Can we see where to cut?

Delineating skin tumors using new imaging technology

On November 22, 2024, Jenny Hult defended her thesis "Skin tumor delineation using photoacoustic imaging and hyperspectral imaging" at the Faculty of Medicine, Dept. of Clinical Sciences/ Ophthalmology, Lund University, Sweden. Her main supervisor was Prof. Malin Malmsjö, and her co-supervisors were Karl Engelsberg, Docent, Aboma Merdasa, Docent, and Bodil Gesslein, PhD, all at the Dept. of Clinical Sciences, Lund University.

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Skin tumors suspected of malignancy are typically treated with surgical excision. However, the extent of the tumor beneath the skin surface is often invisible to the naked eye or to dermatoscopic examination, and in some cases, the superficial margins may also be poorly defined. To increase the probability of removing all tumor cells while preserving healthy tissue, there is a need for imaging techniques that can guide surgery. This balance is particularly critical in the periocular region, where even small margins can affect eyelid function and cosmetic outcome. In the thesis, two novel techniques—photoacoustic imaging (PAI) and hyperspectral imaging (HSI)—were explored for non-invasive visualization and delineation of skin tumors. Several imaging techniques have previously been studied for this purpose, but most techniques suffer from limitations such as shallow imaging depths or an inability to image molecular contents, for example melanin, hemoglobin and lipids. PAI and HSI are spectral techniques that can image molecular contents and have the potential to differentiate between healthy and tumor tissue, allowing the imaging of tumors and delineation of their borders. While HSI collects a vast amount of spectral information from the skin surface, PAI combines laser light and ultrasound to collect spectral information from deeper layers of the skin (up to several millimeters in depth) while maintaining a high resolution, making 3D skin tumor imaging possible. The skin tumors used for the research in this thesis were examined *ex vivo*, and differences in the spectral signals between the tumor and the surrounding healthy tissue were used to image and delineate the tumors. Through the development of algorithms and machine learning methods, attempts were made to make the imaging analysis more objective and independent of the user. In the first study, 33 suspected cutaneous squamous cell carcinomas were scanned using PAI. The results showed a unique signal for confirmed squamous cell carcinomas and demonstrated how the signal could be used for 3D tumor imaging. In the second study, 52 suspected malignant melanomas were scanned with PAI and an automatic algorithm for delineation of the tumors was developed. The PAI-derived tumor widths and thicknesses showed strong correlations with histopathological measurements. In the third study, PAI data from seven malignant melanomas were analyzed with a statistical detection method, and by developing an automatic threshold selection algorithm, the melanomas could be imaged, showing good correlations to histopathological measurements. In the fourth study, machine learning, in the form of 3 different neural networks, was used on HSI data from 18 various skin tumors. Using spectral signals from tumor and healthy skin as training, it was demonstrated that the networks, in combination with a delineation algorithm, could make 2D tumor predictions at the skin surface, with strong correlations to histopathological measurements. In conclusion, the thesis highlights the promising potential of HSI and PAI to help surgeons visualize tumor borders more clearly and operate with greater precision—an important step toward safer, tissue-preserving surgery in sensitive regions such as the eyelids.

Key points:

- Photoacoustic imaging (PAI) and hyperspectral imaging (HSI) are new biomedical imaging techniques that can image molecular contents in tissue.
- PAI and HSI can potentially be used in the future to delineate skin tumors pre- or intraoperatively.
- Automatic threshold algorithms and machine learning models make image analysis more objective and independent of the user.

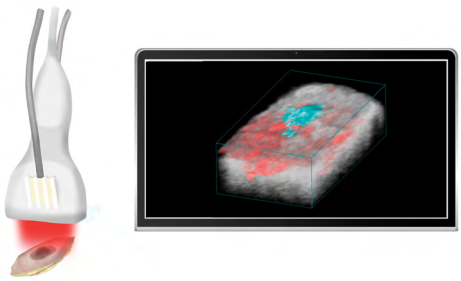

Figure 1. A PAI-scan of an excised skin tumor, rendering a 3D spectral image of the tumor overlaid on a corresponding ultrasound-image. Illustration by Jenny Hult

Future directions:

- The potential of photoacoustic imaging (PAI) and hyperspectral imaging (HSI) for skin tumor imaging must be further explored in larger in vivo studies.

References

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