Tomasz Kupka MSc. – Summary of the PhD dissertation

"Methods of determining the fetal heart rhythm from the ultrasound signal"

Currently, the basic and commonly used method of fetal monitoring is cardiotocography, which is based mainly on the analysis of the fetal heart rhythm (FHR) variability. The computer-aided cardiotocography is gradually becoming a standard, as it allows a more detailed analysis of the signal. Through the extraction of information hidden for visual interpretation, such as assessment of the instantaneous fetal heart rhythm variability, with the beat-to-beat accuracy. Unfortunately, the applied fetal monitors, which were developed while they were still fully autonomous devices, do not provide the required quality and accuracy of the signal. This fact was an inspiration to undertake research work as part of the presented doctoral dissertation.

The basic aim of the dissertation was to develop methods for the analysis of the signal describing the mechanical activity of fetal heart, which will allow delivering the fetal heart rate signal in the form of a time event series. This concerns both a full Doppler ultrasound signal and determined on its basis the fetal heart rate signal in the form of evenly measurements of instantaneous FHR values.

First, a metrological evaluation of a classic fetal monitor (a model commonly used in clinical practice) was carried out. The author identified basic errors in the form of invalid and duplicate measurements, making it impossible to reliably analyze the beat-to-beat variability of the FHR; and then developed a method for correcting invalid measurements and two methods for correcting duplicate measurements. The proposed original method for evaluating algorithms enabled a detailed analysis of their operation at the level of individual heart cycles. The most important element of the conducted research was the development of a complex Doppler ultrasound signal processing channel, enabling precise measurement of periodicity. The author has developed four different methods, three of which are based on the autocorrelation function, with dedicated algorithms for extracting the resulting sequence of events. The fourth method was based on cross-correlation, in which the sequence of events was obtained directly at the stage of determining successive heart cycles. An important part of the research concerned the determination of optimal values for particular control parameters, in terms of the accuracy of FHR measurement as well as clinical indices describing the instantaneous FHR variability.

The final stage of the work concerned the metrological evaluation of the proposed new methods for mechanical fetal heart activity analysis in comparison to the reference values determined from the fetal electrocardiogram. The author proposed two independent comparative procedures. In the first, the direct comparison of FHR signals was based on the assessment of differences between the corresponding instantaneous values. This allowed us to assess the accuracy of the Doppler ultrasound signal processing method, in the aspect of classical FHR signal analysis including detection of acceleration/deceleration and tachycardia/bradycardia patterns. The second procedure allowed the assessment of the impact of the determined FHR signals on the values of clinical indices describing the instantaneous variability in the short-term and long-term.

The proposed measures of agreement allowed to confirm the justification for determining the instantaneous FHR variability in signals recorded with the Doppler ultrasound method, and the obtained results of the research made it right to formulate the thesis.