Laser Tissue Interaction and Real-Time OCT Monitoring

Degree programme: BSc in Micro- and Medical Technology | Specialisation: Optics and Photonics
Thesis advisor: Prof. Dr. Patrik Arnold
Expert: Dr. med. Dr. phil. Andreas Häberlin

In Switzerland, approximately 10% of people over 75 suffer from atrial fibrillation. There are several medical operations, like catheter based radio frequency ablation, that successfully eliminate this disease. However, existing methods lack a reliable feedback system. My goal is to perform this treatment using a high power laser and at the same time analyze the treatment success using optical coherence tomography.

Mirko Marinato
marinato.mirko@gmail.com

Introduction

Atrial Fibrillation (AF) if left untreated can lead to a stroke or heart failure. In case initial anticoagulant medicaments not achieve the desired effect, a minimal invasive operation as for example radio frequency ablation (RFA) is performed. The main reasons of using laser light in place of radio frequency for treatment are:

- Simple guidance in catheter
- Combination with optical coherence tomography (OCT)
- Fast treatment times

The absorption of light by a material generates heat. This thermal effect if applied for a certain time leads to coagulation of the tissue. Tissue in this state is no longer electrically conductive, thus, preventing unwanted electrical impulses from propagating, isolating the pulmonary vein.
Various factors determine the thermal effect on a tissue, such as wavelength, power, exposure time and fluence of the incident laser beam as well as the scattering, reflection and absorption coefficients of the tissue. Since each tissue type behaves differently, the heart of a pig was chosen for ex-vivo experiments as it is very similar to the human one.

Goals

The aim of this thesis is to understand and determine the optimal laser parameters for the treatment of tissue with laser and the comparison with RFA.
In addition, the capabilities of OCT as real-time monitoring tool are explored. Further goals are:

- Detailed study of treatment parameters
- Detailed study of OCT as monitoring tool for AF treatment
- Conducting ex-vivo experiments
- Comparing new method to conventional RFA
- Working OCT controlled AF treatment prototype

Concept

The basic concept is that the OCT and coagulation laser are perfectly aligned in order to treat and monitor the treatment success simultaneously. To this end, an experimental free space setup to combine the two lasers allowing to tune critical optical parameters was built. Both, two-dimensional and three-dimensional depth images can be acquired and used to analyze the procedure.

Results

Several experiments have been carried out using different powers, spot sizes, continuous waves and short pulse wave modes.
Maximum coagulation depths of 1.5-2mm and lateral dimensions up to 3mm were reached in 10-20s (see Figure), short times compared to the several minutes required by RFA. To reach the targeted penetration depths of 3-4mm a treatment laser around 1000nm is envisaged.
However, OCT as real-time imaging modality makes it possible to see the evolution of the thermal effect and allows to predict vaporization and carbonization of the tissue. Further investigations will reveal the capability of OCT to predict the size of coagulation assuming uniform heat spread.

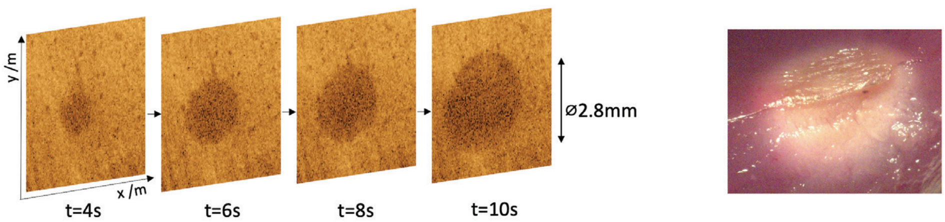

Figure: Time evolution of thermal effect up to coagulation, Enface OCT and microscope analysis