



City Research Online

## City, University of London Institutional Repository

---

**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

This is the accepted version of the paper.

This version of the publication may differ from the final published version.

---

**Permanent repository link:** <https://openaccess.city.ac.uk/id/eprint/14698/>

**Link to published version:** <https://doi.org/10.1213/01.ane.0000290771.60068.d5>

**Copyright:** City Research Online aims to make research outputs of City, University of London available to a wider audience. Copyright and Moral Rights remain with the author(s) and/or copyright holders. URLs from City Research Online may be freely distributed and linked to.

**Reuse:** Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge. Provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

---

---

---

City Research Online:

<http://openaccess.city.ac.uk/>

[publications@city.ac.uk](mailto:publications@city.ac.uk)

---

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

P. A. Kyriacou<sup>1</sup>, K. Shafqat<sup>1</sup>, S. K. Pal<sup>2</sup>

<sup>1</sup>School of Engineering and Mathematical Sciences, City University, London, EC1V 0HB, UK

<sup>2</sup>St Andrew's Centre for Plastic Surgery & Burns, Broomfield Hospital, Chelmsford, CM1 7ET, Essex

[P.Kyriacou@city.ac.uk](mailto:P.Kyriacou@city.ac.uk), [K.Shafqat@city.ac.uk](mailto:K.Shafqat@city.ac.uk), [Sandip.Pal@meht.nhs.uk](mailto:Sandip.Pal@meht.nhs.uk)

## 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 (SpO<sub>2</sub>) under controlled vasoconstriction.

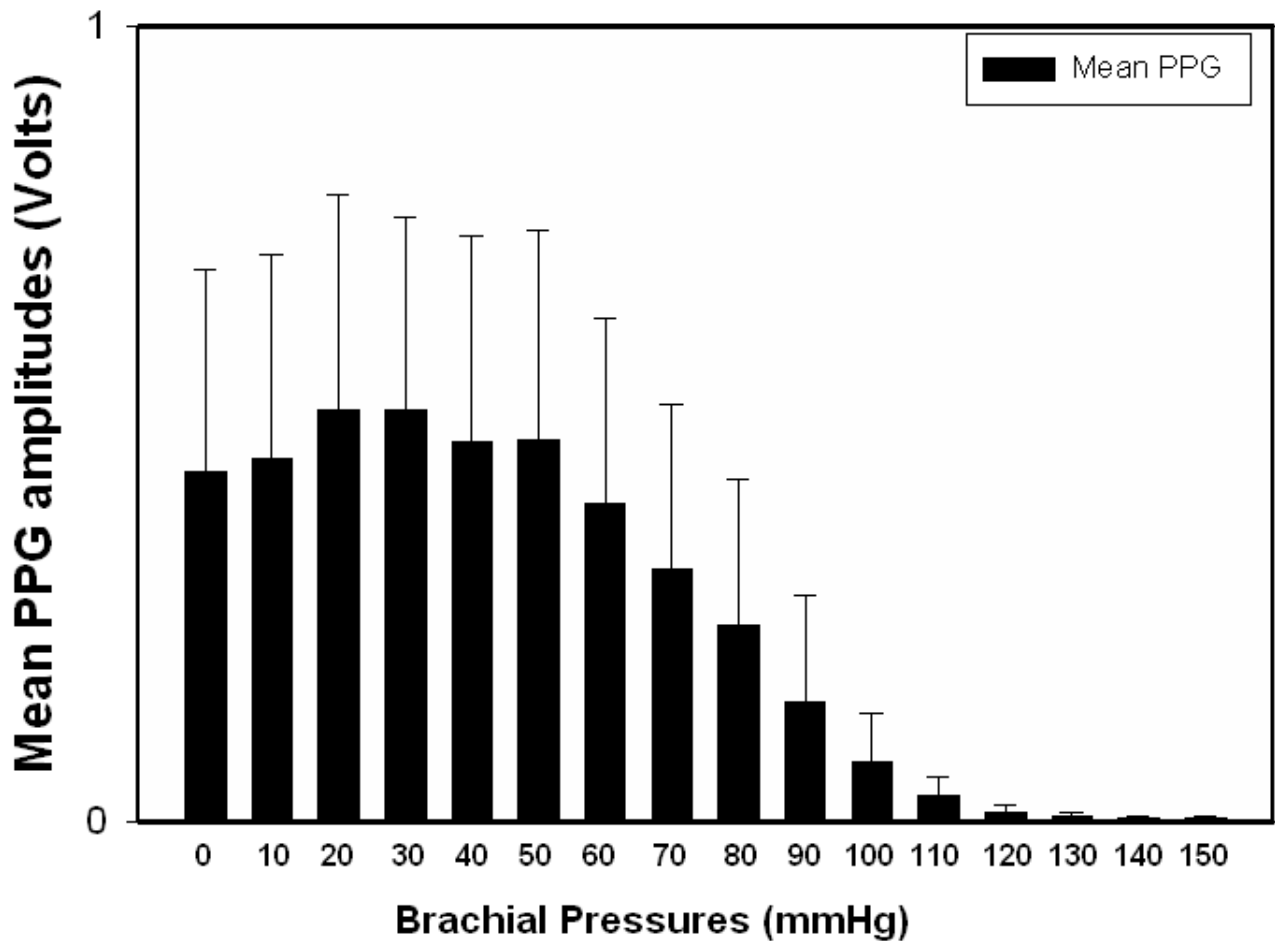
## 1. Methods

A reflectance finger PPG/SpO<sub>2</sub> probe was constructed comprising two infrared and red emitters and a photodetector. A processing system was also developed<sup>1,2</sup> 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 SpO<sub>2</sub> 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 ( $28 \pm 5.2$ ) 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/SpO<sub>2</sub> 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 SpO<sub>2</sub> 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 SpO<sub>2</sub> 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<sub>2</sub>. 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<sub>2</sub> values measured at a vascular site downstream from the stenosis. The custom finger pulse oximetry was found to be more sensitive to SpO<sub>2</sub> 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

1. Kyriacou P A, Powell S, Langford R M and Jones D P. *IEEE Transactions of Biomedical Engineering*, 49(11) 1360-1368, 2002
2. Kyriacou P A. *Physiological Measurement* (27) R1-R35, 2006