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Intelligent multichannel sensors for pulse wave analysis

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Abstract

Aortic pulse wave velocity is an independent predictive indicator for all cause mortality and cardiovascular morbidity. Unfortunately it is only invasively accessible and thus the A. carotis–A. femoralis pulse wave velocity (cfPWV) is recommended as a non-invasive substitute. This work presents a model based analysis method for the beat-to-beat online determination of an arbitrary, peripheral pulse transit time (PTT). The method is based on the recording of a three lead electrocardiography (ECG) and of pulse waves (PW) at a peripheral site such as the A. carotis by means of a multiple sensor array. The two modules for the signal acquisition work autonomously but time-wise simultaneously and transmit the data via a radio unit to the central processing unit. There the algorithms for the pulse transit time determination exploit these signals. In doing so the main focus is on an efficient implementation to assure real-time usability. The evaluation of the developed modules and algorithms was done in two separate trials. First the algorithms were tested offline against manual signal annotation using invasive data previously recorded to proof their accuracy. The resulting mean differences in PTT for pulse waves assessed at the aortic root and the aortic bifurcation are 2.86 ms (4.72 ms SD) and 2.00 ms (2.28 ms SD). To evaluate the whole system integrity in a second step online measurements on probands were carried out and compared to data from literature. The trials resulted in a mean PTT of 174.6 ms (17.7 ms SD) for the A. radialis and of 81.9 ms (13.2 ms SD) for the A. carotis. The results suggest that the method may be useful and deployable at general practitioners (GP) and in ambulatory care of (chronic) cardiovascular diseases.

Keywords: Pulse transit time; Pulse wave velocity; Arterial stiffness; Cardiovascular risk; Electrocardiography

1. Introduction

The medical research regarding hypertension has changed considerably during the last two decades. Around the year 1990 the diastolic blood pressure has been the most important value to look at [18] and about ten years later the focus has been on the systolic blood pressure. With the beginning of the new millennium the topic of arterial stiffness of major vessels related to hypertension has slowly arisen in clinical practice. Arterial stiffness and its indicators have

Abbreviations: BP, blood pressure; cfPWV, A. carotis–A. femoralis pulse wave velocity; dBP, diastolic blood pressure; ECG, electrocardiography; FIR, finite impulse response filter; ICA, independent component analysis; Idx_{ao}, index of the artificial onset point; Idx_s, index of the maximum slope; Idx_o, index of the onset point of the pulse wave; INA, instrumentation amplifier; LED, light-emitting diode; $p(Idx_s)$, pulse wave signal at the maximum slope point; $p(Idx_o)$, pulse wave signal at the onset point; $p'(Idx_s)$, differentiated pulse wave signal at the maximum slope point; $p'(Idx_o)$, differentiated pulse wave signal at the onset point; PTT, pulse transit time; PW, pulse wave; PWV, pulse wave velocity; sBP, systolic blood pressure; SD, standard deviation.

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