oBPM™—Location Independent Continuous Optical Blood Pressure Monitoring

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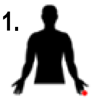
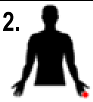
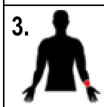
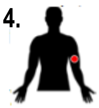
The clinical demand for technologies to monitor blood pressure (BP) in ambulatory scenarios with minimal use of inflation cuff is rising. To differentiate from an increasing number of worldwide actors claiming methods to measure BP, CSEM positions itself in terms of reliable and clinically-supported results. In this context, CSEM accelerated the transfer and validation of its Optical Blood Pressure Monitoring (oBPM™) technology to multiple form factors such as smart bracelets (aktiia), armpods (Biovotion), and more recently smartphones (Biospectal, Riva Digital).

The need of medical solutions for continuous blood pressure (BP) monitoring combined with the development of cuffless solutions significantly increased the industrial demand to integrate BP measurement in embedded devices with medical validation. In this context, CSEM transferred its oBPM™ technology – which provides beat-by-beat BP estimates from photoplethysmographic (PPG) signals – to multiple form factors located at different body locations, and performed clinically-supported validations (Table 1). Clinical studies were conducted for each form factor using invasive and non-invasive reference systems, with experimental protocols designed to induce significant BP variations to validate and test the oBPM™ algorithms in real-case and challenging conditions.

Table 1: Summary of clinical studies performed to test the performance of the oBPM™ technology at multiple body locations: 1) Fingertip with smartphone camera; 2) Fingertip with PPG sensor; 3) Wrist with smart bracelet (PPG sensor); 4) Upper arm with armpod (PPG sensors).

Location	Form Factor	Population	Reference
1. 		35	Brachial cuff
2. 		8	Arterial line
3. 		15	Brachial cuff
4. 		17	Arterial line

The performance of the oBPM™ algorithms (Table 2) was assessed in terms of the following metrics:

- The average and standard deviation of the difference between the BP estimate and the reference, which allow evaluating the agreement between both quantities in actual pressure units (mmHg). The ISO81060-2 standard for non-invasive sphygmomanometers sets a maximal error of ±5 mmHg and a maximal standard deviation of 8 mmHg.
- The correlation between the BP estimate and the reference, which allow evaluating the sensitivity and capability of the algorithms to track BP trends or changes.

Table 2: Performance results of the clinical studies.

Form Factor	Error (mean±SD) (mmHg)	Correlation	Publication
	4.0 ± 8.2	0.63	[1]
	0.3 ± 7.7	0.94	[2]
	3.2 ± 4.3	0.75	[3]
	1.1 ± 4.2	0.80	[4]

The overall performances of the oBPM™ algorithms are compliant with the requirements of ISO81060-2 standard for all form factors except the smartphones which exhibit a slightly higher standard deviation than the required 8 mmHg (SD = 8.2 mmHg). Nevertheless, further developments are currently conducted to increase the accuracy on the smartphone. The high correlation suggests a strong ability of the algorithms to track changes in BP. Finally, the versatility of the technology to multiple body locations demonstrates its robustness in various contexts of use. On the strength of these results, CSEM collaborates with clinical and industrial partners to integrate the oBPM™ technology in different devices:

- Smartphones: Biospectal (http://biospectal.com/), Riva Digital (https://www.rivadigital.ch/)
- Smart bracelets: aktiia (https://aktiia.com/)
- Armpods: Biovotion (https://www.biovotion.com/)

[1] J. Solà, M. Proença, *et al.* (2018), "Blood Pressure Monitoring Using a Smartphone Camera: Performance of the OBPM Technology", Proc. IEEE BHI 2018 International Conference, Las Vegas, USA.

[2] J. Solà, *et al.* (2018), "Tracking Blood Pressure Changes in Anesthetized Patients: the Optical Blood Pressure Monitoring (oBPM) Technology", Proc. IEEE EMBC 2018 Annual International Conference, Honolulu, USA.

[3] J. Solà., M. Proença, F. Braun, *et al.*, "Cuffess blood pressure monitoring: experimental evidences of a beat-to-beat PPG technique", IEEE EMBC 2016 Annual International Conference, Orlando, USA.

[4] T. Degen, *et al.* (2018), "Wearable multisensor for continuous physiological monitoring: a feasibility study of blood pressure", Swiss Medtech Day 2018, Bern, Switzerland.