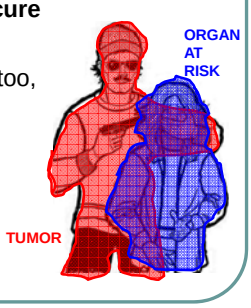


Radiotherapy intentions

- Curative
  - cure the patient
- Radical
  - slow down disease progression
- Palliative
  - pain releave

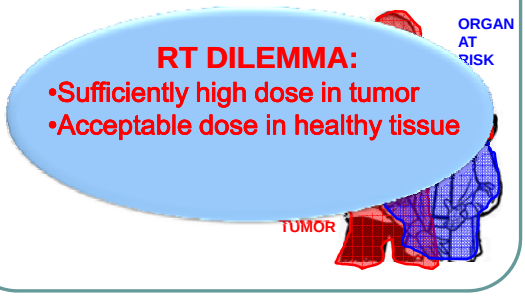
Radiotherapy dilemma

- With radiation we **kill** to **cure**
- We can **kill** any **tumor**
- But if we **kill** the **patient** too, we don't **cure** him.
- Quality of Life.

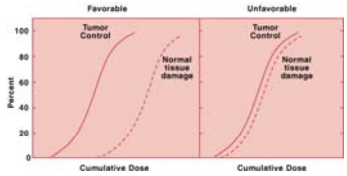


Radiotherapy dilemma

RT DILEMMA:
•Sufficiently high dose in tumor
•Acceptable dose in healthy tissue



Radiotherapy dilemma
radiobiology



- Therapeutic Ratio
- Fractionation: increases Therapeutic Ratio

Radiotherapy
External Beam RT vs Brachytherapy

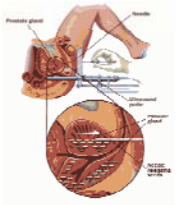
External beam RT:

Nearly always enter and exit dose to healthy tissue

Photons or electrons

Brachytherapy:

source "inside" tumor



REMEMBER:

RT DILEMMA :
- Sufficiently high dose in tumor
- Acceptable dose in healthy tissue

Radiation sources

- Historic (but may still be used)
- Current (present main-stream RT)
- Future /developments (may already be in use)

Sources of radiation - past

- 1895 Wilhelm Röntgen discovers X-rays

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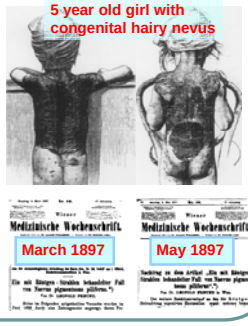
- November 1896 Leopold Freund: (november) First patient treated with radiotherapy (**fractionated!**)



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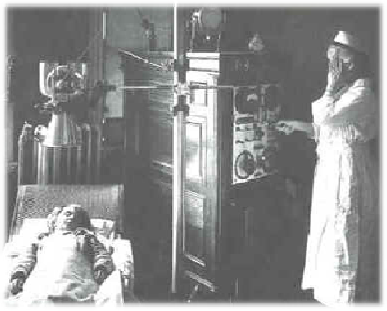
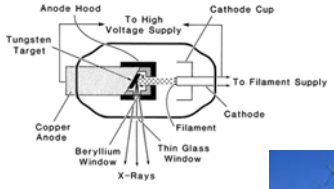
Sources of radiation - past



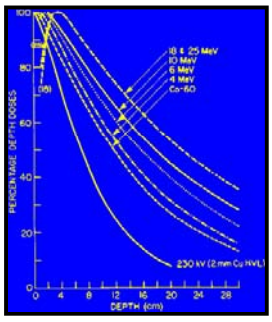
X-ray tube: principle of operation



Isolation: Limit ~350keV

Why higher energies?

- Deeper penetration
- Skin sparing



Why higher energies?

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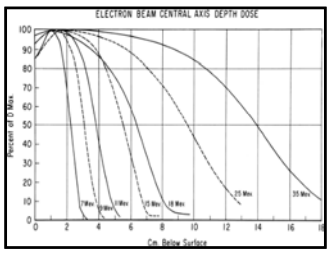
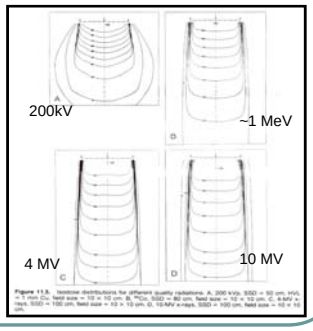
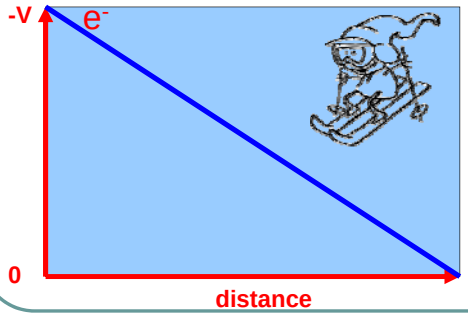


Why higher energies?

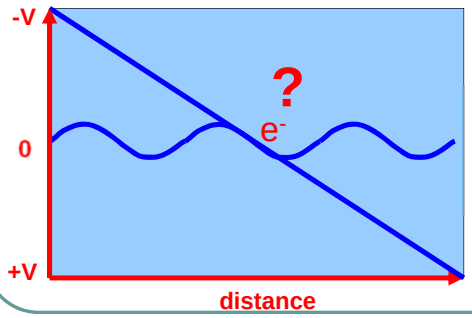
- Deeper penetration
- Skin sparing
- Electrons
- Steepness of penumbra



How higher energies?
Conventional X-ray tube



How higher energies?
Linear Accelerator (Linac)



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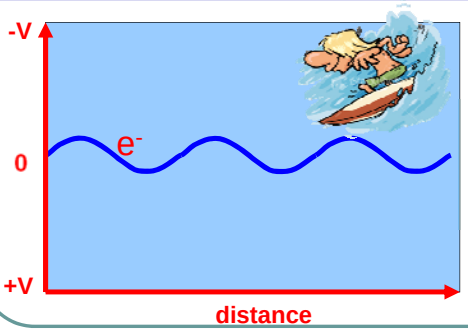

LINAC - present

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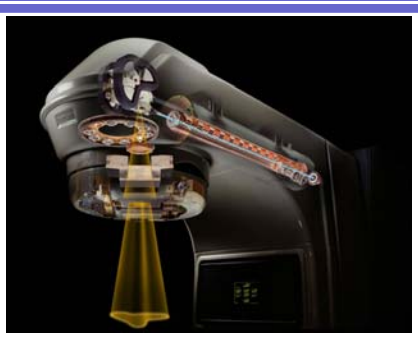
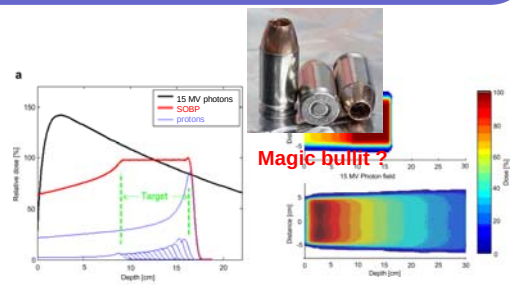
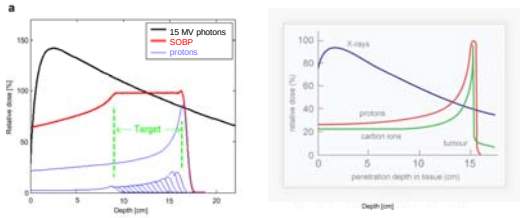


Protons & ions - future

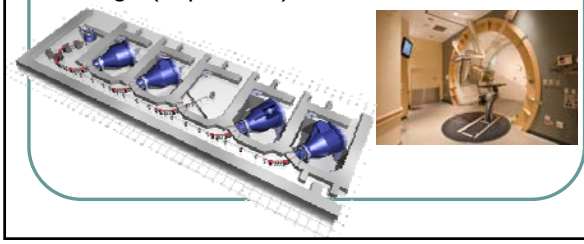


Protons & ions - future



Protons & ions - future

- Future? Has been done for 50 years now
- Getting more widespread now.
- Large (expensive) facilities



Radiotherapy procedure

- Historic (but may still be used)
- Current (present main-stream RT)
- Future /developments (may already be in use)

Radiotherapy procedure

scan

- Locate and delineate
  - Target
  - OAR
  - Body contour
- Mark
  - Reference points

plan

- Set up beams
  - Directions
  - Fieldshapes
  - Modalities
  - Energies
- Calculate dose

- Position patient
  - Positioning
  - Fixation tools
  - Position verification
- Irradiate
- N fractions

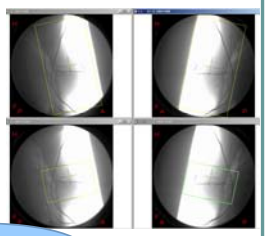
treat

Scan:
pre-treatment imaging

scan

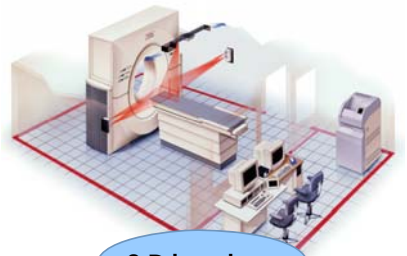
- Locate and delineate
  - Target
  - OAR
  - Body contour
- Mark
  - Reference points

Pre-treatment imaging
conventional simulator - past



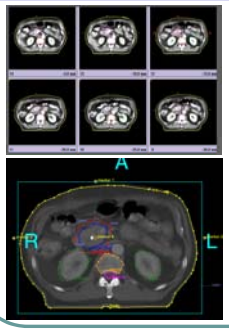
2-D imaging

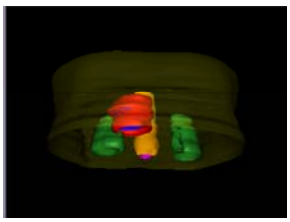
Pre-treatment imaging
CT simulator - present



3-D imaging

Pre-treatment imaging
CT simulator - present

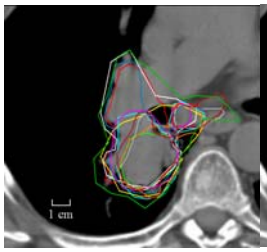


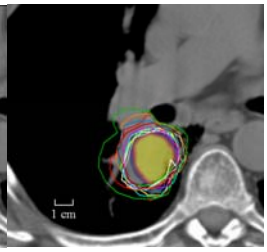


Pre-treatment imaging
Target delineation

- GTV: gross tumor volume
  - Visible tumor
- CTV: clinical target volume
  - Includes microscopic disease
- PTV: planned target volume
  - Taking into account treatment uncertainties
- TV: treated volume
  - Volume receiving > 95% of prescribed dose
- IV: irradiated volume
  - Volume receiving a significant dose

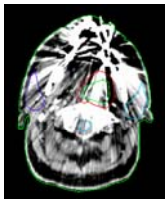
Pre-treatment imaging
Target delineation – observer variablity

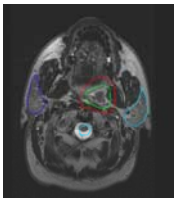


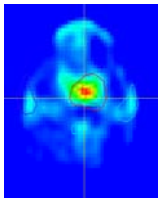


CT only CT + PET

Pre-treatment imaging
multiple modality imaging



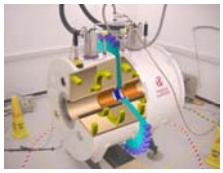




CT MRI PET

- Registration
- CT needed for dose calculation

Pre-treatment imaging
multi-modality imaging – present / future



PET/CT **PET/MRI**

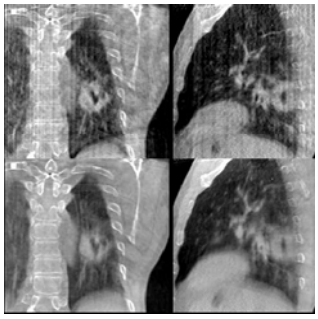
Pre-treatment imaging
4D – time is an issue

- Patients are not stationary!

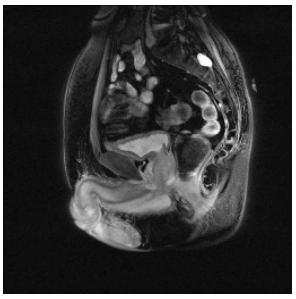
Pre-treatment imaging
4-D CT imaging – future / present

4D

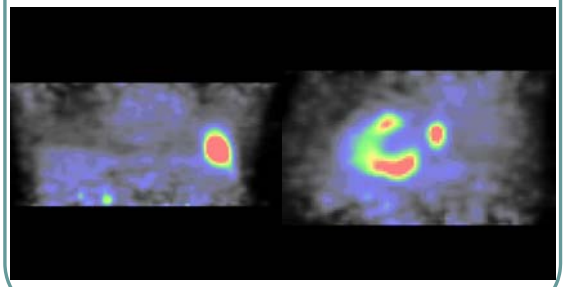
3D



Pre-treatment imaging
4-D MRI imaging – future / present



Pre-treatment imaging
4-D PET imaging – future / present

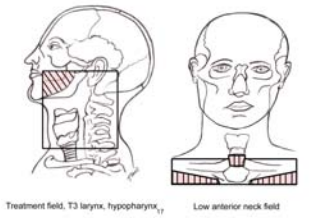


Plan:
Treatment planning

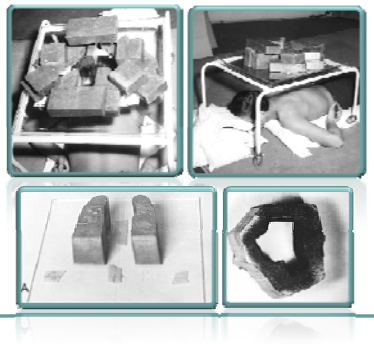
plan

- Set up beams
  - Directions
  - Fieldshapes
  - Modalities
  - Energies
- Calculate dose

Treatment planning
non-conformal - historic

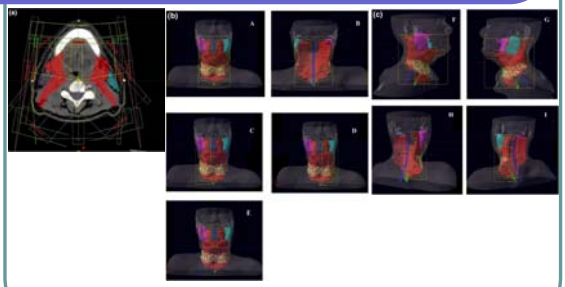


Treatment planning
non-conformal - historic



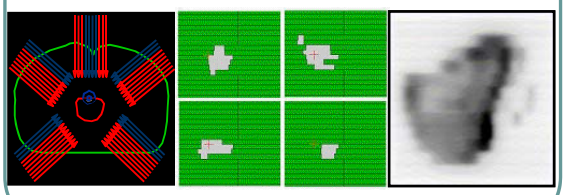
Treatment planning
Multi-leaf collimator

Treatment planning
3-D conformal – old / current

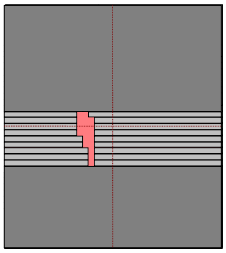


Treatment planning
Intensity Modulated Radiotherapy (IMRT) - current

- Multiple “segments” for each beam
- Inverse planning:
  - Start with constraints



Treatment planning
Intensity Modulated Radiotherapy (IMRT) - current

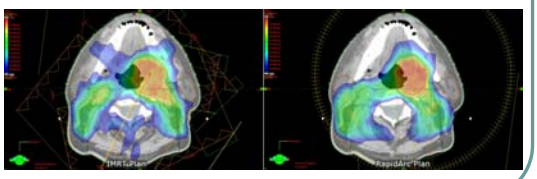


MLC field shape

Fluence or Intensity Distribution

Treatment planning
Volumetric Arc Therapy (VMAT) - future

- "IMRT with continuous rotation of gantry"
  - Continuous change of MLC and dose rate
- No "entry corridors"
- Main advantage: faster (Rapid Arc)



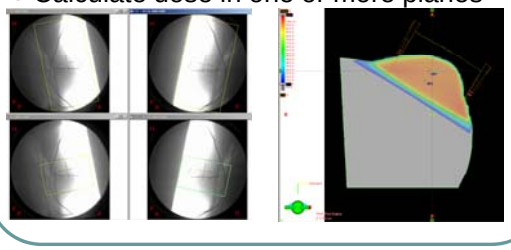
Plan:
Dose calculation

plan

- Set up beams
  - Directions
  - Fieldshapes
  - Modalities
  - Energies
- Calculate dose

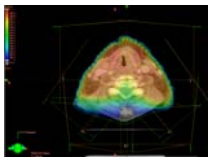
Treatment planning
Conventional 2-D dosecalculation - old

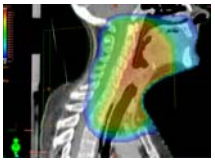
- Manual or with computer
- Calculate dose in one or more planes

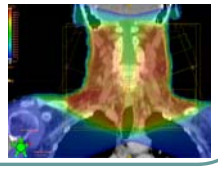


Treatment planning
3-D dose calculation - current

- Based on CT scan
- Produces 3D dosegrid



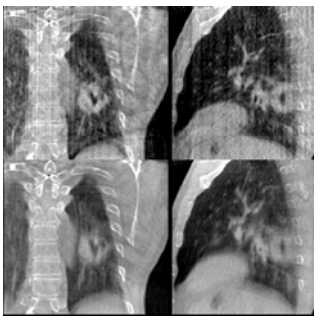




Treatment planning
Adaptive planning - future

- Don't consider the patient as a constant
  - Intrafraction motion

Treatment planning
Intrafraction motion

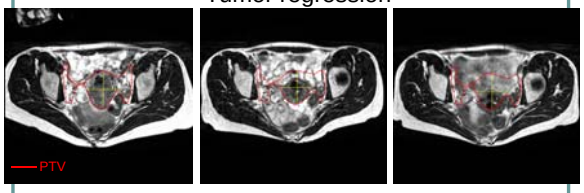


Treatment planning
Adaptive planning - future

- Don't consider the patient as a constant
  - Intrafraction motion
    - Tumor tracking
    - Gating
    - Average position
  - Interfraction motion / changes

Treatment planning
Interfraction motion / changes

Tumor regression



Pre-treatment mid-treatment 1 month after treatment

PTV : cervix; parametria; corpus uteri and regional lymph nodes

Courtesy L. vd Bunt, Ina Schultz ,UMC Utrecht

Treatment planning
Adaptive planning - future

- Don't consider the patient as a constant
  - Intrafraction motion
    - Tumor tracking
    - Gating
    - Average position
  - Interfraction motion / changes
    - Replanning?
    - Safe? GTV vs CTV

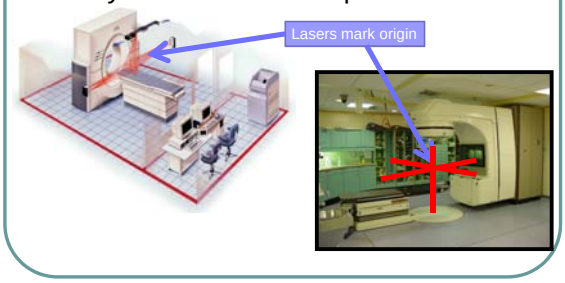
Treat:
Patient positioning

- Position patient
  - Positioning
  - Fixation tools
  - Position verification
- Irradiate
- N fractions

treat

Patient Positioning

- Every fraction the same position



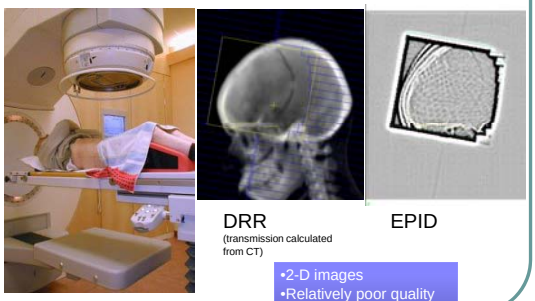
Patient Position
Fixation / immobilisation

Position verification
Skin marks – old/current

Patient Positioning

- Every fraction the same position
- Of the patient's exterior?
- or of the tumor?

Position verification
Electronic Portal Imaging Device (EPID) - current



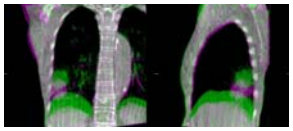
DRR
(transmission calculated from CT)

EPID

- 2-D images
- Relatively poor quality
- Bone/markers

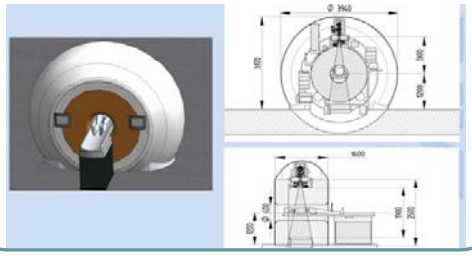
Position verification
Conebeam CT - current

- Better contrast
- 3D imaging
- 4D imaging



Position verification
MRI accelerator - future

- Excellent (soft tissue) contrast
- Live 4-D imaging (during treatment)



Treat:
Dosimetry

- Position patient
  - Positioning
  - Fixation tools
  - Position verification
- Irradiate
- N fractions

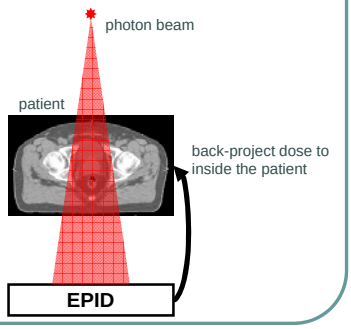
treat

Patient dosimetry

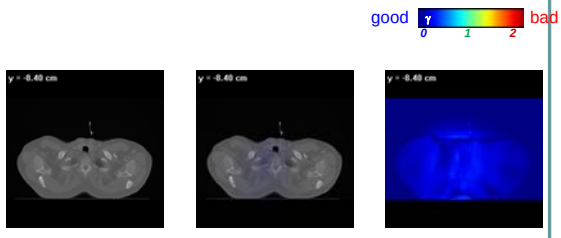
- Check if planning system calculated the correct dose
- Ideally: measure in patient during treatment
  - Problematic to put detectors inside patient

Patient dosimetry
pre-treatment phantom measurements - current

Patient dosimetry
EPID dosimetry - future



Patient dosimetry
EPID dosimetry - future



CT scan | measured dose | compare with planned dose

Patient dosimetry
EPID dosimetry - future

- Measure dose during treatment
- 3D
- May become a legal requirement

Take home:

- Radiotherapy: more than 100 years old, but alive and kicking!
- Expansion: Cancer is or will be the #1 killer

RT DILEMMA :
In most cases healthy tissue tolerance is the limiting factor for tumor control

Thanx

- Leah McDermott
- Eleftheria Astreinidou