Finometer, finger pressure measurements with the possibility to reconstruct brachial pressure
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Objective To evaluate three methods aimed at the reconstruction of brachial pressure from non-invasive finger arterial pressure measurements as implemented in the Finometer™, (FMS, Finapres Measurement Systems, Arnhem, Netherlands), the successor to the Finapres™ (TNO Biomedical Instrumentation, Amsterdam, Netherlands).

Methods Finger arterial pressure (FinAP) may differ from intra-brachial pressure (BAP). Pulse shape differences are removed by applying a generalized waveform filter. Pressure level differences are corrected by a generalized level correction equation using filtered systolic and diastolic levels and by level calibration, which uses an additional return-to-flow (RTF) systolic pressure measurement on the ipsilateral upper arm for an individual calibration of the reconstructed brachial pressure.

Validation These methods were validated in 37 subjects, aged 41 to 83 years after a cardiac catheterization procedure. Intra-brachial and Finometer pressures were recorded simultaneously. Finometer pressures were compared after application of waveform filtering and level correction (flcAP), and after an additional RTF calibration (reBAP).

Introduction For the past two decades finger arterial pressure could be measured with the Finapres™ and the Portapres™ (TNO Biomedical Instrumentation, Amsterdam, Netherlands). These devices are based on the volume-clamp method of Peñáz [1] and the 'Physiocap' criteria of Wesseling [2]. This combined method is well accepted and has been thoroughly validated [3]. Since the blood pressure is measured continuously in a non-invasive way, this method has several advantages over other, more conventional ways of recording blood pressure. However, due to physiological causes, the finger arterial pressure may differ from the brachial pressure, both in pulse shape as well as in pressure levels. This might limit the use of finger arterial pressure in certain circumstances.

Results Finger arterial systolic, diastolic and mean pressures for the group differed from BAP by \(-9.7 \pm 13.0, -11.6 \pm 8.0\) and \(-16.3 \pm 7.9\) mmHg (mean \(\pm SD\)) respectively. Similarly flcAP differed by \(-1.1 \pm 10.7, -0.2 \pm 6.8\) and \(-1.5 \pm 6.6\) mmHg and reBAP differed by \(3.1 \pm 7.6, 4.0 \pm 5.6\) and \(2.7 \pm 4.7\) mmHg.

Conclusion Reconstruction of BAP from FinAP as implemented in the Finometer reduces the pressure differences, with an individual RTF calibration to well within AAMI requirements. Blood Press Monit 8:27-30 @ 2003 Lippincott Williams & Wilkins.

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Keywords: finger arterial pressure, reconstructed brachial pressure, non-invasive, Finometer™, Finapres™

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- Limited remote control from a PC.
- Offline and online downloading of stored measurements.

The reconstruction of the calibrated brachial pressure is discussed in more detail below.

**Methods**

**Waveform filtering**
It appears that the pulse shape differences present between the brachial and finger arterial pressure are typical waveform distortions that are similar in all subjects. Differences between subjects are slightly age related. These distortions can be expressed as a transfer function from the brachial to the finger artery that shows a resonance peak around 8 Hz [4]. To reconstruct the brachial pressure pulse shape from the finger arterial pressure, the inverse transfer function, a waveform filter, is applied to the finger arterial pressure.

**Level correction**
The waveform filter provides a much better estimate of the brachial pressure waveform and thus of the brachial pulse pressure, the difference between systolic and diastolic pressure, compared to the finger arterial pressure. The pressure level differences, however, are less reduced. These level differences can be predicted reasonably well from the systolic and diastolic pressures of the waveform filtered pressure, using a generalized level correction equation [5]. After applying this level correction, the level differences become almost zero on average and the standard deviations of the differences are slightly reduced.

Recently it was shown that this level correction not only strongly reduces the differences between the finger arterial pressure and the brachial pressure but also reduces the variability of these differences and improves tracking of diurnal changes during 24-h blood pressure measurements [10].

**Level calibration**
To reduce the standard deviations of the differences to within the criteria for the evaluation of automated sphygmomanometers (accuracy < 5 mmHg, precision < 8 mmHg) developed by the American Association for the Advancement of Medical Instrumentation (AAMI) [11], mathematical equations are not sufficient, but an additional measurement is needed.

A return-to-flow systolic pressure can be used to calibrate the waveform-filtered and level-corrected pressure [6]. This return-to-flow systolic pressure is determined by deflating a standard Riva-Rocci cuff around the upper arm.
on which the finger arterial pressure is measured and by observing the return of the pulsations in the distal finger arterial pressure. The instant of the return of the pulsations, called return-to-flow, coincides with auscultatory Korotkoff phase I.

Return-to-flow detection with the Finometer has to be started by the operator after which it runs automatically. An upper arm cuff is inflated to a pressure 30 mmHg above the estimated systolic brachial pressure. This estimation is based on the waveform-filtered and level-corrected pressure. Deflation starts as soon as inflation has reached its end level. During this deflation return-to-flow is detected after which a re-inflation is done to a level 30 mmHg above the arm cuff pressure detection level. The arm cuff is again deflated and return-to-flow is detected for a second time. After this second determination the arm cuff is rapidly deflated to zero pressure. The average of both arm cuff pressure detection levels is the return-to-flow systolic pressure that is used for level calibration of the waveform-filtered and level-corrected pressure.

This level calibration decreases the standard deviations of the differences for all pressure levels to within AAMI requirements, providing accurate pressure levels in comparison with brachial levels in individuals [6].

**Validation**

A validation study was performed in 37 subjects (three females, 34 males), aged 41 to 83 years with a mean of 58 years. These subjects all underwent a diagnostic or therapeutic coronary angiography via the radial artery and were in the supine position. In this study the reconstructed brachial pressure from the Finometer was compared to the measured intra-brachial pressure in the other arm. As part of the inclusion criteria left to right systolic and diastolic brachial pressure differences between the two arms had to be smaller than 10 mmHg, which was checked with two oscillometric blood pressure monitors (Omron M4; Omron Matsusaka, Japan) that were inflated simultaneously.

Some results from this study are presented in Table 1. This table shows systolic, diastolic and mean differences for the original finger arterial pressure (FinAP), the waveform-filtered and level-corrected pressure (fAP), and the return-to-flow calibrated waveform-filtered and level-corrected pressure (rBAP), all compared to the measured brachial pressure.

**Discussion**

From these results it can be concluded that the reconstruction of the brachial pressure from the finger arterial pressure as implemented in the Finometer narrows the difference between the finger arterial pressure and the central arterial pressure when subjects are in the supine position. If in addition to the finger arterial pressure measurement a return-to-flow measurement is performed, the brachial artery pressure is slightly overestimated, but the differences fall within the AAMI criteria for the evaluation of automated sphygmomanometers. Because level correction also reduces the variability of the pressure level differences during the day [10], the return-to-flow calibration probably needs to be performed only once during the day. Additional research will help to confirm this and is needed to study the effect of orthostatic stress on the reconstruction methods.

**References**

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