Netherlands
The Journal of Medicine

REVIEW

Oscillometric wrist blood pressure measuring devices

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ABSTRACT

Devices measuring blood pressure oscillometrically at the wrist are becoming more and more popular. These devices are small, easy to handle and can measure blood pressure without the need to undress. However, few of the wrist devices have been validated properly, i.e. according to internationally accepted protocols. In this article current literature on wrist blood pressure measuring devices is presented. The importance of positioning the wrist at heart level for accurate measurements is stressed.

INTRODUCTION

The first devices constructed to measure blood pressure in humans were devices measuring blood pressure at the wrist.[1] Early experiments in this field in the 19th century eventually led to the development of the conventional blood pressure measuring technique at the upper arm by Scipione Riva Rocci.[2] However, the art of feeling the pulse has an even longer history, going back to Chinese medicine. Nowadays, oscillometric blood pressure (BP) measuring devices for home blood pressure measurement (HBPM) are becoming increasingly popular. When asked, patients choose HBPM as the preferred method for measuring BP over ambulatory blood pressure measurement (ABPM) or measurements by the nurse or physician.[3] Moreover HBPM has been shown to have a stronger predictive power for mortality than screening BP measurement.[4] Over 11 million devices for HBPM were sold world-wide in 2000.[5] Most of these devices measure blood pressure at the upper arm. However the proportion of the sold devices that measure BP at the wrist is increasing.[5] Devices measuring BP at the finger have shown to be inaccurate.[6] Many patients ask their physician for advise on which device to buy. Using the available literature on wrist BP measuring devices this overview will hopefully help physicians to advise their patients better in their choice for a particular BP measuring wrist device.

FACTORS DETERMINING BLOOD PRESSURE LEVEL AT THE WRIST

Many factors determine the BP measured at a given moment. In general there should be an adequate resting period before starting the measurements. Differences in the order of 5 to 10 mmHg can result from differences in arm position.[7] The influence of arm position on the measured blood pressure level is due to the influence of the hydrostatic pressure: raising the arm (or wrist) 1 cm lowers the blood pressure by 0.7 mmHg and vice versa.[8] The cuff should be held at heart level, i.e. at the level of the right atrium. This generally means midway between the jugular notch and the xiphoid process.[7] Because of its more distal position accurate positioning of the cuff at heart level is of even more importance for BP measurement at the wrist. The importance of the arm position on measured BP level has led to the development of a positioning system by Braun®.[9] A wrist BP device equipped with an inclination sensor helps to manoeuvre the patient's wrist to the same position for every measurement. This ensures that subsequent measurements are comparable.

 # Th. Thien was not involved in the handling and review process of this paper.

The measured BP level is further influenced by flexion and extension of the wrist.[10] BP measured with the wrist in palmar flexion is significantly higher than that measured in palmar extension. BP measured in palmar dorsiflexion is significantly lower than that in palmar extension (for both diastolic and systolic BP).
Besides these positional aspects, the BP itself is different at the wrist compared with the arm. Moving more distally from the ascending aorta to the radial artery, systolic BP increases and diastolic BP decreases, hence pulse pressure increases.[11] Most wrist BP measuring devices are validated relative to upper arm BP measurements. So differences in BP between these two measurement sites can be expected from the outset. However, mean arterial pressure differs only slightly.[12]

INSTRUCTION FOR SELF-MEASUREMENT AND (DIS)ADVANTAGES OF WRIST DEVICES

Proper instruction is pivotal to be able to obtain reliable results. Patients should be instructed on how to operate the device and to adequately register all measurements taken. A short course should preferably be given at the outpatient clinic. Unless the device has been equipped with a positioning system, proper positioning of the cuff at heart level should be stressed. HBPM can have several advantages. These are shown in *table 1*. HBPM can help to establish the diagnosis of hypertension, to find cases of white-coat hypertension, assess the efficacy of antihypertensive therapy, evaluate the effect of dose adjustments, detect unexpected BP derangements, reduce costs and to increase compliance.[1,13] However BP levels during sleep are not obtained as they are in ABPM, reference values have not been firmly established and misreporting of the measured BPs can occur. The cut-off values for hypertension are lower for the BP measured at home than at the office.[4,14-16] This should be taken into account when interpreting BP measurement taken at home. BPs measured at home can be lower than at the office as part of white-coat hypertension. However the opposite (BP at home higher than at the office) can also occur. This phenomenon has been described as the so-called reverse white-coat hypertension or masked hypertension, which is actually a misnomer and self-measurement related hypertension would be a better term.[17] These phenomena make interpretation of BP levels acquired through self-measurements more difficult.
Using wrist devices can have additional advantages: measurements at the wrist can be more comfortable, because these small, light-weight devices are easy to use, patients do not need to undress for measurements and measurements can be done in various circumstances.[1] However, most wrist devices have not been properly validated or have been found inaccurate.

Table 1
(Dis)advantages of home blood pressure measurement with automated devices in general and wrist devices in specific

GENERAL ADVANTAGES
May help to diagnose hypertension
May help to detect white-coat hypertension/white-coat effect
Stronger predictive power for mortality than screening blood pressure
Patient's compliance may increase
Efficacy of antihypertensive medication and effect of dose adjustments can be better monitored
Earlier detection of derangement of blood pressure

ADVANTAGES OF WRIST DEVICES
Devices are light-weight
Easy applicability, greater comfort, no need to undress
Costs in general lower than ABPM/upper-arm devices

GENERAL DISADVANTAGES
No blood pressure measurements during the night
Reference values for hypertension not firmly established
Misreporting of measured blood pressure values possible

DISADVANTAGES OF WRIST DEVICES
Most devices not properly validated or not meeting BHS/AAMI criteria
Blood pressure level at the wrist is influenced by many factors (angle between hand and fore-arm, hydrostatic pressure)

VALIDATION REPORTS ON WRIST DEVICES

Validation studies on wrist blood pressure measuring devices are scarce. The British Hypertension Society (BHS) protocol 1993 and the protocol of the Association for the Advancement of Medical Instrumentation (AAMI) are the most widely used protocols for validating BP measuring devices.[18,19] For a short review of these protocols we would like to refer to our article on upper-arm devices. In a recent review by O'Brien only three wrist devices were shown to be tested by the British Hypertension Society (BHS) and/or Association for the Advancement of Medical Instrumentation (AAMI) criteria.[20] Only one device passed the requirements of these protocols.
For this review, we selected well-performed studies using the following criteria: a minimum number of 40 patients had to be included and an internationally accepted protocol (BHS or AAMI) had to be used as a guideline to evaluate the test device. The studies that fulfilled these criteria are presented in *table 2*. *Table 3* shows the rest of available validation reports on wrist BP measuring devices.
Comparison between different validation reports testing the same device is quite difficult because validation is not

Table 2

Validation reports on wrist devices, including at least 40 patients and using BHS or AAMI protocols as a guideline[10,21-28]

DEVICE		N	STANDARD	MEAN DIFFERENCE (± SD) (DEVICE - STANDARD) SBP	DBP	AAMI	BHS
BP 2000[21]		86	M	0.1 ± 7.1	1.9 ± 7.0	P/P	
Boso-Mediwatch[22*]	Nt	20	M	3.9 (0.1; 7.6)	7.0 (4.7; 9.2)		
	Ht	20	M	-5.8 (-11.6; -0.3)	-5.5 (1.4; 6.3)		
Klock[23]		255	M	16 ± 25	6 ± 17	F/F	
Matsushita Denko EW[10]		92	M	2.3 ± 10.2	5.6 ± 8.6		D/B
NAiS EW 28[24]	S	125	An	-1.1 ± 5.0	-1.7 ± 3.0		
	C	40	An	-1.9 ± 2.9	-1.2 ± 2.8		
Nissei WS-310[25]		87	M	-4.6 ± 8.3	-2.8 ± 4.8	F/P	B/A
Omron HEM 601[10]		173	M	2.1 ± 9.7	-1.2 ± 7.3		C/B
Omron RX (HEM 608)[26]		85	M	0.3 ± 9.0	2.6 ± 9.0	F/F	B/B
Omron RX[25]		87	M	-4.9 ± 8.8	-4.2 ± 6.4	F/P	B/A
Omron RX-M[27]		89	M	2.5 ± 12.2	7.5 ± 8.4	F/F	D/D
Omron R3[28]		85	M	-5.7 ± 6.2	-6.8 ± 6.8	F/F	D/D
Omron R3[22*]	Nt	20	M	3.2 (0.6; 5.8)	4.2 (1.6; 6.7)		
	Ht	20	M	-5.8 (-8.8; -2.8)	-5.5 (-9.3; 1.6)		

*M = mercury sphygmomanometer, An = aneroid sphygmomanometer, Au = auscultatory sphygmomanometer, device not mentioned, Nt = normotensives, Ht = hypertensives, S = surgery, C = community, SBP = systolic blood pressure, DBP = diastolic blood pressure, P = passed; F = failed. * 95% confidence interval instead of SD.*

Table 3

Various validation reports of wrist devices, not fulfilling the criteria stated in table 2[9,27,29-34]

DEVICE	N	MEAN DIFFERENCE (± SD) SBP	DBP	AAMI	STANDARD
Intra-arterial measurements as standard					
NAiS Matsushita BP Watch[29]	27	1.5 ± 10.2	4.1 ± 7.3	F/P	
NAiS BP Watch[30]	100	4.3 ± 14.1	6.0 ± 8.9	F/F	
Omron HEM-601[31]	25	-4.0 ± 18.0	3.0 ± 9.0	F/F	
Omron R3[32]	100	-1.0 ± 13.0	1.0 ± 9.0	F/F	
Oscillometric arm device as standard					
NAiS BP Watch[30]	100	3.4 ± 13.3	-3.8 ± 9.5	F/F	Hestia OZ80
Omron HEM-601[33]	26	-0.04 ± 10.0	2.8 ± 8.0	F/P	Visomat Hestia OZ40
Omron RX-M[27]	89	4.1 ± 12.7	6.3 ± 7.1	F/F	Omron HEM 705 CP
BOSO medistar[34]	21	2 ± 7	3 ± 6	P/P	BOSO medicus
Ambulatory blood pressure monitor as standard					
BP 2000[9]	43	-1.5 ± 13.7	5.2 ± 7.9 (P+)		A&D TM-2430
		-0.5 ± 15.0	6.0 ± 8.9 (P-)		
Omron HEM-601[31]	50	n.g.	n.g.		SpaceLabs 90207

SBP = systolic blood pressure, DBP = diastolic blood pressure, P = passed, F = failed, n.g. = not given.

always carried out in the same way. Moreover it is often difficult to determine which type of device has actually been tested, because the type and serial number of the device is not always stated exactly. In general, in comparison with oscillometric measuring devices at the arm, wrist devices seem to be less accurate.

CONCLUSION

The market for automated BP measuring devices is growing rapidly. Particularly the sales of wrist devices are increasing. They have the advantage of a small volume and easy applicability. However, the development of these devices

should be watched with caution. First we should recommend our patients to use only devices that have been properly validated. At present too few wrist devices have been validated according the protocols of AAMI and/or BHS, so no particular device can be recommended. Secondly the readings with these devices should be interpreted with caution and compared with measurements with an ABPM and BP measurements at the office. Interpretation is further hindered by the lack of firmly established cut-off values for normotension and hypertension at the wrist. Thirdly, to be able to compare different wrist devices more easily, accurate description of type and serial number of the device tested is needed. Accurate and reproducible positioning of the wrist at heart level is crucial for BP measurement. However, we think that with recent innovative developments as the position sensor by Braun and developments yet to come, wrist BP measuring devices will gain a prominent place in BP measurement and BP control.
Instead of attributing to the diagnosis of hypertension, wrist devices could be of help in giving follow-up data. That is, provided that sequential measurements are done in the same manner, wrist devices could help to give information about (changes in) blood pressure level over time.

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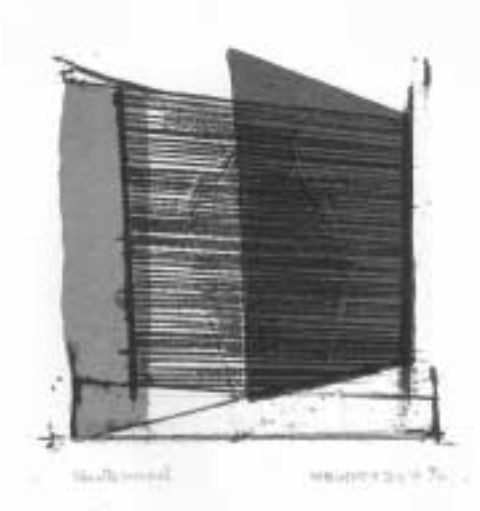
ABOUT THE COVER

History of intervening space from 1991

Bienette Moraal



This month's artist lives and works in Nijmegen as a pictorial artist. She calls herself a still-life painter. Between 1975 and 1980 she studied in Arnhem. Since 1983 she has been exhibiting her work in several solo exhibitions, such as Gallery K-Dijk in Gendt, and in group exhibitions. Her work has been shown at PRENT '99 and at PRENT 2001 and in Gallery Ursula van Heesch in Kleve, Germany. In 2000 and 2001 she exhibited at HUNTENKUNST in Doetinchem. Premises of her series of work are always visibility and tangibility. Even when she makes graphic art, in particular lithography, she works and observes as a painter. Points of special interest in Bienette's work differ per period. In this three-colour stone print, which is part of a panel of 15 lithographies (10 x 10), the theme 'space between objects' or 'emptiness in still life' is well reflected. A limited edition (12) is available at a price of € 150 (the complete series of 15 prints costs € 2000), at Galerie Unita, Rijksstraatweg 109, 6573 CK Beek-Ubbergen, the Netherlands or by e-mail: galerie-unita@planet.nl.