Blood pressure measurement in obese patients: comparison between upper arm and forearm measurements

Angela M.G. Pierin[a], Débora C. Alavarce[a], Josiane L. Gusmão[a], Alfredo Halpern[b] and Décio Mion Jr.[c]

Background It is well known that blood pressure measurement with a standard 12–13 cm wide cuff is erroneous for large arms.

Objective To compare arm blood pressure measurements with an appropriate cuff and forearm blood pressure measurements (BPM) with a standard cuff, and both measurements by the Photopletismography (Finapres) method.

Methods One hundred and twenty-nine obese patients were studied (body mass index $= 40 \pm 7\,kg/m^2$). The patients had three arm BPM taken by an automatic oscillometric device using an appropriate cuff and three forearm BPM with a standard cuff in the sitting position after a five-minute rest. Data were analysed by the analysis of variance. The correction values were obtained by the linear regression test.

Results Systolic and diastolic arm BPM with an appropriate cuff were significantly lower ($p < 0.05$) than forearm BPM with a standard cuff. The measurements obtained by Finapres were significantly lower ($p < 0.05$) than those found for forearm systolic and diastolic blood pressures and upper arm diastolic blood pressure. The equation to correct BPM in forearm in obese patients with arm circumference between 32–44 cm was: systolic BPM $= 33.2 \pm 0.68 \times$ systolic forearm BPM, and diastolic BPM $= 25.2 + 0.59 \times$ forearm diastolic BPM.

Conclusion This study showed that forearm blood pressure measurement overestimates the values of arm blood pressure measurement. In addition, it is possible to correct forearm BPM with an equation. *Blood Press Monit* 9:101–105 © 2004 Lippincott Williams & Wilkins.

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[a]University of São Paulo School of Nursing, [b]Obesity Unit, Endocrinology Division and [c]Hypertension Unit, Nephrology Division, University of São Paulo General Hospital, São Paulo, Brazil.

Prof. Dr. Décio Mion Jr., Av. Dr. Enéas Carvalho de Aguiar, 255, 7° andar, sala 7032 Instituto Central do Hospital das Clínicas, Faculdade de Medicina da Universidade de São Paulo, CEP 05403-000 São Paulo, SP, Caixa Postal 8091, Brazil.
Tel/fax: +11 3082 2659; e-mail: deciomion@uol.com.br

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Introduction

Obesity, one of the most important public health problems, is frequently associated with hypertension. The Framingham study showed that hypertension history was related to obesity in 61% of women and 70% of men [1]. Thus, correct blood pressure measurement in obese people is vital for early hypertension diagnosis.

Office indirect blood pressure measurement, which has been employed for over a hundred years, is still the method chosen for hypertension diagnosis and treatment. This method requires the use of cuffs with adequate relationship between inflatable bladder size and arm circumference to avoid false blood pressure readings. It is well known that small cuff bladders can overestimate blood pressure values and large cuff bladders can result in underestimated readings [2–5]. However, a recent evidence-based review of blood pressure measurement [6] cited a study that evaluated 114 physicians and showed that 97% of them did not use an appropriate cuff bladder size for arm circumference [7]. In a recent study, the authors stated that when the observer is trained and the blood pressure measurement technique is standardized, the problem is smaller. The cuff width/arm circumference ratio accounted for less than 2% of variability [8].

Worldwide, the increasing prevalence of obesity and consequently increase in arm circumference make small cuffs erroneously diagnose hypertension, causing people to be treated unnecessarily or hypertensives to be overtreated.

Most commercially available sphygmomanometers only include a standard cuff with a 12×23 cm bladder. Consequently, standard cuff bladders are commonly used in daily practice for measuring blood pressure on the forearm of obese patients [9]. Moreover, Singer *et al.*, [10] compared blood pressure measurements with appropriate sized cuffs on the upper arm and forearm and showed

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that forearm blood pressure is a fairly good predictor of upper arm blood pressure in most patients; however, they observed differences in systolic and diastolic blood pressures within 10 mmHg in 58% and 70% of the patients and within 20 mmHg in 86% and 94% of the patients, respectively. This measurement would be advisable only in certain situations such as emergencies when there is no possibility of upper arm blood pressure measurement, not in routine clinical practice. However, it is not known if it applies to obese people. Furthermore, it is important to use an appropriate cuff bladder to upper arm circumference so that a comparison can be made with a standard cuff bladder encircling the forearm.

Thus, the objectives of the present study were: (a) to compare upper arm blood pressure values performed with an appropriate cuff bladder for upper arm circumference with forearm values obtained with a standard cuff bladder; (b) to compare both measurements performed by the Photopletismography (Finapres) method; and (c) to determine the correction equation for forearm blood pressure measurements with a standard cuff bladder.

Methods

We studied obese patients from the Obesity and Hypertension Outpatient Service of the University of São Paulo General Hospital, São Paulo, Brazil. The population consisted of 129 obese patients (45 ± 14 years of age, 116 women) with body mass index of 40 ± 7 kg/m^2, upper arm circumference of 39 ± 4 cm and forearm circumference of 29 ± 2 cm.

Obesity was diagnosed when body mass index [weight (kg)/height (m)^2] was higher than 30. Body weight was measured with patients wearing light clothes and no shoes.

Arm circumference was measured in the right arm in the midpoint between the acromium and olecranon. Upper arm measurement was made with an appropriate cuff bladder. Thus, a cuff with a bladder measuring 15 × 34 cm was used for arm circumferences between 32 cm and 44 cm and another measuring 18 × 37 for arm circumferences larger than 44 cm. Forearm blood pressure measurement was made with a standard cuff measuring 12 × 23 cm.

Blood pressure measurements were taken with patients in the sitting position after a 5-min rest. The sequence of upper arm and forearm measurements was randomised. The patients were blind to their blood pressure readings.

Upper arm and forearm blood pressure measurements were taken three times with a 2-min interval between them by an automatic oscillometric device (DIXTAL DX 2710) which was validated according to the requirements proposed by the British Hypertension Society and the Association for the Advancement of Medical Instrumentation and had its calibration monthly assessed [11–13].

After upper arm and forearm blood pressure measurements, a beat-to-beat blood pressure measurement was also made by the Photopletismography (Finapres) method. The patient was placed in the supine position and was connected to the device by a finger cuff placed on their non-dominant hand. After the patient had rested for a while to obtain a stable signal, blood pressure was recorded for 2 min.

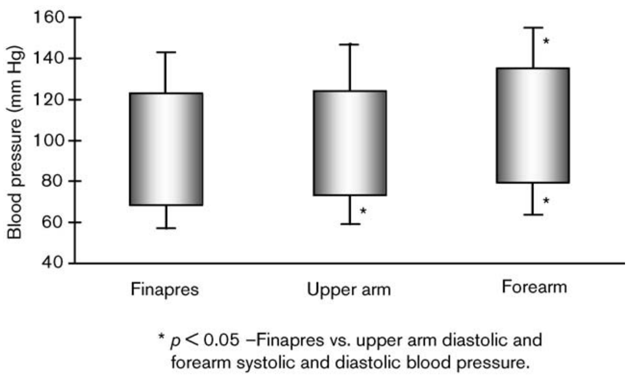
The average of the three upper arm and forearm measurements was used for calculations. Upper arm, forearm and 'Finapres' blood pressure differences were defined as the differences in both systolic and diastolic blood pressures between measurements. The correlation between upper arm and forearm blood pressures was determined by Pearson's test. The correction values were obtained by the linear regression test, having as the fixed matrix, upper arm blood pressure values obtained with an appropriate cuff bladder for arm circumference and as the variable matrix, forearm blood pressure values obtained with a standard cuff bladder. For all tests $p < 0.05$ was considered significant. Results are shown as mean ± standard deviation.

Results

Results showed that upper arm systolic/diastolic blood pressure measurement performed with an appropriate cuff ($n = 129$, 124 ± 21/73 ± 13 mmHg) was significantly lower ($p < 0.05$) than forearm measurement obtained with a standard cuff (136 ± 19/82 ± 13 mmHg). In addition, the mean differences between upper arm and forearm measurements were 12 ± 10 mmHg for systolic blood pressure and 9 ± 9 mmHg for diastolic blood pressure. The correlations between upper arm and forearm systolic and diastolic blood pressure measurements were 0.73 and 0.67 ($p < 0.05$).

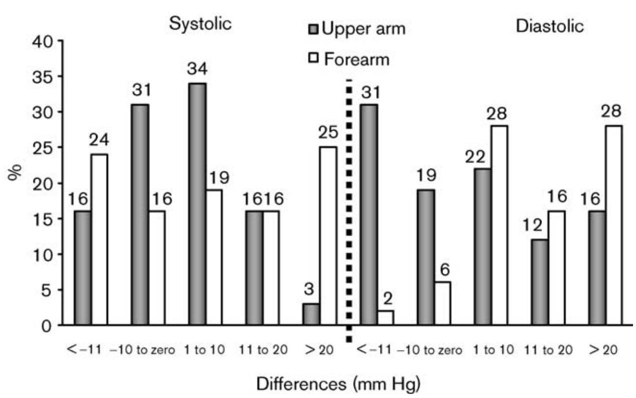
The measurements obtained by the "Finapres" ($n = 30$, 123 ± 19/68 ± 10 mmHg) were significantly lower ($p < 0.05$) than those found for forearm systolic and diastolic blood pressures (135 ± 19/79 ± 14 mmHg) and upper arm diastolic blood pressure (124 ± 22/73 ± 13 mmHg) (Figure 1). The differences between upper arm and 'Finapres' systolic and diastolic blood pressure were within 10 mmHg in 34% and 22% of the patients, respectively, and for forearm, the differences were 19% and 28%. The differences between forearm and 'Finapres' systolic and diastolic blood pressure were higher than 20 mmHg in 25% and 28% of the patients, respectively, whereas differences between upper arm and 'Finapres' systolic and diastolic blood pressure were

Fig. 1



Blood pressure performed with Finapres and with an appropriate bladder cuff on upper arm and standard bladder cuff on forearm.

Fig. 2



Percentage distribution of the differences in systolic and diastolic blood pressure between Finapres values and upper arm and forearm measurements.

higher than 20 mmHg only in 3% and 16% of the patients, respectively (Figure 2).

Hypertension was diagnosed in 23% of the patients considering upper arm measurement while 34% were diagnosed hypertensive based on forearm blood pressure measurement (Figure 3). Moreover, optimal blood pressure values were present in 53% of the patients when upper arm measurement was considered against only 18% when forearm measurement was considered ($p < 0.05$).

The principal point in the present study is that correction values can be established by forearm blood pressure measurements made in patients with arm circumference between 32 and 44 cm. The equation for blood pressure correction can be expressed as follows:

$$\text{Systolic pressure} = 33.2 + 0.68 \times \text{forearm systolic pressure}$$

$$\text{Diastolic pressure} = 25.2 + 0.59 \times \text{forearm diastolic pressure}$$

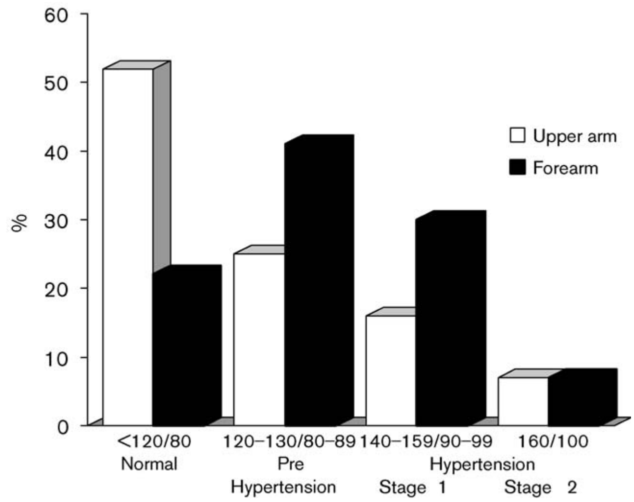
Discussion

The main finding of this study is that forearm blood pressure values obtained with standard cuff bladders are overestimated when compared to values of upper arm measurements performed with an appropriate cuff bladder. Also, it was shown that the correction of these values with an equation is possible and necessary. For patients with arm circumference between 32 and 44 cm, the equations obtained in the present study (systolic pressure = 33.2 + 0.68 × forearm systolic pressure and diastolic pressure = 25.2 + 0.59 × forearm diastolic pressure) are useful to correct blood pressure measurements taken on forearm with a standard cuff. There is a limitation in the present study because the population consisted of women mainly. However, the only variable analysed was the arm and upper arm circumference regardless of gender.

The relationship between obesity and hypertension has been shown by epidemiological studies. However the lack of accuracy in blood pressure measurement by indirect method with auscultatory method is an aspect to be considered. Cuff size can change hypertension prevalence in obese people. Linfors *et al.*, [14] stated that people whose arm circumference was larger than 35 cm presented prevalence twice as higher with a standard cuff bladder than with a large cuff bladder. Irvine *et al.*, [15] made normal people's arms artificially larger by using soft materials like cotton and found readings higher than those found with cuff alone. In these cases, the pressure applied by the cuff is spread in the flabby tissue of an obese arm, being responsible for the false increase in blood pressure. The aspects pointed out here show that obese arms require appropriate cuff sizes so that accurate blood pressure readings can be obtained.

Accurate blood pressure measurement depends on observers, equipment, environment, and technique [6,16,17]. Assuming that it is important to use an appropriated cuff the next question is to decide what cuff bladder size is adequate. The first recommendation of the American Heart Association, in 1939, stated that the appropriate cuff size for blood pressure measurements was a bladder width of 12–13 cm [18]. In the following recommendation, in 1951, was a bladder width 20% larger than the arm circumference [19]. The last two reports recommend a bladder width of 40% of the upper arm circumference and a length that encircles at least 80% of the arm circumference [20,21]. Therefore cuffs containing bladders measuring 30 × 13 cm should be used by adults whose arm circumference ranges from 27–34 cm; cuffs measuring 38 × 16 cm, for adults whose

Fig. 3



Classification of blood pressure according to upper arm measurements performed with an appropriate bladder cuff and to forearm values obtained with standard bladder cuff.

arm circumference ranges from 35–44 cm; and cuffs measuring 42 × 20 cm, which are thigh cuffs, for adults whose arm circumference ranges from 45–52 cm. However, this recommendation is questioned by Marks and Groch [22] who compared blood pressure measured directly and indirectly and showed that the optimum cuff width is not directly proportional to arm circumference but proportional to the logarithm of the arm circumference, expressed by the ratio, cuff width = 9.34 × arm circumference.

In the current study, blood pressure measurement in the forearm did not eliminate the chance of error in blood pressure measurement in obese people since there were significant differences in systolic and diastolic blood pressures. Patients borderline between hypertension and normotension can be falsely diagnosed as hypertensives with forearm blood pressure measurement, making them undergo unnecessary treatment. When upper arm blood pressure and forearm measurements were compared with a beat-to-beat method (Finapres), the data showed that the upper arm measurement was closer to beat-to-beat measurement. This method described by Penaz shows a good relationship with intra-arterial pressure regarding indirect measurement with other methods [23–25].

In clinical practice and most public healthcare services, mainly in less developed countries, healthcare professionals cannot count on having different cuff sizes for blood pressure measurement, and have to find ways to correct blood pressure values. One alternative is to use correction tables such as the one elaborated by Maxwell *et al.*, [4] which subtracts from or adds values to systolic and diastolic blood pressures according to arm circumference and can be used as an adhesive tape [26]. Another is to use a special cuff with three rubber bladders of different sizes in a single cuff (TriCUFF), which automatically selects the appropriate bladder size due to an auto-adjusting technique. This cuff was tested in obese patients against a standard cuff and the results showed no significant difference [27,28].

Conclusions

The findings of the present study showed that forearm measurements in obese people do not replace upper arm measurements made with an appropriate cuff bladder size. The correlations between upper arm and forearm systolic and diastolic blood pressure measurements were good, but the forearm blood pressure measurement could increase the prevalence of hypertension in obese patients.

A finding of considerable interest is that forearm measurements made with a standard cuff bladder could be corrected by an equation; however, there is limitation for correction since the equation can only be applied to arm circumferences between 32 and 44 cm. Therefore, the equation for blood pressure correction on the forearm with a standard cuff bladder can be useful for this situation and avoid errors.

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