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A novel tool for non-invasive monitoring of uterine electrical activity during pregnancy via electrohysterography

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The design described in this thesis has been carried out in accordance with the TU/e Code of Scientific Conduct.

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Public Summary

Monitoring uterine activity throughout gestation is essential to ensure a normal pregnancy course and to prevent dysfunctional or preterm labor, which may increase the risk of premature births and compromise fetal well-being. Early diagnosis plays a crucial role in guiding appropriate clinical interventions and is currently supported by tailored monitoring tools, such as external tocography and intrauterine pressure catheters. However, these standard approaches are limited in their application by poor measurement reliability and invasiveness, respectively. Consequently, during last decades, a novel monitoring method, i.e. electrohysterography (EHG), has emerged. By using surface electrodes placed on the maternal abdomen, EHG is a promising non-invasive and safe technique for assessing uterine electrical activity, providing relevant information about the intensity, frequency, and duration of uterine contractions. Therefore, it has the potential to improve labor management by effectively discriminating between contractile periods and uterine resting tone.

In this context, EHG is especially suitable for integration into sustainable, wearable, and user-comfortable devices, which promote maternal and fetal monitoring in home and remote-care settings. In particular, supporting this ongoing translation in the healthcare system is the objective of the European initiative called "Newlife". In fact, one of its main goals is developing an innovative fetal monitoring patch capable of acquiring multi-sensor vital data, including ultrasound (US), electrocardiography (ECG), and EHG signals. Thanks to the combination of these complementary sources of information, the fetal patch can predict pregnancy-related complications and risks across different gestational ages, thereby enabling timely and targeted treatments.

This Engineering Doctorate thesis is part of the broader Newlife project and specifically focuses on the design of an automated tool for detecting uterine contractions from EHG recordings acquired during both labor and pre-labor periods. This software component was developed with the long-term objective of promoting its integration into the fetal monitoring patch, enabling the extraction of clinically meaningful parameters from continuously acquired biosignals. To support this goal, the project also included, in collaboration with Sencure, the selection of the most suitable dry electrode prototype to embed into the Newlife patch for reliable EHG signal acquisition.

Both the automated detection tool and the electrode integration process were developed through an iterative design and verification procedure aimed at ensuring compliance with the initially defined requirements. The resulting automated tool demonstrated a computational efficiency compatible with near–real-time operation and achieved contraction detection accuracy on labor recordings comparable to literature-reported values. More importantly, performance on the pre-labor subset was similar to that on the full test set, proving that accurate contraction detection is feasible even during early gestational ages. Moreover, textile-based and flat PET-based dry electrode prototypes achieved signal quality comparable to that of conventional gel electrodes.