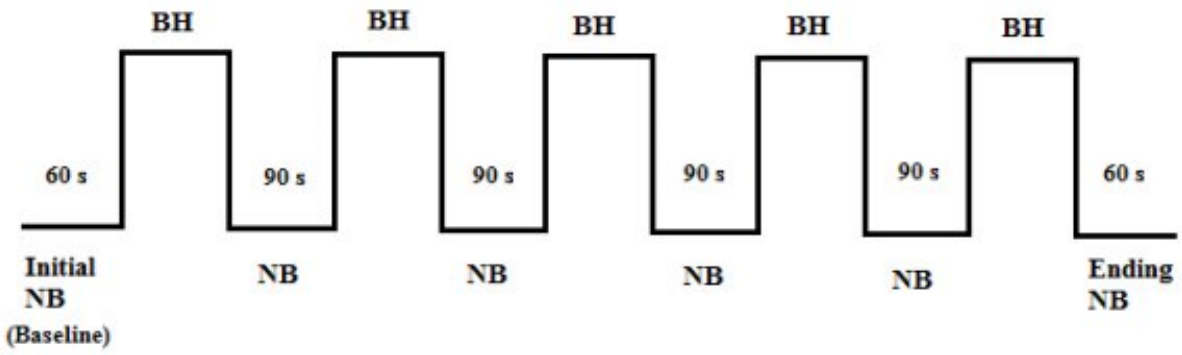
Using photoplethysmography signal for mathematical modeling of arterial blood pressure

November 26 2018, by Ingrid Fadelli



Timing diagram of protocols (NB: Normal breathing, BH: Breath hold). Credit: Soltan zadi et al.

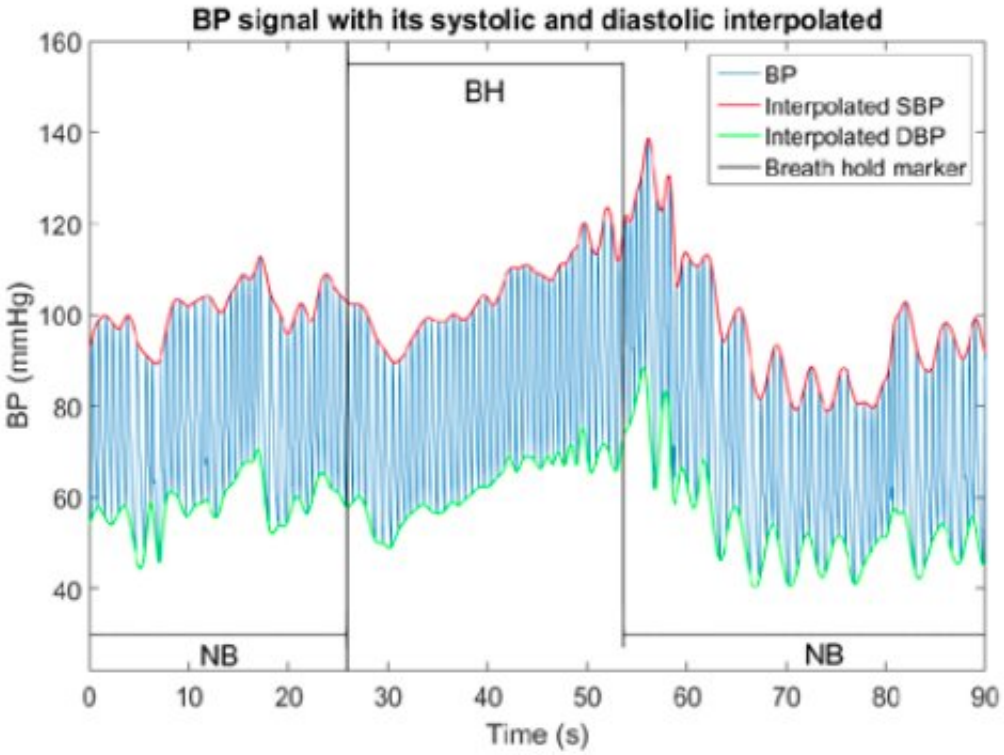
A team of researchers at the University of Texas at Arlington and the University of Texas Southwestern have recently developed a new method to estimate systolic (SBP), diastolic (DBP), and mean (MBP) blood pressure waveforms from photoplethysmography (PPG) signals. PPG is a simple, low-cost, and non-invasive optical technique that detects volumetric changes in the blood within the peripheral circulation. PPG is widely used within clinical settings, both for physiological measurement and monitoring.

Recent research has highlighted the presence of significant oscillations in nocturnal blood pressure (BP) among patients affected by obstructive sleep apnea (OSA). The high frequency and intensity of these oscillations, which typically occur during every apnea episode, suggest that studying them could reveal the root causes of the cardiovascular and cerebrovascular comorbidities of OSA.

While the physiological implications of these BP oscillations are still unknown, developing instruments that can detect them and estimate their magnitude remains of key importance. Existing polysomnography instruments do not allow beat-to-beat measurement of BP; yet some do measure oximetry. The PPG signal detected using sleep lab oximeters could help researchers to measure the magnitude of BP oscillations.

"We have investigated a new method for continuous estimation of systolic (SBP), diastolic (DBP), and mean (MBP) blood pressure waveforms from PPG," the researchers wrote in their paper, which was pre-published on arXiv. "Peaks and troughs of PPG waveform are used as input to a fifth-order autoregressive moving average model to construct estimates of SBP, DBP, and MBP waveforms."

In other words, the researchers used peaks and troughs of the PPG waveform to model SBP and DBP, with autoregressive moving-average (ARMA) models. ARMA models are system identification methods that provide a mathematical model for the dynamics of a system, as well as highlighting any pure time delay.



BP signal and systolic and diastolic interpolated values during breath-hold. Credit: Soltan zadi et al.

Past research suggests that breath hold maneuvers can closely simulate apnea episodes. The researchers hence evaluated the performance of their method on seven subjects in a supine position. These patients were asked to do five breath hold maneuvers, with 90-second periods of normal breathing between each one.

"The findings of this pilot study demonstrate that estimating systolic and diastolic BP from PPG measurements using ARMA models can be a viable method for continuous and non-invasive measurement of key BP focal points in OSA subjects, with accuracy levels comparable to previously reported values," the researchers wrote.

Overall, the study further confirmed the potential of using PPG signal gathered by sleep lab oximeters in conjunction with ARMA models to measure the magnitude of BP oscillations in patients affected by sleep apnea. Ultimately, such instruments could help researchers to better understand the significance of these oscillations and their connection with cardiovascular conditions typically associated with OSA.

Despite these promising results, it is unlikely for a single model to effectively estimate the BP of all members of the population using PPG variations. In future, such a model might hence need to be tailored around individual patients.

"The likely need for person-specific models stems from the fact that there is a wide variation in the physiological systems involved in the control of blood pressure which includes responsiveness of the sympathetic nervous system, mechanical, fluid mechanics, dynamical properties of the cardiovascular system, and metabolic rate," the researchers wrote.

More information: Mathematical modeling of arterial blood pressure using photo-plethysmography signal in breath-hold maneuver. arXiv:1811.06541 [eess.SP] arxiv.org/abs/1811.06541

Armin Soltan zadi et al. Mathematical Modeling of Arterial Blood Pressure Using Photo- Plethysmography Signal in Breath-hold Maneuver, *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (2018). DOI: 10.1109/EMBC.2018.8512776

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