Popular science summary

Atrial fibrillation (AF) is the most common sustained heart rhythm disorder, affecting millions worldwide. It is a progressive condition in which the upper chambers of the heart (the atria) beat rapidly and irregularly due to disorganized electrical activity. This electrical activity controls the contraction of the heart muscle and is influenced not only by the arrhythmia itself but also by the autonomic nervous system, the body's control network for "fight-or-flight" (sympathetic) and "rest-and-digest" (parasympathetic) responses. Breathing patterns and shifts in the balance between these two branches can affect how the heart's electrical signals are generated and conducted. Understanding these interactions is important, as they may play a role in how AF develops and progresses over time, offering clinicians potential markers to better assess heart function and guide more personalized treatment.

This thesis investigates how information contained in the electrocardiogram (ECG) can be used to study respiratory and autonomic influences on the heart, both during AF and during exposure to environmental air pollution. Advanced signal processing techniques are applied to ECG data from patients and healthy volunteers to reveal patterns that cannot be seen through visual inspection alone.

The first part of the work focuses on AF, where the irregular rhythm makes it challenging to measure autonomic nervous system activity from the ECG. New methods are developed to detect subtle variations in the small "f-wave" oscillations of the ECG, characteristic of AF, that are linked to breathing cycles and changes in nervous system activity. The second part applies techniques to study healthy individuals exposed to exhaust from hydrotreated vegetable oil (HVO), a renewable diesel fuel, in order to examine how short-term air pollution affects the heart's regulation.

The results show that, even in the irregular rhythm of AF, it is possible to assess respiratory modulation in the f-wave of the ECG. This modulation appears to be linked to parasympathetic activity in the atrial tissue, offering a new way to study autonomic influences despite the absence of normal heart rhythm. In the environmental exposure studies, different signal processing techniques were applied to ECGs from healthy individuals, but no consistent short-term changes in the heart's autonomic regulation were observed during exposure to exhaust.

Overall, the findings demonstrate that the ECG can serve as a valuable, non-invasive tool for studying respiratory and autonomic function in both disease and environmental health contexts. In the long term, this research could contribute to earlier diagnosis, more tailored treatments, and a better understanding of how environmental factors influence heart health.