Title: Evaluating potential improvements to the intraoperative photoacoustic screening (iPAS) system, a question of trade-offs

Trainee Name: Lawrence Yip

Supervisor(s): Dr. Jeffrey Carson

Structured Abstract:

Introduction: Breast cancer accounts for 25% of all cancer cases among women. In many early stage cases, breast-conserving surgery (BCS) is recommended, where the tumour is excised with a thin layer of healthy tissue. While several techniques for tumour localization exist, achieving a tumour-free margin can still be difficult. Current standards as of a few years ago require “no ink on tumour” for invasive breast cancer and a ≥2 mm clear margin for ductal carcinoma in situ. Despite these more relaxed standards, re-excision rates as high as 40% are still frequently reported and available techniques need to be improved.

Photoacoustic tomography (PAT) is an imaging technique with advantages of both optical imaging and ultrasound. Pulsed laser light is used to safely irradiate tissue, producing acoustic waves, which are then reconstructed into 3D images. PAT can image hemoglobin, lipid, or contrast agents such as indocyanine green, allowing functional and anatomical imaging. This is particularly useful when imaging cancerous tissues; PAT can detect differences between tumour and healthy tissue using their corresponding wavelengths. Our lab has developed an intraoperative photoacoustic screening (iPAS) system. However, limited sensitivity to high frequency acoustic waves and limited detector coverage of the specimens has led to a limited spatial resolution (~2.5 mm). The objective of this project was to investigate improvements in spatial resolution using higher frequency transducers.

Methods: A detector array was constructed with 41 circular transducers positioned on two concentric circular rings aimed 25 mm away. The imaging area was illuminated via an optical window (~4 mJ/cm²) located at the center of the transducer rings. The array was tested on a qualitative text phantom, a line resolution phantom (108 μm polyester monofilament), as well as on porcine tissue (mammary, spleen, liver, and muscle) with comparison to x-ray CT and MRI.

Results: A high-resolution PAT system was developed. Imaging resolved monofilament diameter as 400 μm based on the full width at half max and was able to separately resolve lines 0.8 mm apart. However, tissue imaging was largely unsuccessful except for the spleen.

Discussion: With the current setup, a 6-fold resolution increase has been achieved over the iPAS system at the cost of sensitivity and depth penetration. This paves the way for the next iteration of iPAS which will incorporate a mixture of transducers. In addition, we will also investigate increasing the illumination for stronger photoacoustic signal generation.