Vascular Laser Thermolysis of Vessels Varying in Size in the CAM Model

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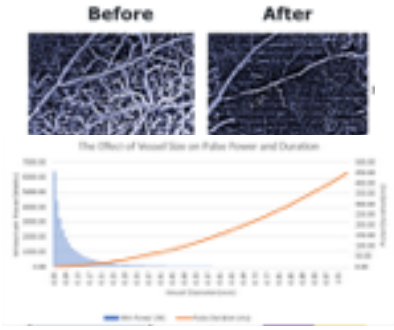
Introduction: Achieving hemostasis during tumor removal surgery is imperative to ensure that the patient being operated on has minimum blood loss. Blood specific laser coagulation offers stark advantages of reduced collateral damage during cancer microsurgery. Coupled with image guidance, the laser can be used for selectively targeting blood vessels during surgery. Optical Coherence Tomography(OCT) produces high-definition cross-sectional and three dimensional images that can reveal information about the structure, size and condition of several biological systems. These characteristics make OCT a great candidate for producing image-guided therapy when it comes to the vascular system. Paired with a 1070nm fiber laser, we can target and coagulate specific blood vessels depending on their size and depth beneath the tissue. A need exists for a methodology to coagulate the blood vessels considering the biological variance in the blood vessel size distribution. Here we present a technique to utilize the blood specific nature of the 1070nm laser wavelength to coagulate vessels in a chick chorioallantoic membrane (CAM) assay, while avoiding collateral tissue damage. The problem is, we need to pinpoint which powers and beam durations are needed to coagulate blood vessels of different sizes.

Materials and Methods: The CAM assay was used as a source of vasculature to test our image guided therapy. Using a drill and a syringe, we extracted 4ml of albumin from each egg to create a false air sac - in order to incite vascular growth. Each egg was then placed in the incubator. The next day, we opened the eggs more to expose the developing embryo. The eggs were then incubated for 8 days to allow for development of vessels that varied in size. On day 8, the eggs were placed under the OCT, and a vessel was chosen to target for coagulation. Using laser fluence, attenuation coefficients, specific heats and a desired change in temperature of 55°C(ΔT), we were able to deduce that each vessel needed 7.77 J of energy to achieve coagulation. However, pulse durations also change with vessel size as thermal relaxation times of bigger vessels are greater than those of smaller size. In order to ensure sufficient confinement of heat in the vessel to ensure coagulation, laser pulse durations were calculated separately for each vessel size. All vessels receive the same amount of energy: 7.77 J. However the time in which that energy is delivered varies. Bigger vessels received the energy over a longer period of time, while smaller vessels received the energy in a quicker period of time.

Results and Discussion: Using our calculated laser pulse duration and powers, we were able to coagulate vessels varying in size - after a few trials and adjustments to our absorption coefficients.



$$\Delta T = \frac{Q}{\rho c V} = \frac{\mu_a \langle \psi \rangle}{\rho c}, \qquad \tau_v = \frac{d^2}{16\alpha}$$

The formulas used to deduce the necessary energy and pulse durations needed for each vessel size

Figure 1. The image on the left is an OCT angiography of the beam spot location before coagulation. The image on the right is an OCT angiography of the same beam spot after it received pulses covering the range of small to medium sized vessels. The bar is equal to 100um. The figure below it shows the pulse durations and laser powers that successfully coagulated for a range of vessel sizes.

Conclusions: We can conclude that the values we tested and used for our attenuation coefficients, change in energy per vessel, and pulse duration were sufficient for the coagulation of vessels varying in size. In the future, it is hoped that this whole process can be simplified into one step through software. A program should be able to look at an OCT angiography, deduce a vessel size distribution, and choose specific laser powers and durations to coagulate vessels of the targeted size.

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