Laser-Assisted Blood Vessel Sealing Device

Abstract

The goal of this project is to design a laser-assisted vessel sealing device and determine the optimal wavelength and power density required to effectively cauterize blood vessels. Laser-assisted vessel sealing would be advantageous over the widely used electrothermal cautery during surgery, since there is a decreased risk of off-site burns using lasers. Various lens systems were modeled using Zemax, and several lens systems were selected for testing based on the theoretical irradiance at the sample plane. A beam profiler was used to select the lens system with the smallest beam diameter. This 3-lens system was used to focus a 6W 791nm laser diode to a point 54 µm in diameter onto chicken tissue up to 2mm thick. Videos of the heating process were analyzed for color change. The color change was used as an indication of when the structural proteins were denatured. The time required to burn the tissue and the diameter of the burnt hole were also recorded. In 11 trials, it took an average time of 3.91 minutes for the proteins to denature and 12.37 minutes for the tissue to burn. The average burn diameter was 1.27mm. For tissue to burn in under 2 minutes, a minimum power density of 166 W/mm² is required. In the future, the system can be designed using cheap materials and miniaturized, so it can be mass-produced as disposable forceps with a tip diameter of 0.5 to 1.5 mm.

Methods

Modeling
- Model absorption for different wavelengths
- Optimize lens systems using Zemax

Experimentation
- Assemble optical system
- Measure beam profile
- Burn hole in tissue
- Translate tissue to create full-length cut
- Record video on webcam

Analysis
- Upload webcam video into Matlab program
- Analyze color change
- Record time to burn and cut diameter

Results

2 mm thick slices of chicken thigh with an approximately 5 mm by 5 mm exposed area were used. The laser beam was focused inside the tissue. After 11 trials, it took the tissue on average 12 min 22 s to start burning. Once the tissue started burning, it took on average 4.55 s to burn a hole through the entire thickness of the tissue. The burn hole had an average diameter of 1.27 mm.

The tissue was also moved while burning to cut a line.

Matlab code subtracted the pixel values in the initial frame from each of the following frames. The frame right before the tissue started burning was set as the end point and used to normalize other values. It took on average 3 min 56 s for the color change to reach 75% of the final frame.

Conclusion & Future Work

This study has demonstrated that a 791 nm laser can generate the necessary temperature in tissue to denature proteins and cut tissue. A minimum power density of 166 W/mm² is recommended. Further work can test vessel sealing using a laser with an optimal absorption coefficient and translate this system for use during laparoscopic surgery. The design would house an optical system that fits inside commonly used surgical forceps, which have tip diameters of 0.5 to 1.5mm (Fig. 9). Any part that comes into contact with human tissue during surgery will be disposable to decrease the incidence of cross-contamination. The laser diode will be situated in a non-disposable attachment to send a high power laser into the tip.

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References