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Citation: Kyriacou, P. A., Shafqat, K. & Pal, S. K. (2007). Photoplethysmography and blood oxygen saturation during blood pressure cuff-induced hypoperfusion. *Anesthesia and Analgesia*, 105(6), S100-S115. doi: 10.1213/01.ane.0000290771.60068.d5

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Photoplethysmography and blood oxygen saturation during blood pressure cuff-induced hypoperfusion

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Purpose of the study

The primary aim of this pilot study was to investigate the morphology and amplitude of the photoplethysmographic (PPG) signal and its effect on blood oxygen saturation (SpO₂) under controlled vasoconstriction.

1. Methods

A reflectance finger PPG/SpO₂ probe was constructed comprising two infrared and red emitters and a photodetector. A processing system was also developed^{1,2} to detect and pre-process the PPG signals. Blood oxygen saturation values were also obtained using a commercial transmittance finger pulse oximeter (*Diascope 2 VISMO*; S&W Medico Teknik). PPG traces from the custom made pulse oximeter, and SpO₂ traces from the commercial pulse oximeter were digitised by a 16-bit data acquisition card. A virtual instrument (VI) implemented in LabView was used for the displaying and storing of all acquired signals. The digitised signals were analysed offline in Matlab 6.5.

The institutional Ethics Committee approved this study, and all subjects gave written consent for participation. Fourteen healthy volunteers, mean age, $\pm$ SD (28 ± 5.2) participated in this study. Volunteers were told to rest comfortably in the supine position in an examination table for three minutes to obtain a stable haemodynamic period. The cuff of the sphygmomanometer was then placed on the left arm at the level of the brachial artery. The custom made reflectance finger PPG/SpO₂ probe was placed on the index finger of the left hand and the commercial pulse oximeter was placed on the ring finger of the same hand. Hypoperfusion was induced by gradually occluding the brachial artery at increments of 10 mmHg (10-15 seconds per pressure increment). During the gradual hypoperfusion process all parameters were monitored and recorded.

2. Results

Measurable PPG traces were obtained in all volunteers in all pressures taken prior to complete arterial occlusion where the finger PPG signals ceased due to no blood flow to the finger. Figure 1 gives the mean (SD) of the ac infrared PPG amplitudes at the different pressure increments. A Kruskal-Wallis One Way Analysis of Variance on Ranks test showed that there were statistically significant differences between the ac PPGs in the low pressures (0 to 80 mmHg) than those in the upper pressures (90 to 150 mmHg) at both wavelengths. The SpO₂ values from both pulse oximeters were decreased gradually as the cuff pressure increased. With the systematic occlusion of the brachial artery the volume of blood reaching the finger was decreased and that was obvious from the changes in the amplitude of the ac PPG signal from the custom made finger probe. In many occasions the commercial pulse oximeter failed to give any saturation values after the release of the cuff for approximately 100 seconds, where the custom made probe was able to estimate SpO₂ immediately after the cuff was released.

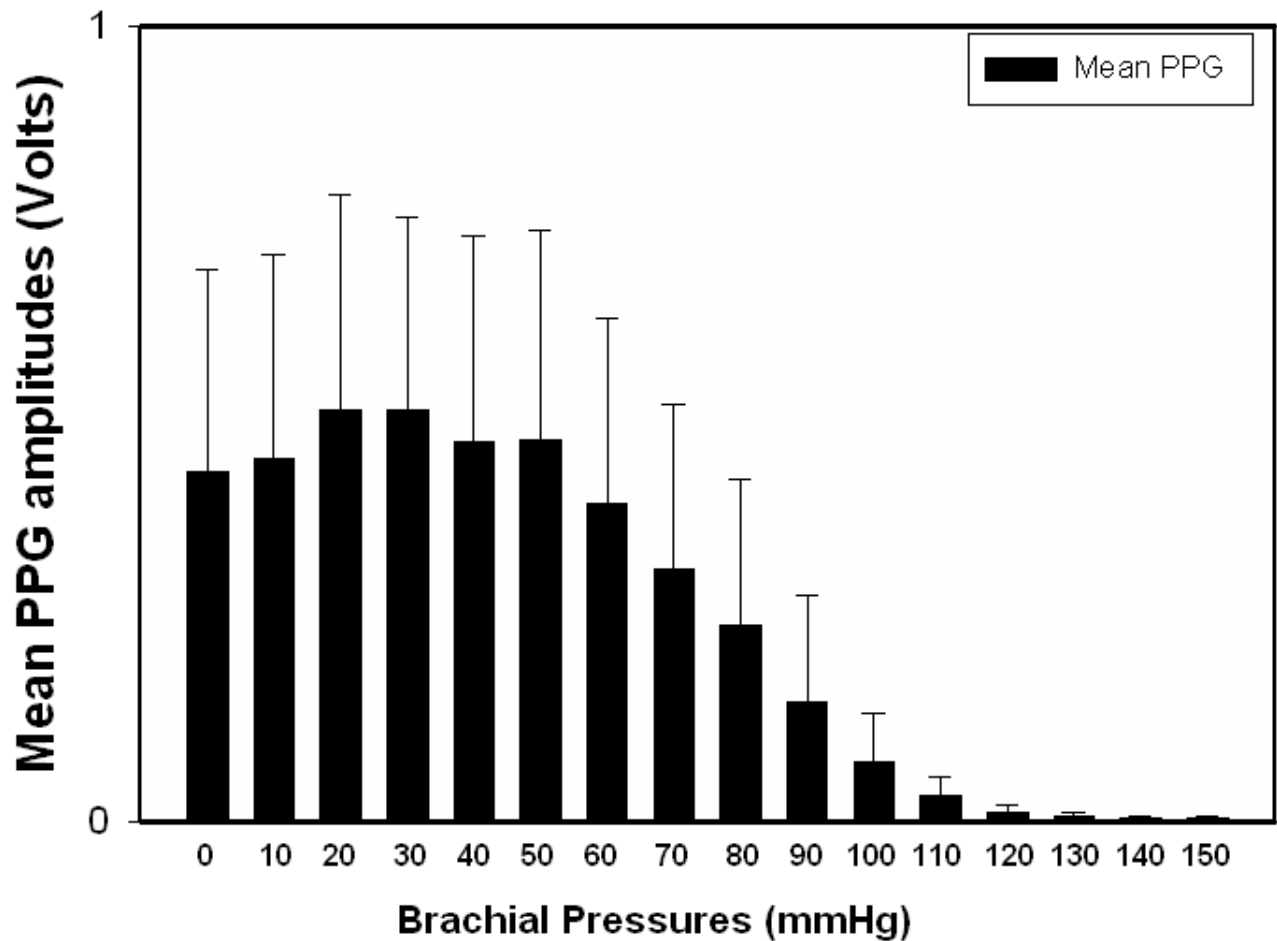


Figure 1: Mean infrared ac PPG amplitudes (SD) at various pressure increments

3. Discussion and Conclusion

Good quality PPG signals with large amplitudes were measured at all induced pressures prior to complete occlusion of the brachial artery in all volunteers. During hypoperfusion the amplitude of the PPG signals were decreased gradually to the point that were not visible. The decrease in the amplitude of the PPG signals correlated well with the decrease in SpO_2 . This is in agreement with the physiological phenomenon that suggests that during arterial vessel stenosis the volume of blood decreases with a direct effect on SpO_2 values measured at a vascular site downstream from the stenosis. The custom finger pulse oximetry was found to be more sensitive to SpO_2 changes during induced hypoperfusion when compared with the commercial pulse oximetry. Additional clinical studies, in a group of patients with peripheral vascular disease, are suggested to investigate such a phenomenon further.

References

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