Novel laser energy applications for the treatment of cardiac arrhythmias

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Significance of Investigation

In this thesis, the studies' aimed to investigate the technical feasibility of laser energy in the treatment of cardiac arrhythmias. These energy-based treatments are called ablation therapy.

Several arrhythmias can be treated by ablation therapy, selectively destroying abnormal tissue to inhibit cardiac arrhythmia. In current ablation therapies, a catheter heats or cools the cardiac tissue to prevent the occurrence and sustainment of the arrhythmia. In the past, laser energy was already explored as feasible energy source for this treatment of cardiac arrhythmias. The linear laser catheter developed and investigated in this thesis could provide an alternative to the existing ablation devices, by delivering the necessary energy to the tissue, achieving the required tissue coagulation.

To deliver the necessary laser energy to the target site, the light needs to be transported and emitted at the desired location. Via an optical fiber the light can be transported from the laser source into the heart. By creating small openings at the end of the optical fiber light is emitted laterally over 20mm. The ability to extract laser light laterally in a linear fashion by creating small holes in the fiber is unique. The completeness of linear ablation is positively associated with ablation success and can be difficult to obtain with current ablation devices. Compared to focal treatment linear emission allows a homogeneous tissue treatment over a longer area, fostering improved procedural outcome and reduced duration.

The technical feasibility, laser interaction and preliminary safety of the catheter design was tested in lab conditions with freshly excised animal tissue (*ex vivo*) and later confirmed during animal studies (*in vivo*). *In vivo* studies showed good results in energy applications from inside (endocardial) and from outside (epicardial) the heart suggesting suitability as alternative to existing treatment devices. The presented results in this thesis contain important new information regarding fast and linear creation of lesions by laser energy, with a small and flexible ablation catheter.

In contrast to the previous *ex vivo* and *in vivo* investigations, laser can also be applied in a pulsed fashion. In these applications optical power appears in pulses of some duration at some repetition rate.
In past research the beneficial properties of pulsed laser sources were investigated. The inherent cool down period between the pulses can reduce or even prevent excessive tissue damage, and increases the safety of energy applications. By *ex vivo* studies these beneficial properties could be confirmed for the developed laser ablation catheter. Damage to the cardiac tissue, and susceptibility to blood clot formation due to laser ablation could be reduced. These findings also of interest for presently existing laser ablation devices to increase procedural safety.

Finally, a possibility was sought, to visualize the lesion formation process. The utilized optical fiber of the ablation catheter also allowed normal light to be transported to the target site, besides the usual laser energy dose. By integrating an extra fiber, the reflection of the normal light could be captured. The recorded spectrum can provide information about the examined tissue. High reflection of red light indicates untreated tissue and low reflection treated tissue. Analysis of the spectra before and after successful treatment showed this reduced reflection of red light, indicating tissue ablation. This could provide the physician with useful information about the catheter position and the successful execution of the ablation procedure.

Overall, the obtained results contribute to understanding how laser can treat arrhythmias by ablation therapy and improve catheter ablation procedures. Furthermore, the results uncovered new capabilities of fiber-based optical systems, allowing lateral extraction of light from an optical fiber. Thus, general interest is created for the physician-scientist in the field of catheter ablations but also for the physicist studying fiber-based optical systems.