# Assessing variable degrees of blood perfusion in ischaemic skin flaps and grafts

**Mark Main[1], Richard J. J. Pilkington[2], Graham M. Gibson[3], Akhil Kallepalli[3]**

[1] James Watt School of Engineering, University of Glasgow, Glasgow G12 8QQ, United Kingdom. [2] Oral and Maxillofacial Surgery, Cumberland Infirmary, Carlisle CA2 7HY, United Kingdom [3] School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, United Kingdom

## Introduction

- Skin flaps are assessed for reperfusion using colour, temperature, capillary refill, texture and Doppler signal.
- These techniques are error-prone by nature as they are qualitative.
- To take quantitative measurements, optical and near-infrared light can be used.
- Through simulations, we can ascertain which wavelengths or combinations are ideal for assessing reperfusion.
- **We propose a simulated understanding of areas with poor reperfusion to facilitate the development of a device to be used in post-operative care.**

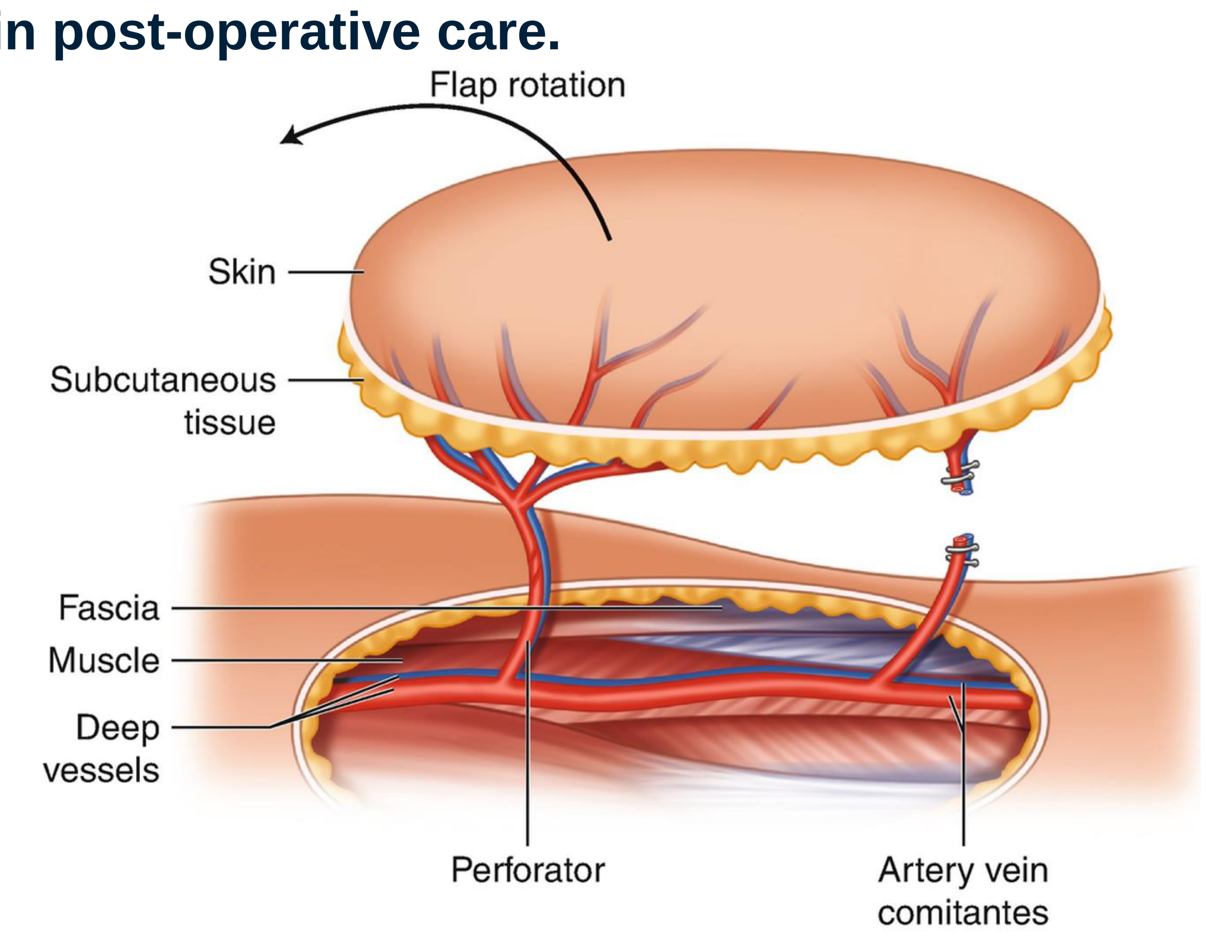


Figure 1. Section of skin being removed before rotation for grafting. Some blood vessels remain to help facilitate reperfusion.

## Methodology

- Using Monte Carlo Simulations, a seven-layer skin model can be created to simulate the optical properties of tissue under illumination.

| Wavelengths | Melanin Distribution | Dermal Perfusion |
|---|---|---|
| Blue (480 nm), Green (520 nm), Red (650 nm), Near IR (950 nm) | Skin colour was quantified in 3 categories, combining consecutive types on the Fitzpatrick Scale | Healthy perfusion was set at 98% and unhealthy/reduced perfusion at 50% |

- To aid in analysis, a mathematical factor was defined, called the Optical Reperfusion Factor (ORF).

$$ORF_{Healthy-Unhealthy} = \left| \frac{\lambda_{Healthy} - \lambda_{Unhealthy}}{\lambda_{Healthy} + \lambda_{Unhealthy}} \right|$$

- The ORF is used to demonstrate how a variation in blood perfusion has a drastic impact on absorption levels.

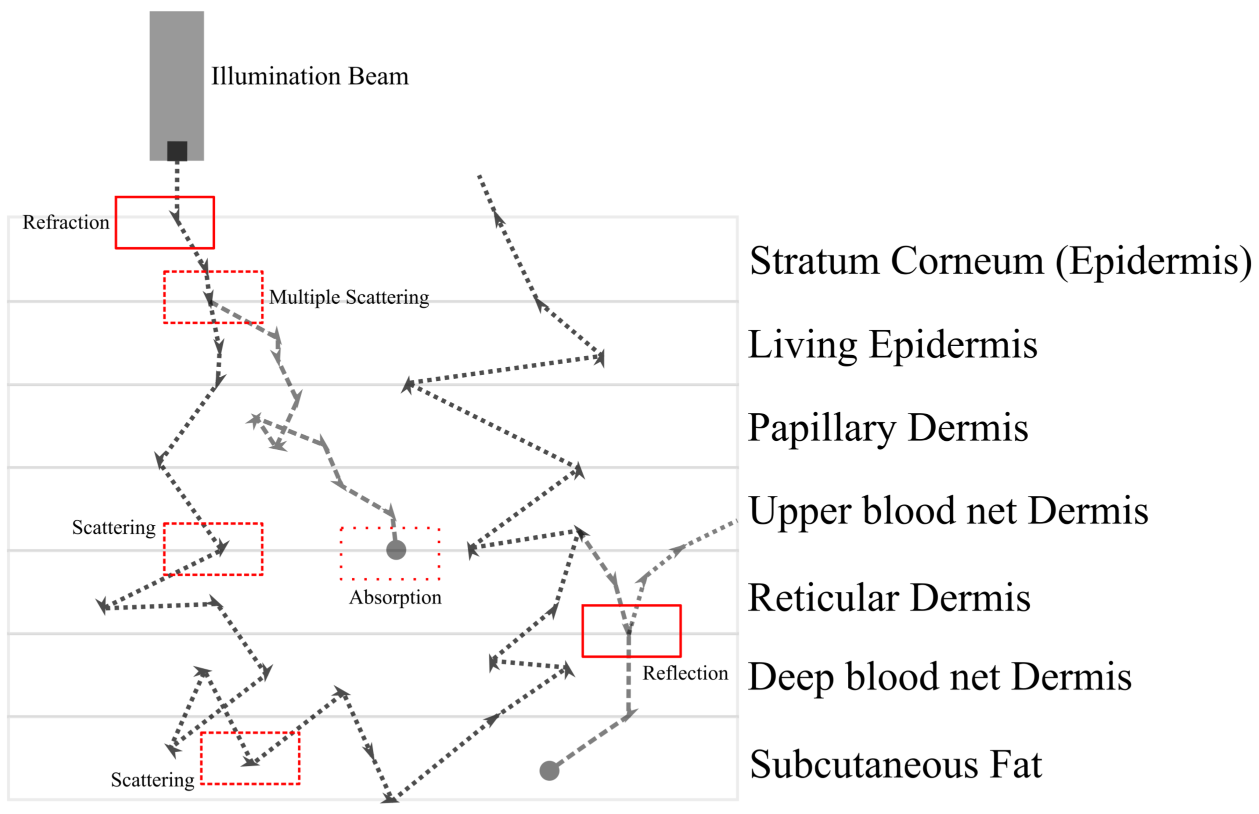


Figure 2. This shows an example of a photon propagating through a multi-layer skin model used in this study. The processes this photon can undergo while inside the tissue is also outlined.

## Results

- Red and near-infrared wavelengths were found to penetrate through the entire tissue depth. This is concurrent with previously published literature and demonstrates these wavelengths are best for imaging at this depth.

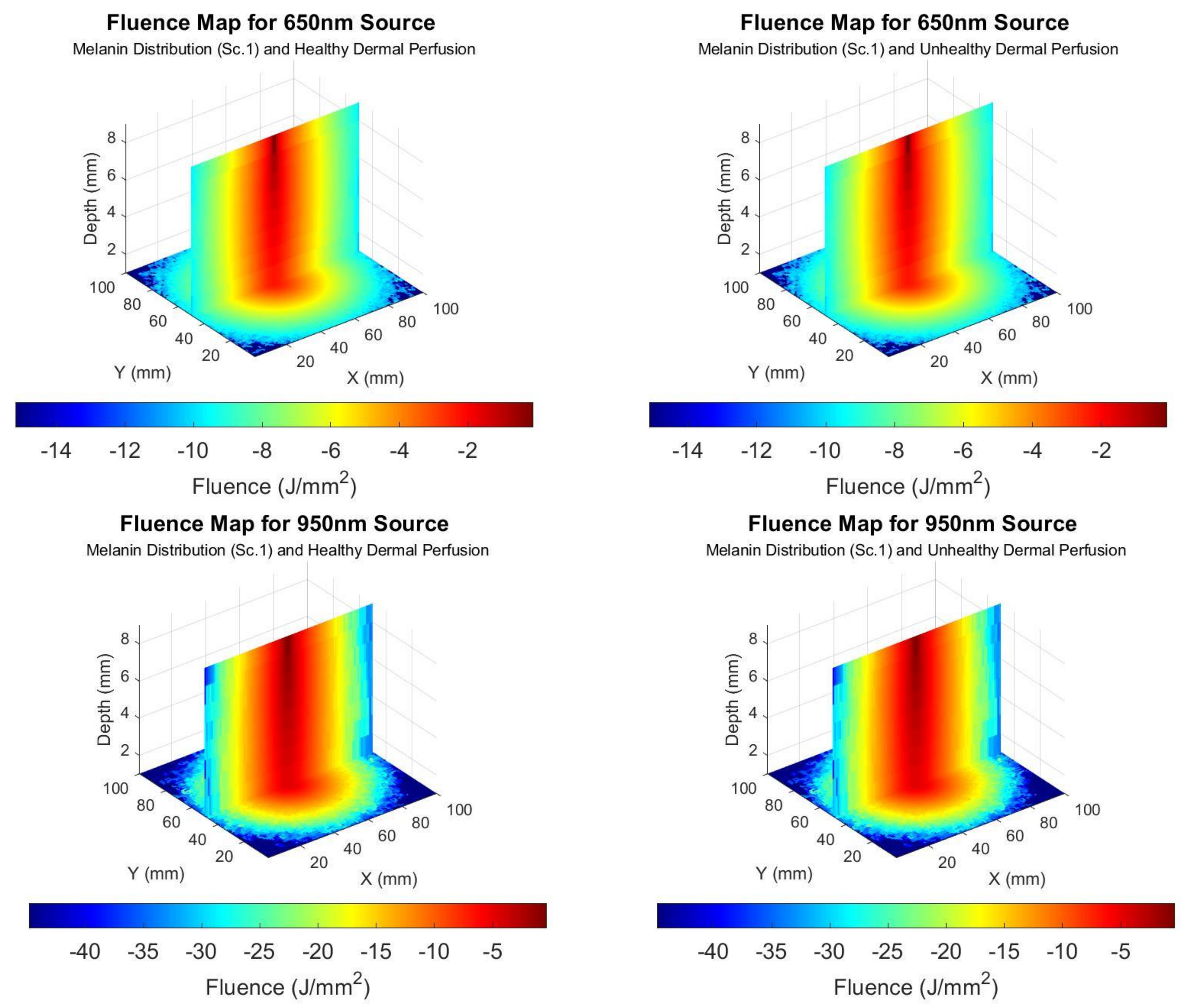


Figure 3. Energy deposition graphs of healthy and unhealthy tissues for red and near-infrared wavelengths at low melanin levels.

- Although variations can be seen between healthy and unhealthy tissue. These differences can be enhanced for analysis.
- ORF was used on the same wavelength and wavelength combinations to show perfusion variation for green, red and infrared
- Figure 3 clearly outlines a difference moving away from the source as healthy tissue absorbs red light much more due to the presence of more blood.

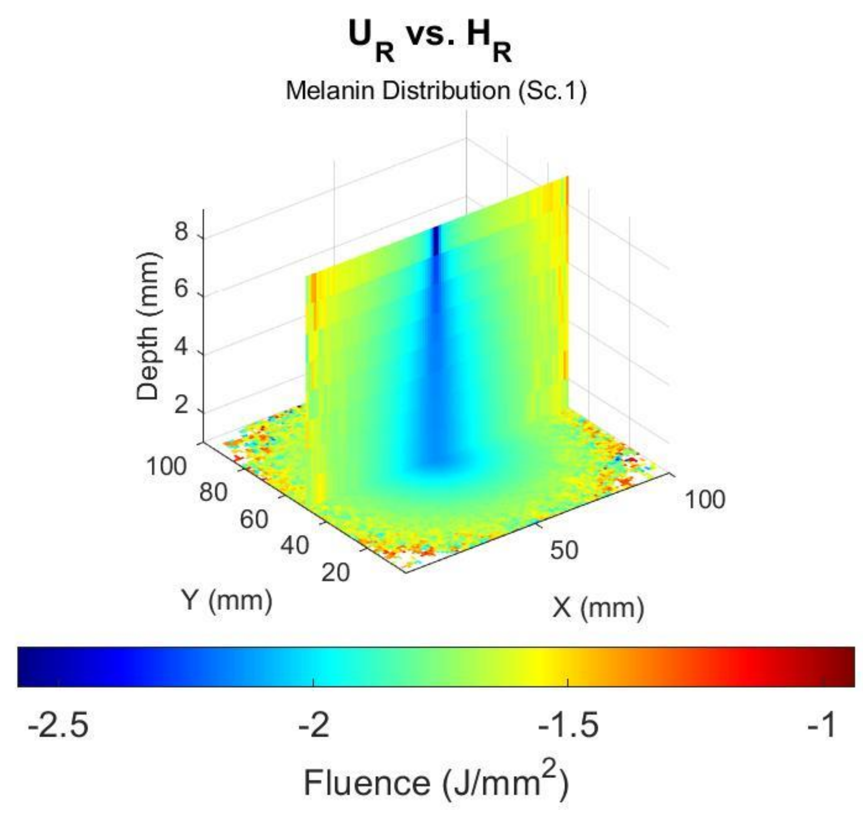


Figure 4. ORF results for red light in healthy and unhealthy tissue. Variation increases as light propagates further from the incident beam.

## Conclusion

**We have shown that by using ORF we can clearly observe variations in blood perfusion in simulated tissue. The substantial difference between healthy and unhealthy conditions of all skin types is an excellent foundation for further simulation and experimental study.**

**[1] I. V. Meglinski, S. J. Matcher, Quantitative assessment of skin layers absorption and skin reflectance spectra simulation in the visible and near-infrared spectral regions. (2002)**
**[2] S. L. Jacques, Optical properties of biological tissues: A review. (2013)**
**[3] A. N. Bashkatov, E. A. Genina, V. I. Kochubey, V. V. Tuchin, Optical properties of human skin, subcutaneous and mucous tissues in the wavelength range from 400 to 2000 nm. (2005)**

THE ROYAL SOCIETY
EPSRC Engineering and Physical Sciences Research Council
BAOMS THE FACE OF SURGERY
QUANTIC The UK Quantum Technology Hub in Quantum Enhanced Imaging