Calculation of central blood pressure by analyzing the contour of the photoplethysmographic pulse measured at the finger with the pOpmètre® device

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Clinic (brachial) BP a useful screening tool

Does not reflect the pressure the heart and organs are chronically exposed to
It is, therefore, reasonable to expect that target organ damage should be more closely related to central rather than brachial BP.

Predictors of target organ damage and mortality, independently of brachial BP\(^1\)

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1. Vlachopoulos C et al, Eur Heart J. 2010
Digital volume pulse analysis

• The central aortic pressure can be derived from the peripheral pressure (Karamanoglu and Feneley, 1997)

• Analysis of the contour of the digital volume pulse (DVP) could be applied to estimate Blood pressure and an index of arterial stiffness (SI)

• The shape of the digital volume pulse changes with age

• Measurement of the DVP offers a number of practical advantages over measurement of the pressure pulse. PPG is inexpensive and, operator independent.

• A transit time can be measured between the systolic and diastolic peaks

Millasseau S et al., 2002
PPG with pOpmètre®

Obeid H et al., Physiological measurement 2017

Obeid H et al., J Hypertens 2017

R² = 0.81; p<0.001
n = 101 subjects

y = 1.19x + 0.6

PPG with pOpmètre®
PBG finger signal

Obeid H et al., Physiological measurement 2017

Obeid H et al., J Hypertens 2017

R² = 0.81; p<0.001
n = 101 subjects

y = 1.19x + 0.6
Objectives

- The objective is to establish transfer functions estimating the central blood pressure

- Using the PPG pulse, measured with the photodiode of the pOpmètre® system

- Calibrated with a brachial pressure cuff

- Deduce a stiffness index (SI) using the parameters obtained with the contour analysis
Design

- n = 69 subjects (42 men)
- Photodiode sensor positioned on the finger
- Brachial blood pressure
- Central blood pressure with Sphygmocor (Radial)
- Finger – toe pulse wave velocity
Methods

- DVP waveforms were recorded over a 20 s period.

- The recorded signal was then divided into cardiac cycles by detecting the foot (using the maximum of second derivative algorithm) and the maxima’s of every peak.

- A heart cycle is defined as the samples comprised between two local minimums preceding the maximums of two successive signal-peaks.
Methods

- DVP waveform divided into cardiac cycles
- Averaging cycles, single waveform
- Gaussian functions, modeling systolic and diastolic part
- Systolic part, foot of the wave till inflection point
- Diastolic part, inflection point to the end of diastolic
Methods

• Central blood pressure: Transfer function based on statistical models
  – Amplification = fc(gaussian characteristics, bSBP, bDBP)
  – CALIBRATION+++ 

• Stiffness index: based on the subject’s height and DVP transit time
### Population

<table>
<thead>
<tr>
<th>Characteristic (n = 69; 27 women)</th>
<th>Mean ± S.D.</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>65 ± 11</td>
<td>[24 83]</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170 ± 7</td>
<td>[153 189]</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>81 ± 14</td>
<td>[48 122]</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>131 ± 13</td>
<td>[104 157]</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>72 ± 9</td>
<td>[48 88]</td>
</tr>
<tr>
<td>Central systolic blood pressure (mmHg)</td>
<td>120 ± 13</td>
<td>[84 147]</td>
</tr>
<tr>
<td>Central diastolic blood pressure (mmHg)</td>
<td>73 ± 9</td>
<td>[48 89]</td>
</tr>
<tr>
<td>Ft-PWV (m/s)</td>
<td>9 ± 1</td>
<td>[5 12]</td>
</tr>
</tbody>
</table>
Results: Comparison between Central and DVP blood pressure

Sphygmocor CSP (mmHg)
PPG - CSP (mmHg) R² = 0.90
y = 0.87 x + 13.57
RMSE = 4 mmHg

Mean CSP (PPG, Sphyg) (mmHg)
Diff CSP (mmHg)
Mean + 2SD 9 mmHg
Mean 1 mmHg
Mean - 2SD -7 mmHg

Sphygmocor CDP (mmHg)
PPG - CDP (mmHg) R² = 0.95
y = 0.97 x + 2.38
RMSE = 2 mmHg

Mean CDP (PPG, Sphyg) (mmHg)
Diff CDP (mmHg)
Mean + 2SD 4 mmHg
Mean -0.8 mmHg
Mean - 2SD -4 mmHg
Results: Comparison between finger-toe PWV and SI estimated with DVP

- $R^2 = 0.25$
- $Y = 0.27x + 4.79$
- RMSE = 0.7 m/s
Discussion and conclusion

• Good agreement between the central blood pressure, estimated from the PPG signal, and the reference technique

• The central blood pressure values estimated with the DVP were calibrated with the cuff blood pressure, and the reference CBP values were also calibrated with the same cuff blood pressure

• A good correlation between the estimated stiffness index and the finger-toe PWV values

• The only drawback with PPG relates to the damping of the signal’s amplitude as a result of peripheral vasoconstriction (Takazawa et al., 1998)

• Invasive central and peripheral blood pressure measurements are needed for further analysis and to confirm the outcome of this study

• The central and peripheral blood pressures could be approached by analyzing the contour of the DVP with an acceptable agreement, and arterial stiffness can be assessed by deriving an index of stiffness from the PPG signal
Acknowledgments

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THANK YOU !!