Research Paper

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Evaluation of non-invasive blood pressure measurement by the Finapres method at rest and during dynamic exercise in subjects with cardiovascular insufficiency

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THE accuracy and precision of the Finapres in recording rest and exercise blood pressure compared with the intra-arterial (aortic and brachial) and random-zero sphygmomanometer methods was assessed in 84 ischaemic patients in three different studies. Firstly, comparison at rest with the aortic intra-arterial pressure in 50 ischaemic patients demonstrated that the Finapres systolic (136.5 ± 21.1 vs. 129.3 ± 19.0 mmHg; $p < 0.001$) and mean (92.4 ± 13.4 vs. 90.7 ± 11.4 mmHg; $p < 0.001$) arterial pressures were higher and diastolic pressures lower (70.4 ± 11.5 vs. 71.5 ± 9.8 mmHg; $p < 0.001$). The reproducibility of the Finapres and invasive method was similar for systolic (4.6% vs. 4.0%), diastolic (2.8% vs. 2.7%) and mean (3.3% vs. 3.0%) blood pressures. Second, in seven subjects studied twice at rest and during 4 min supine bicycle exercise, the exercise increase in blood pressure was greater on the Finapres compared with the brachial intra-arterial pressure (systolic +10.2 ± 6.3 vs. +3.6 ± 9.8 mmHg; diastolic +9.6 ± 11.1 vs. +0.2 ± 2.1 mmHg; $p = 0.02$ for each); however, at steady-state the peak/trough differences in pressure between the methods were similar. Thirdly, compared under rest conditions, to random zero sphygmomanometer (RZO), the Finapres systolic pressure was higher (6.8 ± 3.5 mmHg) and diastolic pressure lower (–6.0 ± 1.9 mmHg). During upright bicycle exercise, the difference between the Finapres and RZO in systolic blood pressure increased at each level of exercise (+14.3 ± 4.2, +17.9 ± 4.0 and +22.2 ± 4.1 mmHg respectively at each exercise stage: $p < 0.01$). For RZO, diastolic blood pressure fell as exercise workload increased whereas Finapres diastolic blood pressure increased on exercise (3.1 ± 2.6, 7.0 ± 2.1 and 8.1 ± 2.0 mmHg respectively: $p < 0.01$). Thus there were systematic differences between the values recorded by the Finapres and proximal blood pressure methods and limited agreement in the rest to exercise increments related to light exercise. Calibration of the Finapres values in terms of the other methods is limited by the variable relationship to these related changes in arterial distensibility.

Key words: Finapres, Non-invasive blood pressure, Exercise

Introduction

Conventional non-invasive measurement of blood pressure is based upon the auscultatory method under steady-state conditions. However, this technique has recognized limitations which include poor agreement with intra-arterial blood pressure,[1–3] unsuitability for rapid consecutive recordings and is subject to inter-operator variability.

Several of these problems may be overcome by use of automated devices; the Ohmeda 2300 system used in this study is based upon servo-plethysmomanometry employing the volume clamp technique.[4,5] The total finger volume under an unloading cuff is determined by infrared plethysmography and despite the changing pressure, this volume is clamped by modulating the cuff pressure using a high speed electro-pneumatic servo-system. The continuously changing cuff pressure is measured electronically, and the signal displayed as the arterial pressure. Studies with the method during the Valsava manoeuvre, posture and hand-grip showed the pattern of pressure change to be qualitatively similar to the intra-arterial method.[6,7]

However, the level of blood pressure is not identical in the central and peripheral arterial system; the amplitude of the arterial waveform increases with distal propagation.[8] This phenomenon, due to dispersion of the waveform is critically dependent on the arterial distensibility; should physiological conditions change sufficiently to alter arterial compliance and pulse wave velocity, then proximal and peripheral measures of blood pressure may diverge. Therefore any assessment of a peripheral blood pressure method should examine the impact of changing physiological conditions on the recorded pressure in comparison with the usual methods of blood pressure determination. We have assessed the accuracy and precision of the Finapres compared with

intra-arterial pressures and random-zero sphygmomanometer at rest and during dynamic exercise.

Methods

Study 1: Fifty patients undergoing routine coronary angiography were included in a rest comparison of the Finapres versus proximal aortic intra-arterial pressures. A standard coronary angiography catheter was inserted from the femoral approach by the Seldinger technique. On completion of coronary arteriography, the catheter was positioned in the aortic arch at the level of the right subclavicular artery and attached directly to the pressure transducer (Bell and Howell 4-327-I) to optimize frequency response; the latter was flat to 20 Hz over the heart range assessed (the catheter transducer system was bench tested with a sinusoidal pressure of constant amplitude while varying the frequency). Both aortic and Finapres pressures were referenced to the mid-axillary point (junction of the line joining the coronal plane between the xiphoid and dostrum with the line drawn at right angles to the fourth interspace where it meets the sternum).

The technique for application of the Finapres was standardized in field studies over some months; careful attention being paid to the technique of cuff application, alignment and the appropriateness of the selected cuff size. Patients with cold peripheries were considered unsuitable for the technique; following application the cuff was allowed to stabilize for at least 5 min prior to recordings. Both the invasive and the Ohmeda 2300 monitor data were recorded for subsequent analysis by an independent observer; data was averaged over at least two respiratory cycles (approximately 10 beats).

Following 15 min quiet rest, ten consecutive and simultaneous measurements of Finapres and aortic blood pressure were recorded. Agreement between these was assessed according to the criteria of the British Hypertension Society[9] which relates the number of observations falling within 5, 10 and 15 mmHg of the reference standard and the American Association Standard for Medical Instrumentation (AAMI; the average difference between the methods should be less than 5 mmHg with a standard deviation of difference < 8 mmHg[10]). These standards are intended to express the degree of correspondence between different devices recording the same pressure signal; for our purposes they permit an assessment of the agreement but not the accuracy, as the pressure level will depend on the distance along the arterial tree at which the measurement is determined.

Study 2: Seven male patients with angina pectoris (aged 57.9 ± 2.5 years):body surface area (BSA) 1.87 ± 0.1 m^2) undergoing haemodynamic evaluation of severity of coronary artery disease were included in the study. A catheter was inserted by the Seldinger technique into the brachial artery and recording methodology identical to Study 1 employed. Each patient was studied on two occasions with an interval of 90 min between the two studies. The only background medication in the previous month was diuretic therapy which was stable over this period.

Data was recorded during quiet rest and at the end of each minute of supine bicycle exercise at a constant 25 W load. The agreement between the rest and exercise data was assessed and agreement in rest–exercise increments calculated. Tracking ability at steady-state was assessed by determining the difference in peak and trough pressures between the methods; these values were calculated from 20 simultaneous arterial and Finapres values at rest and from ten comparisons obtained between the second and fourth minute of exercise.

Study 3: In 28 patients (age mean 60: range 44–74 years) with stable angina pectoris undergoing upright bicycle ergometric testing, blood pressure was determined by the Finapres method and by conventional random zero sphygmomanometer (Hawskley) before, during and after exercise. Background medication included nitrates (51%), beta-blocking agents (37%), calcium-antagonists (34%) and aspirin (16%) or other medication (4%). Observations were made sitting at rest, during three stages of exercise at increasing workloads and on three occasions during a 10 min recovery period.

Data analysis: Systematic difference between the Finapres and the intra-arterial method was assessed by the method of Bland and Altman[11] by plotting the difference between the two methods against the average of the two methods for each measurement. Reproducibility was assessed from the ten resting comparisons and expressed as the coefficient of variation (SD expressed as a percentage of the mean). All values are expressed as the mean ± SD. Differences between the blood pressure recorded by the Finapres and intra-arterial blood line were analysed by MANOVA (SPSS-PC) with Dunnett's multiple comparison test; the variance being partitioned between patients, method and state (rest vs. exercise).

Results

Study 1 (Fig. 1a–1c): Under resting conditions, the Finapres systolic blood pressure was consistently higher than the intra-arterial values (136.5 ± 21.1 vs. 129.3 ± 19.0 mmHg; $p < 0.001$). The diastolic blood pressures were lower (70.4 ± 11.5 vs. 71.5 ± 9.8 mmHg; $p < 0.001$) and calculated mean pressures higher (92.4 ± 13.4 vs. 90.7 ± 11.4 mmHg; $p < 0.001$).

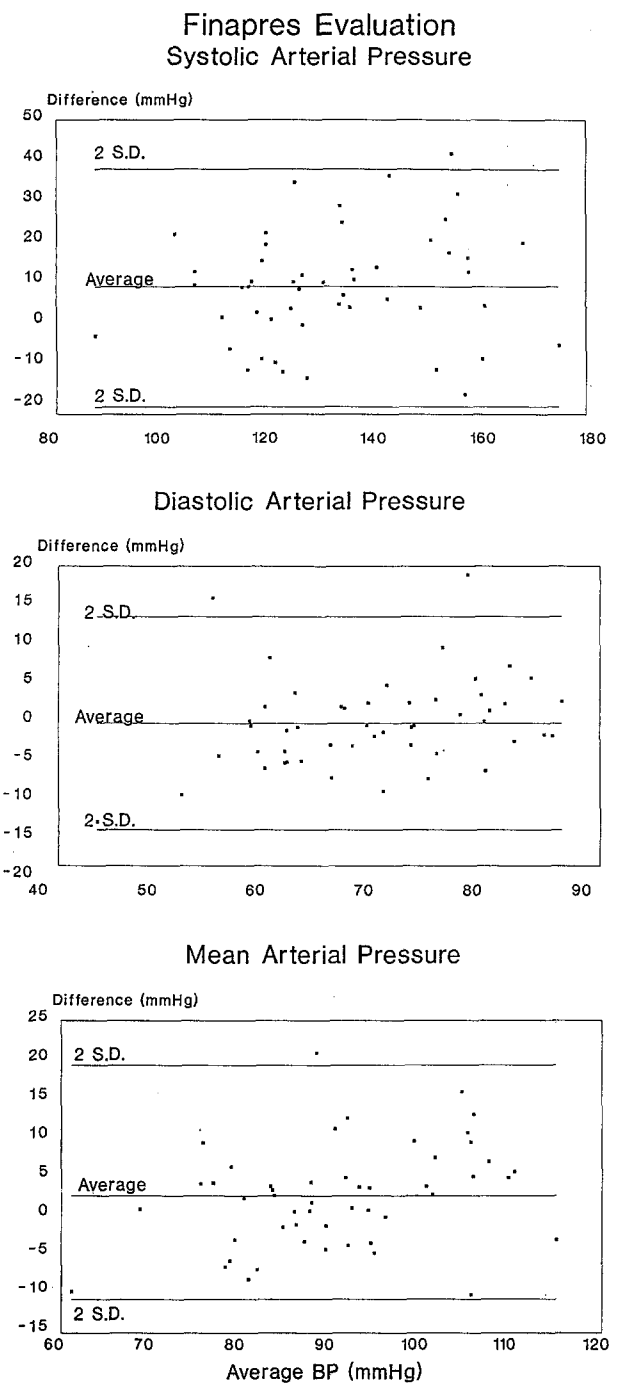

FIG. 1. Comparison of average (abscissa) plotted against difference (ordinate) of Finapres and intra-arterial pressures. Lines are the average and 2 SD of the difference. Graphs are (a) systolic, (b) diastolic and (c) mean arterial blood pressure.

The Finapres was rated as D for systolic and B for diastolic pressure according to the criteria of the British Hypertension Society. Furthermore, the Finapres complied with AAMI accuracy criteria for diastolic (-1.0 ± 6.9 mmHg) and mean (1.7 ± 7.6 mmHg) blood pressures but not for systolic pressure (7.2 ± 14.6 mmHg) when compared with the intra-arterial method.

Notwithstanding these statistical differences revealed by the method of Altman and Bland[11] for all pressures, the average difference in resting pressures between the methods would be deemed important only for systolic blood pressure. The reproducibility between the two methods, expressed as the coefficient of variation, was similar for systolic (4.6 vs. 4.0; range: 1.7–14.6 vs. 0–7.6), diastolic (2.8 vs. 2.7; range: 1.2–11.1 vs. 0–7.6) and mean (3.3 vs. 3.0; range: 0.9–9.9 vs. 0.8–6.9) blood pressures.

Study 2 (Fig. 2a and b): The rest and exercise systolic and diastolic blood pressures, together with the rest to exercise increments, are reported (Table 1). For systolic blood pressure there was a state effect ($p < 0.001$: increased exercise systolic blood pressure), no overall between method difference ($p = 0.41$), but significant state vs. method interaction. Thus the Finapres systolic blood pressure increased to a significantly greater extent compared with the intra-brachial values as exercise progressed ($p = 0.02$). For diastolic blood pressure there was a significant increase in pressure during exercise ($p < 0.001$), a trend for higher Finapres pressures ($p = 0.053$) and significant state vs. method interaction with Finapres pressures increasing to a greater extent as exercise progressed ($p < 0.02$). When the rest to exercise increments were analysed, the systolic increment showed differences related to method ($p = 0.04$), state ($p < 0.001$) without state vs. method interaction ($p = 0.43$). For diastolic blood pressure there were differences related to state ($p = 0.006$), state vs. method interaction ($p = 0.003$) but not for method alone ($p = 0.13$). For mean blood pressure there were significant state ($p < 0.001$), no between method effect ($p = 0.23$) but a method/state interaction ($p < 0.04$); by the fourth minute of exercise the Finapres pressure increase ($+38 \pm 27$ mmHg) tended to be greater than the brachial increase ($+27 \pm 12$ mmHg; $p < 0.07$). The correlation coefficients for the exercise systolic blood pressure between the methods was 0.53 and for the rest to exercise increments 0.71; the respective figures for diastolic blood pressure were 0.86 and 0.53 and for mean blood pressure 0.86 and 0.80. This reflected the lower agreement for systolic compared with diastolic pressure between the Finapres and the intra-arterial brachial values at rest; the systolic exercise pressure increment was tracked better by the Finapres in contrast with the poor tracking of diastolic pressure exercise alterations. Closest correlation was evident both for the absolute exercise mean blood pressure and for the rest to exercise increment in mean blood pressure. At steady-state the ability to track dynamic changes in pressure (assessed from peak/trough difference averaged from ten consecutive beats) was comparable between the methods (average systolic differences Finapres vs. brachial 0.25 ± 12.5 vs. 1.7 ± 16.4 mmHg; diastolic 0.42 ± 7.7 vs. 1.5 ± 9.0 mmHg) (Fig. 2a and b). Thus these results suggest that the calibration or absolute difference between the Finapres and the brachial values altered between

Table 1. Comparison of Finapres and intra-brachial arterial pressures from rest to exercise

Variable	Systolic BP	Rest	Exercise 4 min	State	Method	Method/State
Systolic BP	Brachial	158 ± 27	207 ± 33			
	Finapres	155 ± 24	217 ± 39	$p < 0.001$	$p = 0.41$	$p < 0.02$
Diastolic BP	Brachial	95 ± 12	110 ± 19			
	Finapres	95 ± 14	120 ± 30	$p < 0.001$	$p < 0.06$	$p < 0.02$
Exercise–rest						
Systolic BP	Brachial		48 ± 17			
	Finapres		62 ± 36	$p < 0.001$	$p < 0.04$	$p = 0.43$
Diastolic BP	Brachial		16 ± 12			
	Finapres		25 ± 24	$p = 0.006$	$p = 0.13$	$p = 0.003$

Data is mean ± SD.

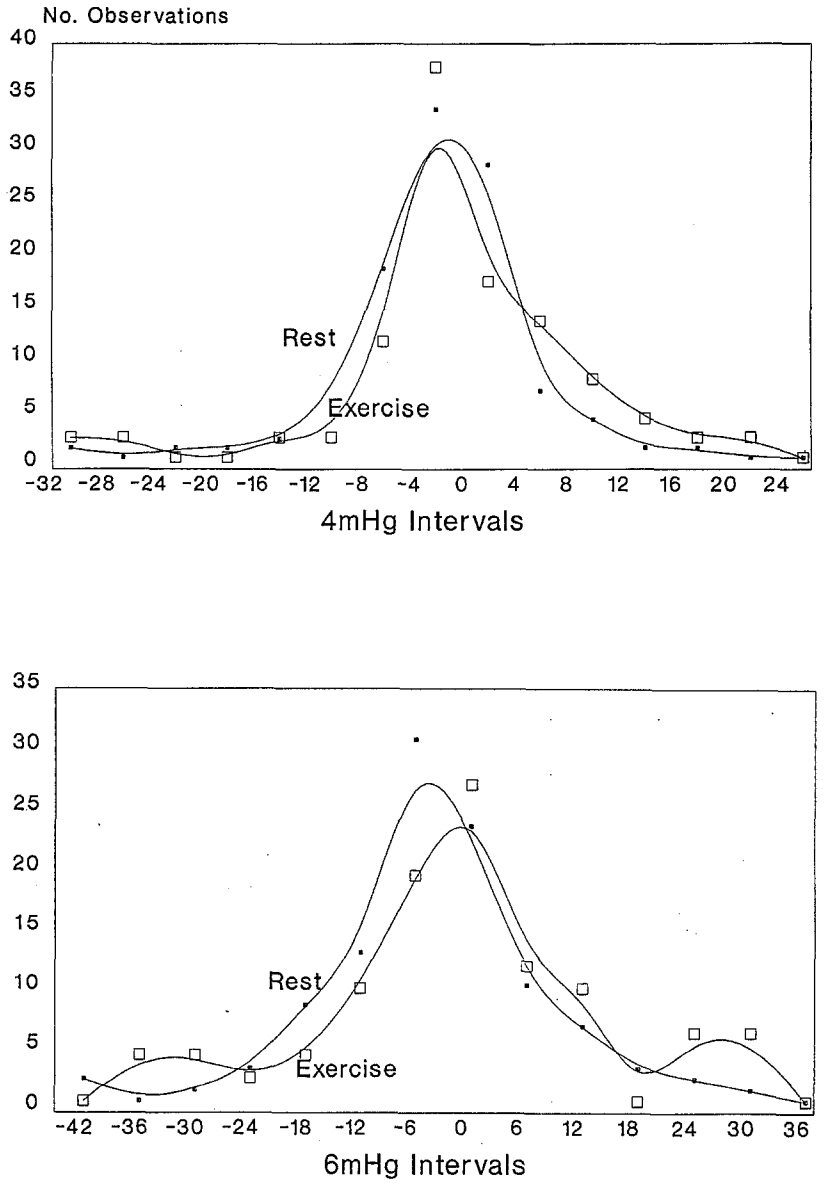

FIG. 2. Comparison of peak-to-trough differences between the Finapres and intra-arterial pressures. Data are numbers of observations at a particular difference computed from 20 observations at rest and 10 during steady-state supine bicycle exercise.

rest and exercise; once a new steady-state had been achieved the peak to trough pressures (i.e. assessing dynamic tracking ability) between the methods were not different when a new relationship between the pressures had been established.

Study 3 (Table 2; Fig. 3): Compared with random zero sphygmomanometer (RZO), the Finapres systolic pressure was higher (6.8 ± 3.5 mmHg) and diastolic pressure lower (–6.0 ± 1.9 mmHg). On exercise, the difference in systolic blood pressure in-

Table 2. Comparison of Finapres and random zero sphygmomanometry from rest to exercise

Variable	Systolic BP	Rest	Exercise 3	State	Method	Method/State
Systolic BP	RZO	140 ± 27	159 ± 27			
	Finapres	146 ± 23	182 ± 29	$p < 0.001$	$p < 0.001$	$p < 0.001$
Diastolic BP	RZO	83 ± 12	82 ± 15			
	Finapres	77 ± 15	90 ± 16	$p < 0.001$	$p = 0.10$	$p < 0.001$
Exercise–rest						
Systolic BP	RZO		20 ± 22			
	Finapres		35 ± 24	$p < 0.001$	$p < 0.001$	$p < 0.03$
Diastolic BP	RZO		−1 ± 9			
	Finapres		13 ± 13	$p < 0.02$	$p < 0.001$	$p < 0.02$

Data is mean ± SD.

creased at each level of work (14.3 ± 4.2, 17.9 ± 4.0 and 22.2 ± 4.1 mmHg respectively at each exercise stage; $p < 0.01$). For RZO, diastolic blood pressure fell as exercise workload increased whereas Finapres diastolic blood pressure increased with each level of exercise (3.1 ± 2.6, 7.0 ± 2.1 and 8.1 ± 2.0 mmHg respectively; $p < 0.01$).

For systolic BP (Table 2) there was a state effect ($p < 0.001$: increased exercise systolic BP), between method difference ($p < 0.001$), and significant state vs. method interaction ($p < 0.001$). Thus the Finapres systolic blood pressure increased to a significantly greater extent compared with RZO values as exercise progressed ($p < 0.001$). For diastolic blood pressure there was a significant increase in pressure during exercise ($p < 0.001$), no between method effect ($p = 0.10$) and significant state vs. method interaction with Finapres pressures increasing to a greater extent as exercise progressed ($p < 0.001$). For mean blood pressure there were significant state, between method and method/state interactions ($p < 0.001$); by the third level of exercise the Finapres pressure increase (+20 ± 14 mmHg) was greater than the RZO increase (+6 ± 12 mmHg; $p < 0.001$). For correlation coefficients for the exercise systolic blood pressure between the methods was 0.67 and for the rest to exercise increments 0.63; the respective figures for diastolic blood pressure were 0.65 and 0.33 and for mean blood pressure 0.72 and 0.59.

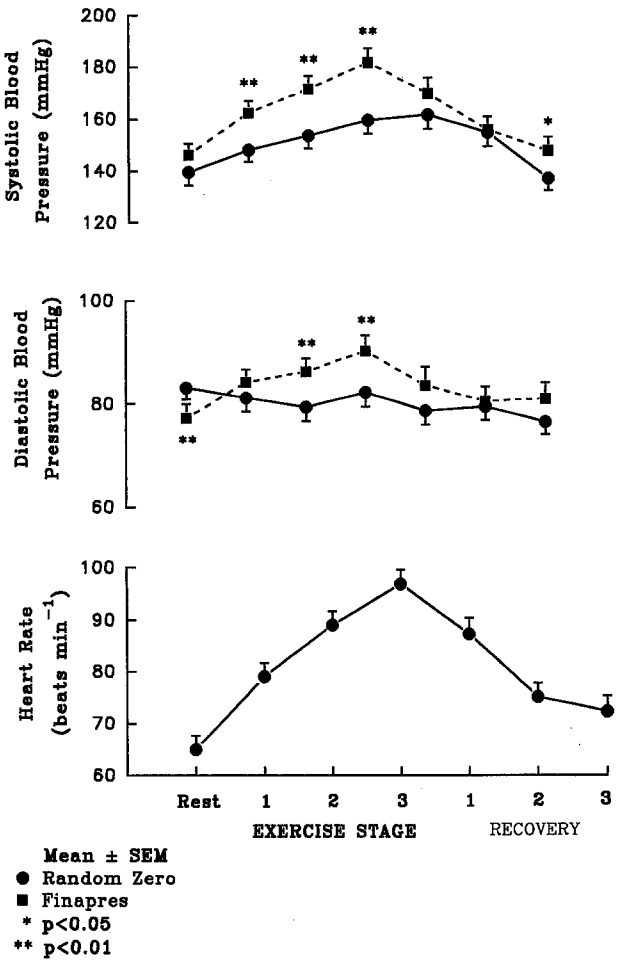

FIG. 3. Comparison of Finapres and random-zero blood pressures at rest and during three levels of upright bicycle exercise in 28 patients with ischaemic heart disease during exercise stress testing.

Discussion

In summary, these studies demonstrated small but consistent differences between the Finapres values and other pressure methods assessed; systolic pressure was higher and diastolic blood pressure lower compared with arterial or random-zero pressures under resting conditions. The Finapres achieved similar reproducibility to the intra-arterial method despite the observed systematic difference in pressures noted between the methods. On exercise, there was a greater increase in Finapres pressure values compared with brachial pressures obtained by either direct arterial cannulation or indirect measurement using the random-zero sphygmomanometer. However, at a constant workload the Finapres accurately followed dynamic changes compared with the intra-arterial measurements.

Due consideration should be given to the factors influencing the outcome and validity of such comparisons as well as their applicability. Important prerequisites for any valid comparison between methods include equivalent precision of the techniques, a stable and reproducible test situation; this is likely to be obtained only after very critical appraisal of

many aspects of the methodology. In this study, the technique for application of the Finapres was standardized and refined during field studies over some months, careful attention in particular being paid to the technique of cuff application and the size. The intra-arterial recordings were undertaken using systems with a frequency response better than 20 Hz to ensure adequate frequency response over the anticipated heart rate range. In our laboratory the reproducibility of rest intra-arterial blood pressure is typically < 2% (range 0.4–4.2). These considerations suggest that our data reliably described the operational characteristics of each method and that the differences described are real.

An important consideration relative to pressure methodology is that the magnitude of the recorded values is significantly influenced by the site of measurement. As the pressure pulse wave travels peripherally, there are characteristic alterations in its shape and an increased amplitude. The explanation for this phenomenon was formerly thought to be due to the occurrence of standing waves (interaction of incident and reflected waves) in the arterial system. However this phenomenon may be attributed to 'dispersion' of the pulse wave at increased velocity; the peak of the wave travels more rapidly than its base resulting in a steeper wave front of greater amplitude. Pulse wave velocity is a function of arterial distensibility; this may be related to the 'frequency' (rate of pressure rise) and the degree of distention (arterial pressure level) of the arterial system. Thus under altered physiological conditions with increased inotropic state, heart rate or blood pressure, the arterial distensibility will decrease and pulse wave velocity and waveform amplitude increase. The distance down the arterial tree at which the pressure is determined is then critical with marked waveform amplification encountered in the peripheral arterial system. During exercise divergence between central and peripheral pressure may be anticipated; in the present study for example three patients with Finapres systolic values 5.6, 7.3 and 12.2 mmHg higher than brachial pressures increased these differences to 38.4, 25.2 and 32.2 mmHg during 4 min supine bicycle exercise at a light workload. Thus an important limitation of the Finapres is the absence of a constant relationship to more proximal pressures; differences between the Finapres and these methods reflect the pulse wave velocity under a given set of physiological conditions and if these are altered the relationship will be expected to alter. Our studies outline the nature of the differences seen at rest and the extent to which they were altered under light exercise conditions.

It has been suggested[12,13] that the mean pressure decreased by as little as 2–3 mmHg peripherally. It is therefore of interest that the majority of previous studies with the Finapres suggested that the peripheral systolic and diastolic pressure were lower than the more proximal pressure.[5,6,14–17] This might appear logical; it has been summarized thus 'because if there was no pressure difference between the radial and finger arteries, blood would not flow'.[18] However, the relationship between pressure and flow is widely misunderstood; indeed for flow to be maintained the only requirement is that total energy (pressure, potential and kinetic) proximally must be greater than distally. Thus flow is maintained in the foot in the upright position even though pressure energy is substantially higher there compared with the aorta. Even at the same hydrostatic level, flow may be maintained against an apparent pressure gradient provided there is sufficient kinetic energy in the blood. Thus our data, showing a higher peripheral systolic and a somewhat lower diastolic pressure, suggests that the Finapres accurately reflected the physiological differences that would be expected between more proximal and distal estimates of blood pressure. During changing physiological states, the peripheral pressure may increase disproportionately compared with proximal estimates of pressure; on exercise the peripheral/central blood pressure ratio increased by 52% to 124% so that systolic blood pressure in the radial artery exceeded the aortic pressure by 82 mmHg.[19] This may account for much of the 'lack of agreement' between the Finapres and the more proximal pressures.[20]

Within the literature the uncertainty about the precision and accuracy of the Finapres has largely related to rest evaluations with almost no consideration of the possible impact of a changing physiological state. Both the TNO model 4 and model 5 devices satisfied the AAMI 5 mmHg standard for accuracy when measuring systolic and diastolic blood pressure (mean differences –3.5 and –4.4 mmHg, respectively) but not mean blood pressure (–8.0 mmHg[17]). However, the precision in measuring systolic (12.5 mmHg), diastolic (8.4 mmHg) and mean (8.2 mmHg) blood pressures did not satisfy the AAMI standard. In the same report the Ohmeda 2300 NIBP system was tested and only fulfilled the AAMI accuracy standard for mean pressure (1.5 mmHg), while the precision standard was satisfied for diastolic (7.0 mmHg) and mean (6.9 mmHg) but not for systolic (14.7 mmHg) blood pressures. Furthermore, the Ohmeda 2300 recording system over-estimated, while the TNO systems under-estimated, blood pressure when compared with intra-brachial pressure. The discrepancy in estimation of diastolic and mean blood pressure between the present study and that of Imholz *et al.*[17] cannot be readily explained but may be due to use of a different recording site, difference in frequency response or different methodological accuracy.

Idema *et al.*[20] compared Finapres blood pressures of six normotensive healthy males, during increasing levels of bicycle exercise, using simultaneously registered ipsilateral intrabrachial artery pressures as a

reference. At rest, finger systolic blood pressure was higher and finger diastolic and mean arterial pressures were lower than the corresponding intrabrachial pressures in five of the six subjects. During exercise, average finger diastolic and mean arterial pressures did not differ further from these intrabrachial pressures, but finger systolic pressure increased considerably more than the direct systolic pressure, exceeding it by 26 ± 20 mmHg (mean ± SD) at maximal exercise. These findings are comparable with those of the present study for the higher systolic and lower diastolic blood pressure with the Finapres; the systolic blood pressure difference between random-zero sphygmomanometry and the Finapres in our study (22.2 ± 4.1 mmHg—peak exercise) was similar. Similar increases for rest systolic blood pressures were described by Dorlas *et al.*;[21] average Finapres systolic BP was 7.0 mmHg higher than the reference although diastolic and mean blood pressures were substantially lower (–9.1 and –10.0 mmHg).

The data of Kermode *et al.*[16] obtained from patients under general anaesthesia also showed that the Finapres complied with the AAMI standard for accuracy and precision in measuring diastolic (accuracy: –2.94, precision: 2.75 mmHg) and mean blood pressures (accuracy: 1.28, precision: 5.87 mmHg), but not for systolic blood pressure (3.91 mmHg; precision: 10.54 mmHg). This agrees with our findings. The accuracy of Finapres mean arterial pressure measurements relative to simultaneous direct radial arterial pressures was determined in 20 patients undergoing general anaesthesia for major elective surgery. The overall bias of the Finapres mean pressure was −0.5 ± 1.0 mmHg, which was not significantly different from zero. However, 32.3 ± 6.2% of all mean pressure comparisons differed by greater than ±10 mmHg, and 5.0 ± 1.1% differed by greater than ±20 mmHg. There was an average of one episode every 2 patient-hours when the Finapres mean pressure differed by greater than ±20 mmHg for more than 1 min. Although the mean pressure measured by Finapres accurately reflected direct MAPs most of the time, there were occasional discrepancies of different magnitude such that clinical usefulness may be limited in patients in whom continuous accurate blood pressure measurements are essential.

The reproducibility of the Finapres was similar to that of the intra-arterial reference for systolic and diastolic blood pressure. This is in agreement with the data of Imholz *et al.*[17] who quote the reproducibility (standard deviation of the pressure measurements over 30 s) of the Finapres as 4.0, 1.8 and 2.0 for systolic, mean and diastolic blood pressure respectively. From this they inferred that the Finapres would be suitable for tracking changes in blood pressure. This inference was tested and confirmed by our study; although the absolute difference between the two methods increased considerably from rest to exercise, there was no systematic difference between the ability to track dynamic pressure changes between rest and exercise (i.e. at steady-state).

The application of the Finapres to clinical practice or during pharmacodynamic monitoring of circulatory changes is problematic; our data suggests that it probably reliably reflects the peripheral arterial pressure level but that this cannot be readily related to more proximal recordings of pressure. The phenomenon of waveform dispersion suggests that if pulse wave velocity alters significantly, then the relationship between proximal and distal blood pressure will adjust and at steady-state a new balance will be achieved. However, the pressure differences between the peripheral and proximal pressures may be large with the Finapres showing disproportionate increase (i.e. the relationship between proximal recording and distal methods will not be linear). In our study the systolic blood pressure difference between the Finapres and random-zero values increased from 6.8 ± 3.5 mmHg to 22.2 ± 4.1 mmHg but only from 3.6 ± 3.2 to 10.2 ± 6.3 mmHg for the corresponding brachial values. This is in agreement with other studies where changing physiological conditions, resulted in non-proportionate alterations in peripheral and more proximal estimates of pressure,[19,20] it has been noted that the fall in vascular resistance during exercise will reduce the amplification between the aorta and active limb[22] but may lead to greater amplification in the non-active limb. Thus Rowell *et al.*[19] showed marked amplification of the pulse wave amplitude from aorta to brachial and radial arteries during leg exercise, which was abolished during reactive hyperaemia in the arm.

The exercise non-invasive study illustrates another important point; it is feasible for the central and peripheral pressure to not alone demonstrate quantitative differences in pressor response, but also directional differences in response. On exercise the fall in peripheral vascular resistance lowered the arterial diastolic pressure (random-zero pressure) while the Finapres pressure increased. For pharmacodynamic interventions the loading alterations may not similarly alter peripheral and central blood pressure; thus O'Rourke suggested that peripheral blood pressure may be maintained during nitro-glycerine therapy despite falls in central pressure.[23] Interpreting data on the hypotensive actions of drugs from the peripheral pressure trace may be difficult; it would be of interest therefore to compare Finapres and other pressure methods during such pharmacodynamic studies to examine the extent to which these theoretical considerations are relevant.

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