Public summary of PhD thesis of Ümit Arabul
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Improved diagnosis of stroke and heart attacks via photoacoustic imaging

Cardiovascular diseases (CVDs) are the number one cause of death in today's world. One of the most common causes of CVDs is *atherosclerosis*, the accumulation of fatty plaques in arteries. Atherosclerosis might be fatal if the plaques rupture or inhibit blood flow to tissues and vital organs, resulting in strokes or heart attacks. Current diagnostic tools to visualize vascular plaques are still suboptimal and, as a result, a high number of rupture events remain overlooked. In his PhD project, Ümit Arabul developed a diagnostic method based on photoacoustic imaging (PAI) to visualize internal bleeding of a plaque, which is a strong indicator of plaque's rupture. Pre-clinical tests performed by Arabul demonstrate the higher potential of PAI over the clinically available imaging techniques for the prevention of strokes and heart attacks.

Atherosclerosis is a slow and progressive cardiovascular disease characterized by the buildup of fats, cholesterol and other substances in the artery walls ("plaques"). Vascular plaques can restrict blood flow and impede the transport of oxygen and nutrients from the heart to the rest of the body. Although the exact cause of atherosclerosis is unknown, it might be ascribed to wrong dietary habits, a sedentary life, smoking, and to comorbidities, such as obesity and arthritis. Early diagnosis and timely treatment can stop atherosclerosis from worsening and prevent, for example, a heart attack or a stroke.

Ultrasound imaging and surgical intervention

To date, plaque's rupture can be avoided only by surgical intervention. Doctors choose whether to surgically remove a plaque or not by looking at its size via ultrasounds (US). However US are not capable of visualizing plaque's composition and internal bleeding, which are stronger indicator of rupture than the plaque's size. For this reason, current imaging techniques based on US remain suboptimal, and several patients still undergo unnecessarily risky treatments while dangerous cases are missed.

Photoacustic imaging

In his PhD project, Arabul used a technique called photoacoustic imaging (PAI) in combination with US to investigate plaque's composition and bleeding. In PAI, laser pulses are directed towards biological tissues which respond by absorbing the transferred energy and by emanating ultrasonic emissions. Ultrasonic emissions are then converted into images by an ultrasonic transducer. As optical absorption and the magnitude of the resulting ultrasound emission depend on the physiological properties of the tissue, tissue composition can be visualized.

Improved diagnosis

Arabul developed an innovative and low-cost PAI device that can be attached to clinically available US systems. To test this device, Arabul used human carotid plaques obtained from patients of the Catharina Hospital of Eindhoven. Also, Arabul introduced new experimental approaches and data processing techniques to improve the quality of the images created by PAI. With the developed techniques, he was able to visualize intraplaque bleeding. The results obtained by Arabul demonstrate that PAI is quickly progressing from a mere laboratory-based technique to a valid clinical alternative to diagnose rupture-prone plaques and, thus, reduce the overall risk of strokes and heart attacks.

Ümit Arabul is a PhD candidate in the group of Cardiovascular Biomechanics at the Biomedical Engineering Department of TU/e. His research is part of the FULLPHASE and CVENT program. On December 7th 2018, Arabul will defend his PhD thesis entitled "Multi-wavelength photoacoustic imaging of the atherosclerotic carotid artery", with prof. ir. Frans van de Vosse as Promotor, and dr. ir. Richard Lopata and dr.ir. Marcel Rutten as co-promotors.