Cardiac Virtual Biopsy by OCT

Biomedical Engineering / Prof. Christoph Meier, Prof. Dr. Dr. Rolf Vogel, Prof. Dr. Volker Koch
Projectpartner: ARTORG Center, Cardiovascular Engineering, Bern
Medical University Vienna, Center of Biomedical Engineering and Physics, Vienna

Allograft rejection is a common problem after heart transplantation. Today, routine endomyocardial biopsy is required for the monitoring of the optimal clinical management after cardiac transplantation. This project is targeted at the major drawback of cardiac biopsy, which in fact is a destructive method. By means of Optical Coherence Tomography, a non-destructive, virtual biopsy is sought to be developed. This master thesis comprises the initial steps for this promising project by developing of a biological phantom and by performing ex-vivo measurements for detecting lymphocyte infiltration.

Lukas Bösch

After heart transplantation (allo) graft rejection can occur as immunologic reaction of the host. For an adequate treatment strategy and since most patients are asymptomatic in early stages, monitoring by endomyocardial biopsy with subsequent histological assessment is required to identify lymphocyte infiltration into heart tissue. This gold standard is performed according to a standard protocol and to the clinical status of the patient (yearly up to weekly investigation). The specimens are harvested minimal-invasively by inserting a catheter either into the jugular or the femoral vein. Subsequently, this catheter is advanced into the right ventricle and up to four samples are taken from arbitrary sites of the septal wall using a forceps. Besides complications such as cardiac perforation or destruction of the tricuspid valve, the approach is inherently associated with a sampling error, resulting false negative outcomes. Furthermore tissue from a transplanted organ is, independent of it health state, removed piecewise.

Therefore a non-destructive method for the in-situ detection of lymphocytic infiltrates inside the cardiac muscle is highly desired. Optical Coherence Tomography (OCT), a new emerging biomedical optical imaging method, is capable to provide high-resolution, cross-sectional tomographic images through a simple fiber-optic access. While the penetration depth of light in non-transparent tissue is limited to 2-3mm, the resolution down to 1µm allows for imaging on cellular level.

Due to the lack of clinical samples, ex-vivo measurements on artificial and biological phantoms were performed on a dedicated phantom that had to be developed for this thesis. Mice hearts with induced myocarditis showed a similar histo-pathological pattern with extensive infiltration of lymphocytes throughout the whole cardiac muscle. Local lymphocyte spots are existent, especially on outer layers of the heart. Therefore, we mainly performed measurements from the epicardial side of these mouse hearts using OCT with wavelengths of 860nm and 1310nm. Furthermore, polarization sensitive OCT (PS-OCT) was performed with both wavelengths.

First visual sighting is heartening, as differences between healthy and infiltrated heart tissue were observed: For 1310nm alignment of patterns on micrometer scale for the infiltrated heart tissue were observed. For 860nm, dark areas which have equal expansion as infiltration spots observed in histological cuts were visible. On both wavelengths, extensive cardiomyopathy can be well recognized. PS-OCT images showed differences in phase retardation. At the moment, no statement concerning the statistical significance is possible based on the observations above and therefore, ongoing work should provide evidence. However, with the developed phantom a big facilitation for the future research is available.