Estimation of the central blood pressure waveform from the radial photoplethysmogram

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Abstract: Recently, there is an increase in global interest to access the central blood pressure waveform (CBP) [1]. It is already demonstrated that the CBP conveys ample significant information which can be used for early diagnosis of cardiovascular diseases [2]. The aorta is mostly attended for obtaining the CBP due to the particular configuration between aorta and the heart. The CBP waveform can be obtained via both invasive and non-invasive approaches. The most reliable way to obtain the CBP is cardiac catheterization in which a very thin-flexible tube is inserted into an artery (e.g. femoral, radial) to be guided to the aorta. However, this is not a routine clinical practice for diagnosis and monitoring blood pressure due to its complexity and cost [3]. Alternatively, the CBP waveform can be estimated from distal pressure signals (e.g. radial, femoral or carotid) non-invasively. The SphygmoCor is a well-known device of such method in which the CBP waveform can be estimated from the radial pressure pulse via a transfer function [4]. Using this device, the radial pressure pulse is obtained by attaching an applanation tonometer around the subject's wrist (radial artery) so that the CBP waveform can be estimated near real-time. In fact, the applanation tonometry is a piezoelectric sensor which is used to convert the pulsatile blood flow to an electrical signal (radial pressure pulse). However, this technique is highly operator dependent because the tonometer should be vigilantly placed (adjusted) over the radial artery by an experienced operator. Such limitation makes it less popular in clinical practice.

Our method: We recently propose a new approach to estimate the CBP waveform via *Photoplethysmography (PPG)*. PPG is an established technique to access the blood volume change using an optical sensor. Nowadays, PPG is widely used in clinical practice because this approach is considerably easy to use, operator independent and cost-effective [5]. This paper explains the main concept of our proposed technique in which, the CBP waveform can be consistently estimated from the radial PPG signal. We used the SphygmoCor device to obtain the CBP waveform. At the same time, an optical sensor was used to obtain the radial PPG signal. A mathematical model (transfer function) between the SphygmoCor-derived CBP waveform and the radial PPG was then established.

Data collection: In order to obtain the CBP waveform, the applanation tonometry of the SphygmoCor was attached to the subject's right wrist. At the same time, an optical sensor was attached to the left wrist to obtain the radial PPG (RPPG). An earlier-designed Labview program was used to display the signals. Using this program, each signal was separately displayed in a specific window (real-time). The goodness of signals was visually checked by an operator on site. The CBP and RPPG waveforms were simultaneously recorded using a data acquisition unit (NI 9239). Data were stored -in a laptop- in ASCII format with default sampling rate of 1613 Hz.

Data Analysis: As a first step of data analysis, all signals were processed using the Matlab 2012. A typical low-pass filter with a cut-off frequency of 15 Hz was used to remove the effect of motion artifacts (noise). In order to estimate a dynamic model between the CBP and RPPG, a fourth-order autoregressive models with exogenous input was estimated using Matlab, System Identification toolbox. To this end, processed signals were fragmented into several segments of three seconds lengths. Then, a time series data was generated by addressing the CBP segment as model input and its corresponding RPPG segment as an output. An individual model was estimated for each particular segment. Then, an averaged model was computed by averaging among coefficients of all individual models. Hence, at the end of this section, a single forward model was computed which could estimate the RPPG signal from the CBP waveform. However, the main objective of the proposed technique is to estimate the CBP waveform from the RPPG signal so that an averaged model was inversed. It was done by interchanging the numerator and denominator of the averaged model. The inversed model was then applied to the measured data knowing that model input and output are RPPG and CBP respectively. The result shows that, the CBP waveform can be reliably estimated from the RPPG signal with overall fitness value of 89%. Figure 1 shows the similarity between measured data (measured CBP from the SphygmoCor) and the proposed model-derived CBP waveform.

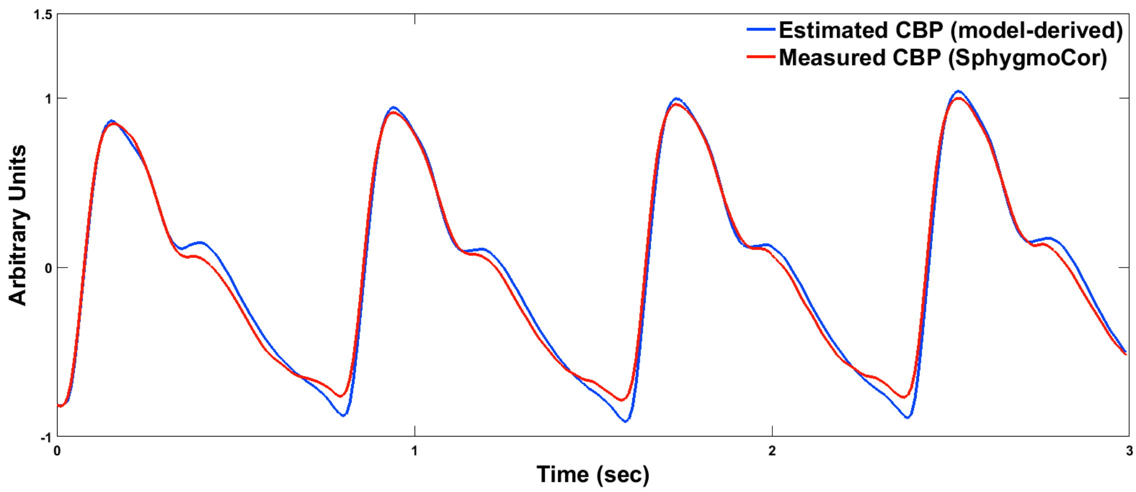

Fig.1: The similarity between measured and estimated CBP waveforms.

Conclusion: The proposed technique can be considered as a potential operator independent screening tool of the CBP waveform. Furthermore, it can be used to assess the central vascular stiffness and some other hemodynamic parameters through further investigation. Our team is currently working on the suitability of this model among more subjects including both healthy and unhealthy individuals. Primary result confirms the goodness of such a model to be clinically used.

References

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