Radiation Therapy and Dosimetry

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Pius-Hospital

– Founded in 1869 in honour of pope Pius IX

- nowadays the largest catholic hospital in north-western Germany

Clinic für Radiotherapy and internistical Oncology

- approx. 50 employees
- 2 LINACS, 1 Co-60, 1 Brachytherapy
- approx. 1500 patients per year
- Medical Radiation Physics Group with approx. 16 members
WG Medizinische Strahlenphysik

(University and Pius-Hospital, Oldenburg)

Cooperation in Medical Radiation Physics between both institutions

Group Members
5 Medical Physics Experts
4 Physicists
3 Bachelor-Engineering
1 PTA

Rad. Protection
- Rad. Therapy
- Nuclear Medicine
- Radiology

Teaching:
- University
- MTR-A School
- Radiation Prot. Courses

Foreign Cooperations
- Pakistan (Aga Khan Society)
- Nicaragua (Uni Managua, IAEA)
- Afghanistan (Kabul)

Research & Development:
- Dosimetry
- Radiology (ZKH LDW, Bremen)
- Radiation Protection (Oeko-Institute, BfS)
Education in Medical Radiation Physics:

Suggested Lectures/Seminars:
- Physics of Radiation Therapy and Dosimetry
- Seminar: Modern Aspects of Medical Radiation Physics (Fr. 12:00-14:00, Pius Nursery School)
- Seminar: Radioactivity and Radiation Protection (H. Fischer, University of Bremen, Mo 10.00-12.00, NW1 N1250)
- Neurophysik und Bildgebung (Neurophysics and Imaging, S. Uppenkamp, SS)
- Kernphysik (Nuclear Physics, SS)
- Treatment Planning (in preparation)
- „Einführung in die Medizinische Physik“ (Medicine for Physicists), SS)
- Environmental Radioactivity (H. Fischer University of Bremen, SS)
- Internships in Pius (especially when you are interested in professional career in medical physics)

Advanced students:
- Radiation protection courses
- Bachelor / Master Thesis (Waiting List approx. 6 month Bachelor, 8 month Master)
  to be on waiting list: passed lecture and seminars, interview (no exam!)
- Additional Training Courses (for students writing their Master Thesis only)

- Medical Physics Expert (Physicist in Hospital), 2 years practical experience + 2 radiation protection courses
Education in Medical Radiation Physics:

Suggested Lectures / Seminars:

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WebPage: www.uni-oldenburg.de/medical-radiation-physics
WebPage: www.uni-oldenburg.de/medical-radiation-physics
Contents: According to IAEA

Dosimetry and Medical Radiation Physics

The Dosimetry and Medical Radiation Physics (DMRP) section is responsible for the quality assurance (QA) aspects of the use of radiation in medicine to ensure safety and effectiveness, and deals with the science and technology involved in this area. The accurate measurement of radiation dose (dosimetry) is important in various applications such as radiation oncology, diagnostic radiology, nuclear medicine and radiation protection.

By providing dosimetry calibration services to Member States through the network of Secondary Standards Dosimetry Laboratories (SSDLs) the Agency establishes a link to the international measurement system. Dosimetry verification services are also provided both for SSDLs and for end-user institutions engaged in radiotherapy, diagnostic radiology and radiation protection. The primary beneficiaries of these activities are hospital patients undergoing medical...
Klinik für Strahlentherapie und Onkologie
Rules

• 1 Lecture per week (1-2 labs in Pius, Friday afternoon)
• Power Points available together with tests on webpage
• 1 Test per week (multiple choice)
• Test available on webpage, On-line test
• you have exactly 1 week to take the test
• you will get randomn questions to the lecture (10 questions)
• 90 minutes to answer, first submission “counts“
• for training purposes you may take tests several times, but only the first trial counts
Rules

• 7 out of 10 questions must be right to pass
• 8 passed tests to write the final exam
• all tests together 1/3 of the grade
• last lecture small talk under conference conditions
  (8 minutes, 2 minutes questions, „no questions“ no A)

Final Exam (Multiple Choice)
Grade: 1/3 Tests, 1/3 talk, 1/3 Exam
Tests available on webpage:

Login: DGMP
Password: DGMP
Tests available on webpage:
Tests available on webpage:
Tests available on webpage:
Tests available on webpage:
Tests available on webpage:
Introduction
Cancer

Malfunction of cells of the body

Uncontrolled cell growing -> tumor

All cells of the body may form tumors
Cancer

Malfunction in DNA

Reason:

Mutations e.g.:

• spontaneously
• chemical
• radiation
• hereditary
Cancer

- second often occurring reason for dying in Germany
- since beginning of 20th century increased by a factor of 7
- reason: increased live expectancy
Cancer

Aims of Radiotherapy:

- local tumor control
- destruction of the tumor
- destruction of tumor rest after surgery
- destruction of sub-clinical tumor manifestations in lymph-nodes
Effect of ionising radiation on cells

**Direct effects**
- Damaging of DNA of tumor cells
- Limited repair abilities (in comparison to healthy tissue)
- Reproductive cell death

**Indirect effect**
- Ionisation of $\text{H}_2\text{O}$ molecules
- Free radicals (cytotoxin)
- Cell death (direct oder reproductive)

$$\text{H}_2\text{O} + \gamma \rightarrow \text{e}^-_{\text{aq}} + \text{OH}^- + \text{H}^+ + \text{H}_2\text{O}_2$$
Effect of ionising radiation on cells II

Unit of absorbed dose: Gray  
1 Gy = 1 J/kg

Important dose values:
Total body:
Lethal-Dose 4,5 Gy (50% probability within 30 days)

**Organs** (Risk of complication: 5% in 5 years)
- Skin 70Gy (10cm²) Necrosis
- Lung 17,5 Gy (100%); 45 Gy (30%) Pneumony
- Rectum 60 Gy Nekrosis
- Bladder 65 Gy Nekrosis

**Tumordoses**
- Mama-Carcinoma 50,4 - 54 Gy (Fractions of 1,8Gy)
- Prostate bis 81Gy (common 70-74 Gy in 1,8Gy)
Effect on Cells III

- Energy transfer by scatter processes
- Energy of a photon is transferred to electron
- Electrons loose further energy to tissues
Brachy- und Teletherapy

Radiotherapy

„Brachy“ (greek) = close
„Tele“ (greek) = far

Brachytherapy

Radiation source inside body

Teletherapy

Radiation source outside body
## Used types or radiation:

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Energy</th>
<th>Creation</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons</td>
<td>some 100kV</td>
<td>x-ray tube</td>
<td>surface</td>
</tr>
<tr>
<td></td>
<td>1.3MeV</td>
<td>Co-60</td>
<td>general</td>
</tr>
<tr>
<td></td>
<td>4-6MV</td>
<td>Accelerator</td>
<td>mid depth</td>
</tr>
<tr>
<td></td>
<td>10-24MV</td>
<td>Accelerator</td>
<td>deep seated</td>
</tr>
<tr>
<td>Elektrons</td>
<td>4-24MeV</td>
<td>Accelerator</td>
<td>&lt; 10cm depth</td>
</tr>
<tr>
<td>Protons/Heavy Ions</td>
<td>70-250MeV</td>
<td>Accelerator</td>
<td>all depths; Accuracy (&lt; mm)</td>
</tr>
<tr>
<td>Neutrons</td>
<td>only in some institution</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Basic Problem of Teletherapy:

- High dose to normal tissues
- Lower dose to normal tissue

Cut through patient
Target (Tumor)
Tumor-Control-Probability (TCP) vs. Normal-Tissue-Complication-Probability (NTCP)

**Target (Tumor)**

**Organ-at-Risk**

- Probability Tumor Control / Complication
  - 100%
  - 50%
  - 0%

**Absorbierte Dosis im Tumor [Gy]**

**Tumor Control**

- Complication in Organ-at-Risk
- Therapeutic Range
Strategy of Modern Radiotherapy

Decrease of dose to Organs-at-Risk:

- allows an increase of dose in target without increasing probability for complications in organ-at-risks

- increase of dose in target increases tumor control probability

- and therefore to an increase of life expectancy
Machines and Techniques
Radiation Therapy till 1940

100 treatments in 9 months

50 treatments in 30 months

Today: bis 40 treatments in approx. 8 weeks
Radiation therapy after 1940

“Cobalt-bomb“ Pius-Hospital approx. 1960
Radiation Therapy after 1956

Stanford accelerator with young boy to be treated for retinoblastoma
Modern Linear Accelerators
Modern LINACS

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aus Schlegel et al. „3D-Conformal Radiation Therapy“
Modern LINACS
Modern LINACS

Electrons from Accelerator

Figure 9.19: Treatment head for the production of an X-ray beam.
Modern LINACS

Boyer, Physics Today 9/2002
Multileaf-Collimator (MLC)

- **Target**
- **Organ-at-Risk**
- **Squared Field**
- **additional block(s)**
- **MLC-Feld**

Conformal field shape with optimal sparing of healthy tissue and organs-at-risk
MLC

Leaf-View

Leaf-View

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Typical Treatment:

1. **Patient**
2. **MR-scan**
3. **Image set**
4. **Computer-planning**
5. **CT-scan**
6. **Simulator**
7. **Irradiation**
Intensity Modulated Radiation Therapy

"Conventional" Planning

Inverse Planning

Treated Volume

Target Volume

Collimator

OAR

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IMRT

homogenous

Wedegd fields

Typical intensity distributions of conformal therapy

Intensity distribution in IMRT
IMRT: Step-and-Shot
IMRT: Sliding Window
IMRT
Homework for next week:

- Visit webpage and register in „Weiterbildungsportal“
- Register in Stud.IP
- Next week: Chapter 1 of IAEA book (read if possible)
-- Lecture will be given by S. Heidorn