Measurement of absorbed dose to the skin and its relation with microcircular changes during breast cancer radiotherapy

Master of Science thesis in Medical Radiation Physics
Content

- Aim of the project
- Background and Material
- Methods
  - Phantom study
  - Patient study
- Results
  - Patient study
  - Phantom study
- Discussion and Conclusion
Aim of the project

- Determine skin dose for breast cancer treatment by *in vitro* and *in vivo* measurements

- Investigate if a possible correlation may exist between the absorbed dose to the skin and the changes in microcirculation of the skin during breast cancer radiotherapy

- Characterisation of the equipment at Linköping University hospital for future studies
Background & Materials

- The dermis begins at a depth of ~100 µm and can be up to a few millimetres thick [1]

- Radiation disrupts the self-renewing property of the epidermis

- Today the patients’ skin reactions are visually graded

Gafchromic EBT3 film:
- Similar interaction properties as tissue
- Not angular dependent [2]

Epson Perfection V600 Photo Scanner
- Scanner model: J252A

Adapted from M.Well et al. [7]
Adapted from D.Lewis et al. [8]
Methods – Anthropomorphic phantom study

- Anthropomorphic female phantom (Model number 702-004, CIRS, Virginia, USA) was planed to a prescribed dose of 2.66 Gy per fraction (16 fractions)
- Treatment plan using 6 MV beam with opposed fields at 124° and 305°
- 21 pieces of film (2x1 cm²) were taped on the left breast and irradiated with all fields applied in the treatment plan
Methods – Patient study

- Absorbed dose measurements
- Skin microcirculation measurements
  - Laser Speckle Contrast Imaging (LSCI)
  - Polarised Light Spectroscopy (PLS)
- Pearson’s correlation test
Methods – Patient study

- A female patient was irradiated with prescribed dose of 2.66 Gy in 16 fractions using 6 MV beam at 57° and 234°
- 21 pieces of film (2x1 cm²) were taped on the breast
Methods — Patient study: LSCI and PLS

Laser Speckle Contrast Imaging

- LSCI is a high resolution and fast technique that uses coherent light for visualization of the microcirculation.
- Inverse correlation between the speckle contrast $C$ and blood perfusion [3]

\[ C \equiv \frac{\sigma}{I} \]

Polarised Light Spectroscopy

- PLS is based on a digital camera (TiVi600, Wheelsbridge AB, Linköping, Sweden) and measures the RBC concentration (RBCC) in the upper dermis using polarised light
- The TiVi indices are linearly correlated to the concentration of the RBCs in the volume of tissue [4]
Absorbed dose range: 0.10-1.68 Gy

Max dose at film placements 5 and 12 (63.2 %) and min dose at film placement 13 (3.8 %)

Mainly 45-64 % of the prescribed dose (2.66 Gy) is deposited in the skin. These results are in good agreement with the founding by Almberg et al. [5] and Rudat et al. [6]
Results — Patient study

- Absorbed dose range: 0.19-1.69 Gy
- Max dose at film placement 12 (63.5 %) and min dose at film placement 13 (7.1 %)
- Similarities in the absorbed doses in the phantom and patient studies
Results — Patient study: Microcircular changes

- An increase in mean perfusion for all 21 regions
- Highest increase in mean perfusion at placement 1, 2 and 3
- Highest increase in TiVi\text{index} for placement 1, 2 and 3 while a decrease for placement 15, 16 and 17
- The reason for why the largest changes appear centrally may be due to the vascular reactivity or the capillary density
The correlation is referred to as *Pearson's r*:
- Perfect correlation if $r = +1/-1$
- No correlation $r = 0$

### Results – Patient study: Pearson’s correlation test

<table>
<thead>
<tr>
<th>$X/Y$</th>
<th>Change in mean perfusion/Absorbed dose</th>
<th>Change in $\text{TiVi}_{\text{index}}$/Absorbed dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson’s $r$</td>
<td>0.30</td>
<td>0.48</td>
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<tr>
<td>P-value (two-tailed)</td>
<td>0.18</td>
<td>0.03</td>
</tr>
<tr>
<td>Significance ($\alpha = 0.05$)</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Discussion and conclusion

- It is difficult to make a concrete error-analysis but one must be aware of the uncertainties related to e.g. the calibration, scanner readout inhomogeneities.

- There are biological factors that are difficult to account for: the thickness of the epidermis, the age and general health condition.

- More studies should include methods for quantification of the skin reactions instead of using subjective methods.

- The midline of the breast receives highest dose.

- A good agreement between phantom- and patient study was found.

- Future studies should include a larger population, patients with different breast geometries and also mastectomy patients.

- Not reliable to draw conclusions about a general correlation from the results in this study due the small population sample. A larger sample must be included in future work.
Bibliography


Figures


Thank you! 😊
• With increased beam energy:
  - Less surface dose
  - Larger depth (in water) before CPE is reached
  -> increase in $z_{\text{max}}$
Fig. 4. Probability density functions of the Monte Carlo simulation. 100,000 photons were launched into an optically simulated dermis. The Stokes vector of backscattered photons was used as the gating technique, thus separate detection of CR photons is possible. The vertical arrows show the average depth of both detected CR photons and total detected photons in the red and green wavelength region, respectively.

Adapted from O’doherty et al.
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