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

Radiation therapy, 2016-11-17, Chahed Yacoub Gabro

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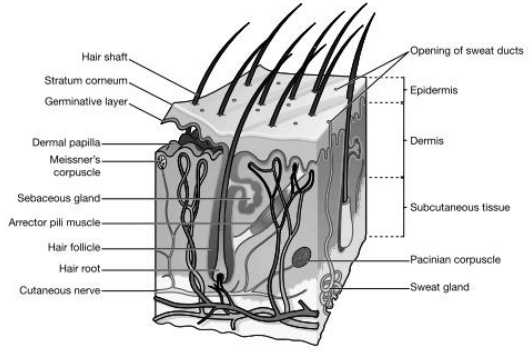
Aim of the project

- 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



Adapted from M.Well *et al.* [7]

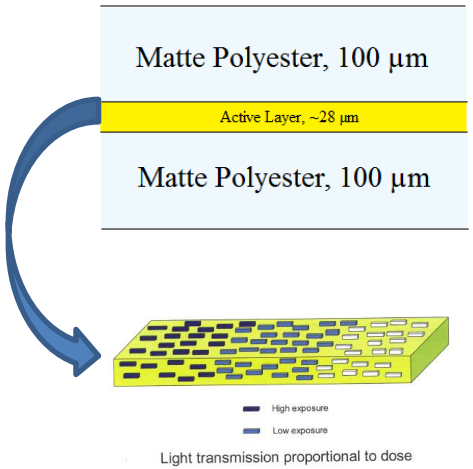
Gafchromic EBT3 film:

- Similar interaction properties as tissue
- Not angular dependent [2]

Epson Perfection V600 Photo Scanner

- Scanner model: J252A

Ashland Specialty Ingredients, Bridgewater



Adapted from D.Lewis *et al.* [8]

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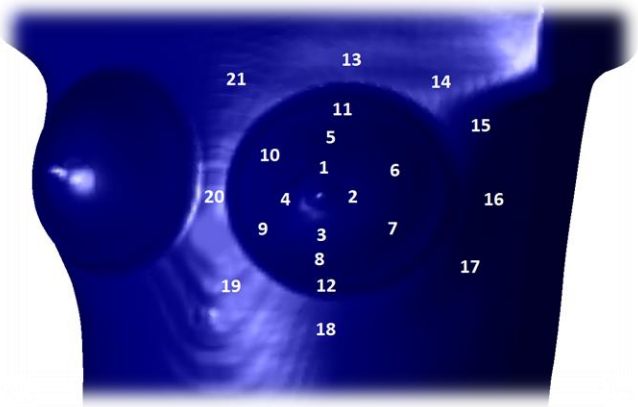
Methods – Anthropomorphic phantom study

- 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 cm^2) were taped on the left breast and irradiated with all fields applied in the treatment plan



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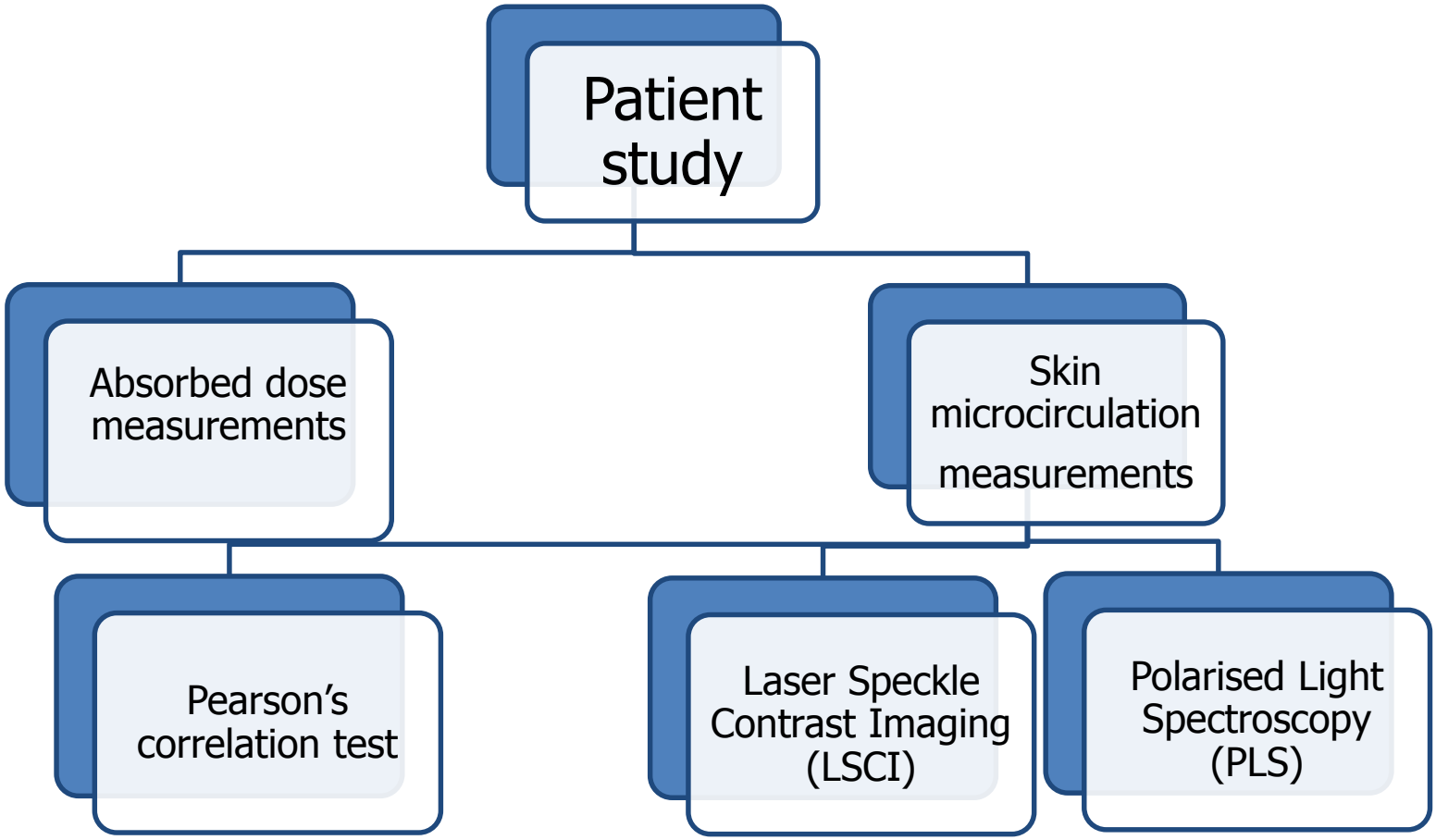
Methods – Patient study



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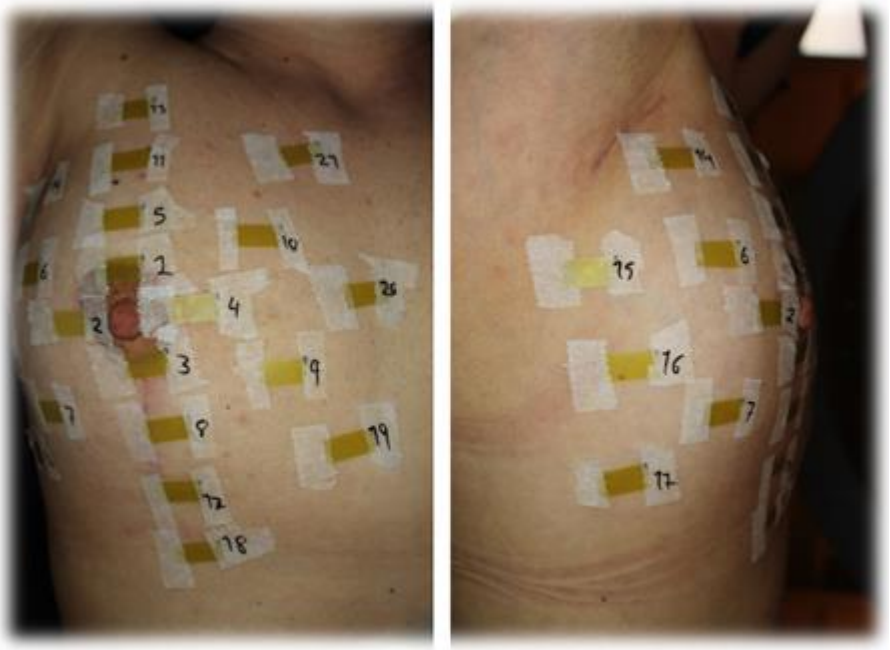
Methods –Patient study

- A female patient was irradiated with prescribed dose of 2.66 Gy in 16 fractions using 6 MV beam at 57^{o} and 234^{o}
- 21 pieces of film (2x1 cm^{2}) were taped on the breast



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Methods –Patient study: LSCI and PLS

Ref. [9]

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]

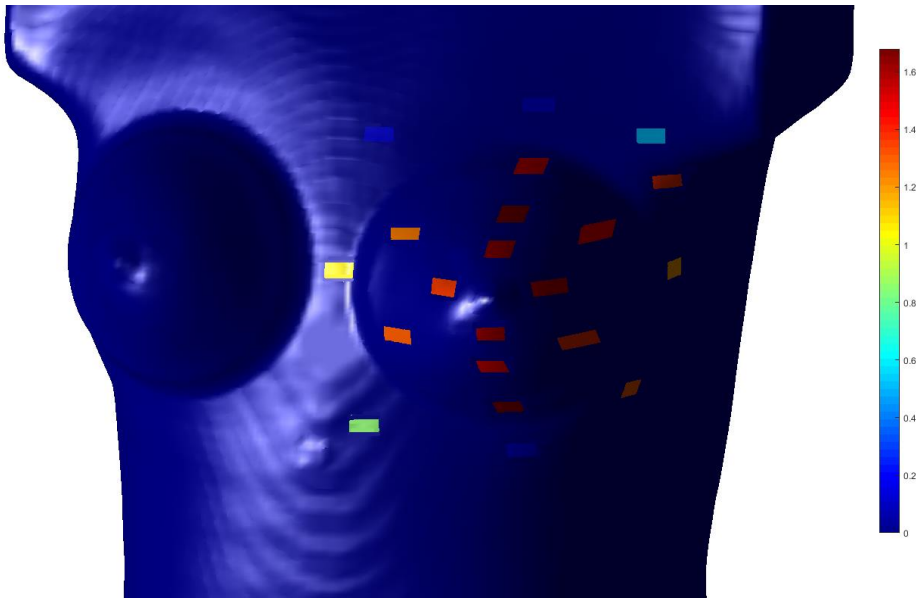
$$C \equiv \frac{\sigma}{\bar{I}}$$

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]

Results – Phantom study

- 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]



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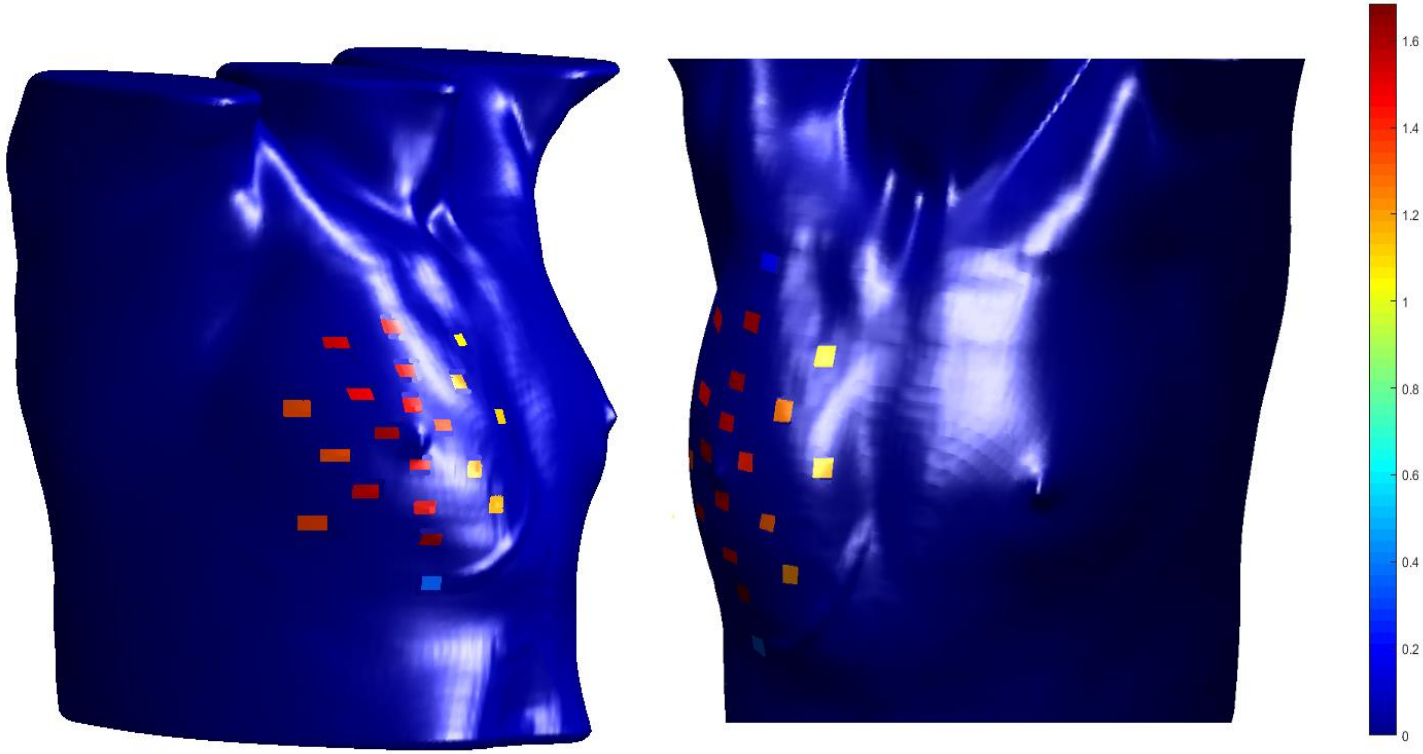
Results – Patient study

- 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



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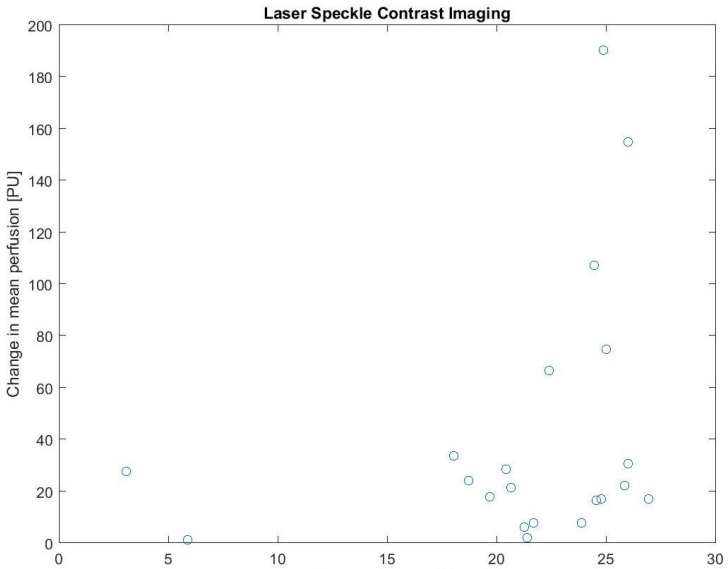
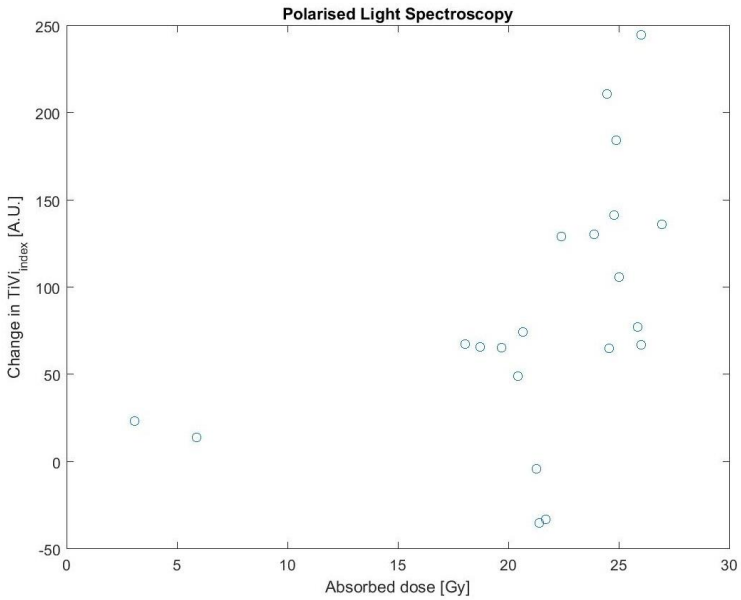
Results – Patient study:

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 $TiVi_{index}$ 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





Results –
Patient study: Pearson's correlation test

- The correlation is referred to as *Pearson's r* :
  - Perfect correlation if r = +1/-1
  - No correlation r = 0

X/Y	**Change in mean perfusion/Absorbed dose**	**Change in $TiVi_{index}$/Absorbed dose**
Pearson's r	0.30	0.48
P-value (two-tailed)	0.18	0.03
Significance (α = 0.05)	No	Yes

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

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[2] Lewis D, Micke A, Yu X, Chan MF. An ecient protocol for radiochromic lm dosimetry combining calibration and measurement in a single scan. Medical Physics. 2012;39(10):6339.

[3] Draijer M, Hondebrink E, Van Leeuwen T, Steenbergen W. Review of laser speckle contrast techniques for visualizing tissue perfusion. Lasers in Medical Science. 2009;24(4):639{651.

[4] O'doherty J, Henricson J, Anderson C, Leahy MJ, Nilsson GE, Sjoberg F. Sub-epidermal imaging using polarized light spectroscopy for assessment of skin microcirculation. SkinResearch and Technology. 2007;13(4):472{484.

[5] Almberg SS, Lindmo T, Frengen J. Supercial doses in breast cancer radiotherapy using conventional and IMRT techniques: A lm-based phantom study. Radiotherapy and Oncology. 2011;100(2):259{264.

[6] Rudat V, Nour A, Alaradi AA, Mohamed A, Altuwaijri S. In vivo surface dose measurement using GafChromic lm dosimetry in breast cancer radiotherapy: comparison of 7-eld IMRT, tangential IMRT and tangential 3D-CRT. BioMed Central. 2014;.

Figures

[7] Wells M, MacBride SM. Radiation skin reactions. Supportive care in radiotherapy. 2003;p.135{159.

[8] Lewis DF. A Guide to Radiochromic Film Dosimetry with EBT2 and EBT3. Ashland Specialty Ingredients; 2015.

[9] https://www.perimed-instruments.com/products/pericam-psi, 2016 jun.

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Thank you!

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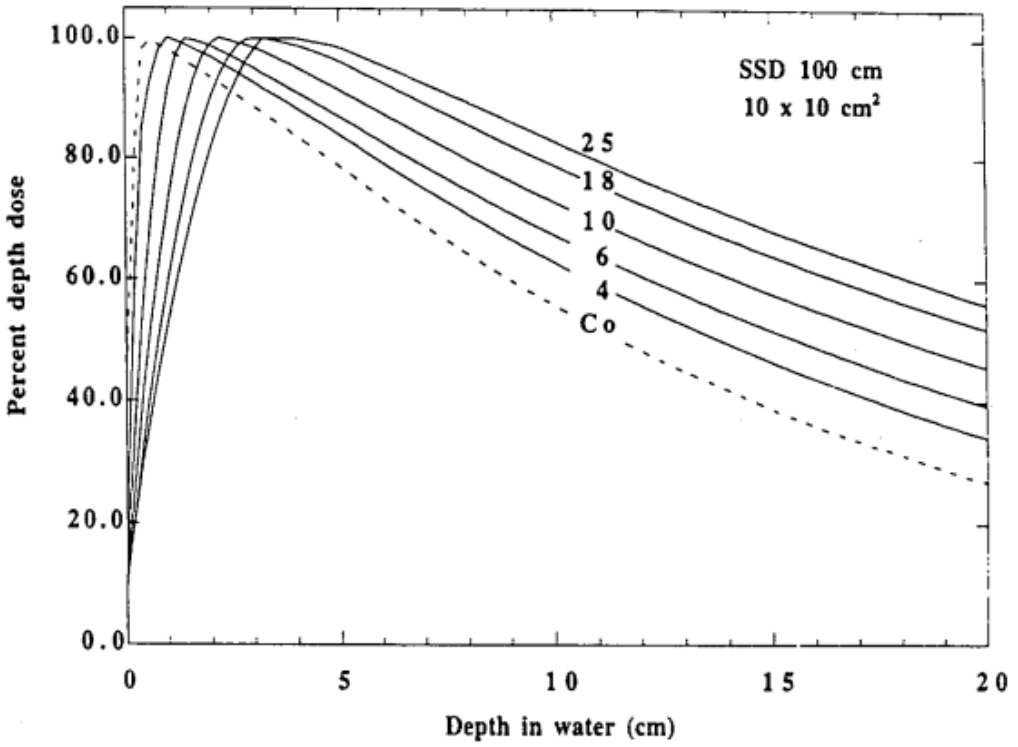
- With increased beam energy:

  - Less surface dose

  - Larger depth (in water) before CPE is reached
  -> increase in z_{max}



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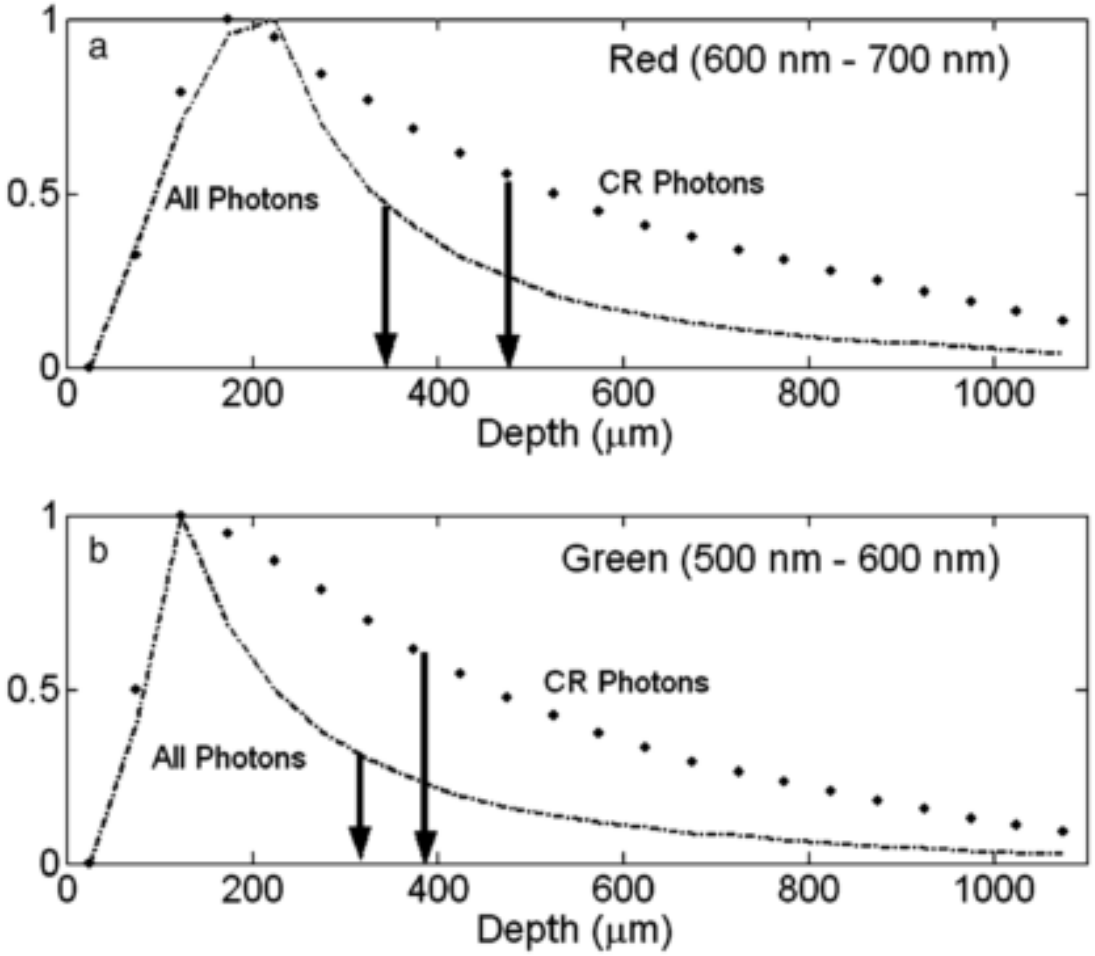

Adapted from O'doherty *et al.*

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.

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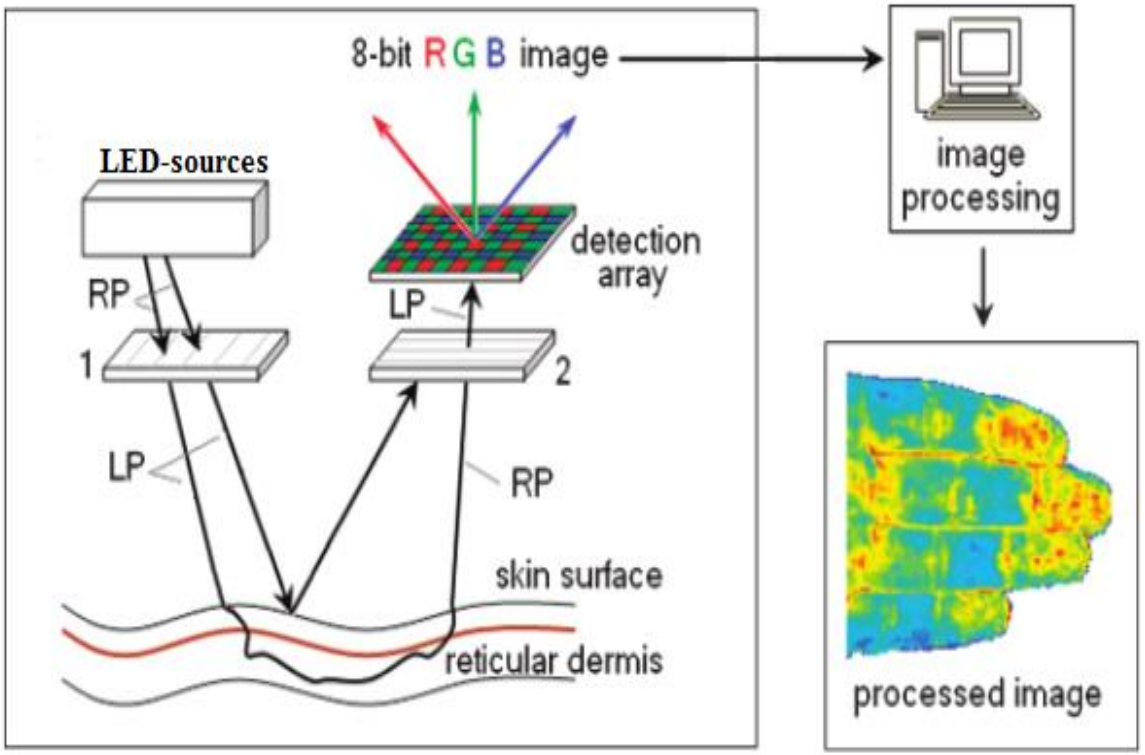

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