Comparison Between Direct and Invasive Arterial Blood Pressure Measurement in Non-Hypotensive Critically ill Patients*

Comparação entre Medidas Invasivas e Oscilométricas de Pressão Arterial Sistêmica em Pacientes Críticos Não Hipotensos.

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SUMMARY

BACKGROUND AND OBJETIVES: *Invasive measurement of systemic arterial blood pressure is frequently used to monitor critically ill patients. The invasive method is related to excessive blood sample collection, blood stream infections, and local thrombotic events. The oscillometric noninvasive measurement of arterial blood pressure can be used in non-hypotensive patients after the acute phase of intensive care unit stay, reducing the invasive related adverse effects. The aim of this study was to compare the invasive measurement of systemic arterial blood pressure to the oscillometric method in non-hypotensive critically ill patients.*

METHODS: *Data of twenty-seven patients non treated by vasopressors or inotropics were prospectively collected. Ten concomitant invasive and oscillometric measurements of systemic arterial blood pressure were performed every 10 minutes in cooperative patients.*

RESULTS: *The correlation between the 2 methods was good, r = 0.75 for systolic blood pressure, r = 0.72 for diastolic blood pressure, and r = 0.73 for mean blood pressure, but agreement was poor, bias = - 5 mmHg for systolic blood pressure, 7 mmHg for diastolic blood pressure, and 6 mmHg for mean blood pressure. Factors identified as a possible source of these great biases were low body mass index (BMI), low weight, and high systemic arterial blood pressure.*

CONCLUSIONS: *The oscillometric noninvasive technique can be used to measure systemic arterial blood pressure in non-hypotensive critically ill patients, taking into account that it correlates well with direct meassurement, but the real value is probably lacking, mainly in thin and hypertensive patients.*

Key Words: *Blood pressure, intensive care, physiologic monitoring.*

Invasive measurement of systemic arterial blood pressure is frequently used to monitor critically ill patients, mainly in the acute phase of the intensive care unit stay[1]. The estimate of systemic arterial blood pressure and other information, such as pulse pressure variation[2] and pulse contour[3], is retrieved from the systemic arterial blood pressure curve, and that information is reliable for monitoring volume challenges in critically ill patients[4]. In contrast, use of the arterial line is related to excessive blood sample collection[5], blood stream infections, and local thrombotic events[6].

The oscillometric measurement of arterial blood pressure is widely used in clinical setting and consists in a noninvasive tecnique that uses a cuff around the limb. After the insuflation of cuff, during the fall of pressure, the pressure oscillation caused by arterial pulsation is detected by the monitor and analysed following different algorithms. Generally, the mean arterial pressure is the pressure inside the cuff corresponding to the major amplitude of oscillations; systolic and diastolic arterial pressures are derivated from the mean arterial pressure[7]. The oscillometry is accurate in noncritically ill subjects and can be used as an alternative to invasive measurement in the critical care setting[7,8].

In this study, we compared the noninvasive oscillometric measurement of systemic arterial blood pressure to the invasive method in critically ill patients who are not treated by vasopressors and inotropics.

METHODS

Twenty-seven consecutive patients from a 7-bed medical intensive care unit in a tertiary care university hospital in São Paulo, Brazil, were prospectively enrolled in the study. Patients were enrolled who were in the non hypotensive phase of their intensive care unit stay, and no inotropics or vasopressors were being used by the patients. Patients on mechanical ventilation were allowed. Informed consent was given by the patient or next of kin. When the patient was off continuous arterial blood pressure monitoring, the proper cuff[7] was positioned on the contralateral arm of the arterial line after checking whether a difference existed between the measurement of noninvasive arterial pressure in both arms. Patients with a difference in systolic arterial pressure > 20 mmHg between the arms were excluded from the analysis[8].

In our unit, all hypotensive or mechanically ventilated patients are sistematically monitored with invasive arterial blood pressure catheter. Right radial artery is preferentially

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cannulated with a 20G, nontapered, teflon catheter (Becton e Dickinson Ind. Cirúrgicas Ltda, Juiz de Fora, MG, Brazil) to access arterial blood pressure and blood samples for laboratory analysis. The catheter and the transducer system (PX260 Pressure Monitoring Kit with TruWave Disposable Pressure Transducer, Edwards Lifesciences, Irvine, CA, USA) are of low compliance, and the flush test was performed frequently during, the study, to assure the correct transmission of pressure through the system. This flush test is able to generate a square-wave signal, and in a properly functioning system this signal must reverberate one or two times and then decay back to the underlying vascular pressure[9].

Measurements of noninvasive arterial blood pressure were done every 10 minutes by the oscillometric technique for a total of 10 measurements / patient. Concomitantly, the invasive blood pressure was recorded at the same time in a single measurement every 10 minutes. Data were collected automatically by DIXTAL 2010 monitor (DIXTAL, São Paulo, SP, Brazil), the oscillometric device of this monitor has been validated following the ANSI/AAMI SP10-1992 norm[10,19]. General data about the patients, such as age, sex, APACHE II score, weight, height, and arm circumference, were also collected. The patients were calm and cooperative during the period of data recording.

Data are shown as medians and interquartile ranges[11]; correlation was performed using the Spearman analysis[12] and agreement using the Bland-Altman plot[13]. The Wilcoxon signed rank test was used to compare within-group medians[14]. To evaluate the possible factors associated with errors between both methods tested, the Spearman correlation between the factor analyzed, and the subtraction of the pressures measured by the 2 techniques were used. $P < 0.05$ was considered statistically significant.

RESULTS

No patient was excluded from the study due to differences in noninvasive measurement of systolic pressure between the arms. General characteristics, diagnosis, and median arterial blood pressures of patients enrolled in the study are shown in table 1. Medians of invasive arterial blood pressures were statistically different from those acquired noninvasively (Table 1). In spite of these differences, the correlation between both was good for systolic, diastolic, and mean arterial blood pressure, but the agreement was poor (Figure 1). Possible factors associated with bias were evaluated in a univariate analysis of systolic, diastolic, and mean pressure. Age, weight, body mass index (BMI), and the level of invasive arterial blood pressure were possible factors associated with errors during the noninvasive measurement of systemic arterial pressure in our patients (Table 2). No patients had complications due to the arterial puncture.

DISCUSSION

In our patients, the correlation between invasive and oscillometric measurements of systemic arterial blood pressure was good, r = 0.75 for systolic blood pressure, r = 0.72 for diastolic blood pressure, and r = 0.73 for mean blood pressure. In spite of this good correlation, the agreement was poor, bias = - 5 mmHg for systolic blood pressure, 7 mmHg for diastolic blood pressure, and 6 mmHg for mean blood pres-

Table 1 – General Characteristics and Arterial Blood Pressure of Patients

Characteristics	Value (n = 27)	
Age (yr)	43 (26-65)	
Gender (male/female)	13/14	
APACHE II *	16 (12-21)	
Arm circumference (cm)	29 (26-30)	
Weight (kg)	60 (60-75)	
Height (cm)	165 (155-179)	
BMI (kg/m^2)#	24 (22-27)	
Heart Rate (beats/min)	102 (91-117)	
Mechanical ventilation (no)	26	
Death (no)	10	
Arterial line stay (days)	4 (3.5-5.5)	
Diagnoses		
Shock syndrome (no)	18	
Septic (no)	16	
Cardiogenic (no)	2	
Respiratory failure (no)	7	
Acute encephalopathy (no)	2	
Arterial blood pressure	Noninvasive (n = 265)	Invasive (n = 265)
Systolic (mmHg)	126 (108-146)	130 (116-150)
Diastolic (mmHg)	72 (62-81)	63 (54-76)
Mean (mmHg)	93 (79-105)	85 (75-98)

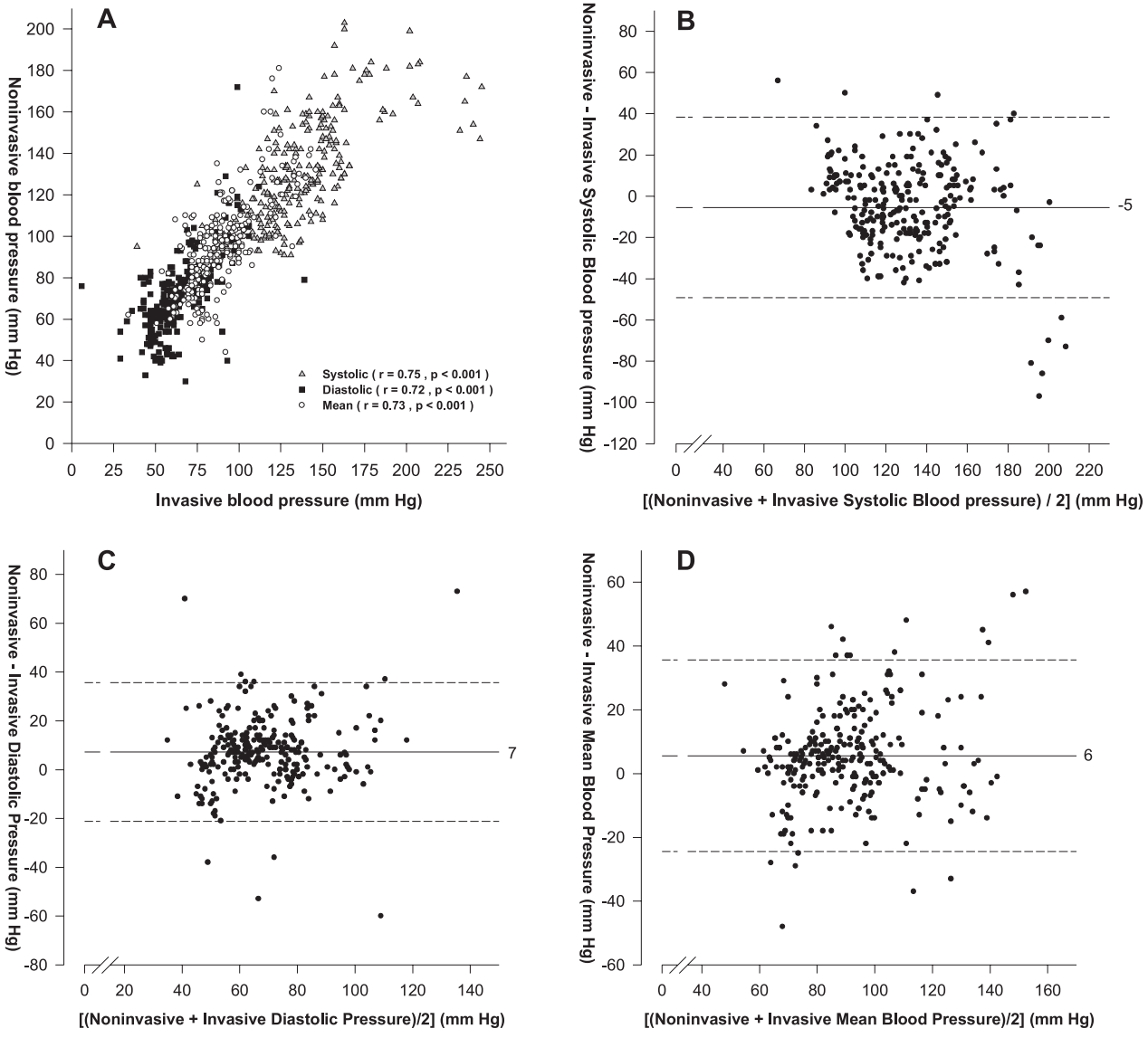
(no) denotes the absolute number of patients
* APACHE II denotes Acute Physiological and Chronic Health Evaluation score and ranges from 0 to 72.
# BMI denotes Body Mass Index.
$p < 0.001$ between invasive and noninvasive arterial blood pressures (Wilcoxon signed rank test).

Table 2 – Variables Associated With Error Between Invasive and Noninvasive Arterial Blood Pressures*

	Systolic	Diastolic	Mean
Characteristics	r coefficient p value	r coefficient p value	r coefficient p value
Age	- 0.043 0.493	0.138 0.027	- 0.052 0.404
Gender	0.004 0.948	- 0.038 0.535	- 0.078 0.208
Height	- 0.023 0.716	- 0.028 0.652	- 0.024 0.704
Weight	- 0.210 < 0.001	- 0.075 0.232	- 0.216 < 0.001
BMI	- 0.196 < 0.002	- 0.009 0.887	- 0.204 0.001
Arm circumference	- 0.039 0.532	0.012 0.855	- 0.110 0.078
Heart rate	0.035 0.576	- 0.006 0.927	0.112 0.076
IBPs	0.457 < 0.001	0.114 0.065	0.190 0.002
IBPd	0.250 < 0.001	0.366 < 0.001	0.298 < 0.001
IBPm	0.295 < 0.001	0.307 < 0.001	0.300 < 0.001

*Error was calculated as invasive minus noninvasive arterial blood pressure divided by invasive blood pressure. These univariated analyses were performed using the Spearman correlation with error as the dependent factor and the characteristic as the independent factor. r denotes the Spearman coefficient.

Figure 1 - Panel A shows the correlation between invasive and noninvasive systolic, diastolic and mean arterial blood pressure, r denotes Spearman's coefficient. Panels B, C and D show the agreement (Bland Altman plot) between invasive and noninvasive systolic, diastolic and mean arterial blood pressures respectively. The bias and the standard deviation of the bias were: – 5 22 mmHg to systolic pressure, 7 14 mmHg to diastolic pressure and 6 15 mmHg to mean pressure. Biases are shown at the right side of the Bland Altman plots.



sure. Some factors were identified as a possible source of this bias: low BMI, low weight, and high systemic arterial blood pressure were associated with greater differences between the 2 measurement methods (Table 2).

Direct arterial measurement of systemic arterial blood pressure is considered the gold standard[15]. One point to be discussed is the reliability of the radial invasive measurement. In the postoperative period after cardiac surgery, the difference between radial to femoral measurements is high[16,17]; otherwise, in general adult critically ill patients, radial artery cannulation is usually attempted initially unless the pulses are not palpable. If this fails, femoral artery cannulation is recommended as a safe alternative to difficult radial cannulation[18]. However, available data do not indicate a preference for any one site[6,18].

The good correlation between the methods point out the tendency of similar behavior of the methods, but we can not extrapolate this result to temporal tendency with our data. The good correlation does not indicate the reproducibility of the values obtained through each technique[12]. Otherwise, the poor agreement shows the inaccuracy of the oscillometric measurements[13]. According to the Association for the Advancement of Medical Instrumentation (AAIM) in the United States, the bias allowed between the 2 methods of systemic arterial blood pressure measurement is < 5 mmHg, and the standard deviation for this bias is < 8 mmHg[19]. Our results are greater than these allowed values showing that the values obtained could underestimate the real value (Table 1, Figure 1). Our study is limited because we have used measurements

in contralateral arm, and physiologically one could argue that pressures measured in one arm can be 20 mmHg different from the other[8]. This difference can explain the poor agreement between the methods in our study.

With regard to factors related to the difference between the techniques, low weight and BMI were associated with a high bias. Higher biases are expected in obese patients, a situation known as "pseudo hypertension"[15]. No severe obese patients were enrolled in our study. High pressures were associated with high bias in our study, but it must be stressed that hypotensive patients were not enrolled in the study, and in these hypotensive patients the bias is supposed to be high[1]. A weak correlation existed between age and diastolic pressure probably due to the higher rigidity of artery walls in the older patients, another cause of "pseudo hypertension"[15].

Several medical conditions are associated with errors with the oscillometric technique, such as in the postoperative period after coronary artery bypass graft[20], in preeclampsia[21], in the labor ward[22], in obese and older patients[15]. In shock states, it is strongly recommended that an invasive technique be used to estimate systemic arterial blood pressure[1]. In a physiological study, Hynson et al[23] showed that during drug-induced vasoconstriction, the accuracy of the oscillometric technique was good. In contrast, in drug-induced vasodilatation, the accuracy was poor. Likewise, an arterial line can be helpful during the acute phase of intensive care because arterial blood pressure must be exactly and frequently measured and repeated blood samples may be easily collected[1].

The continuous beat-to-beat monitoring of systemic arterial blood pressure offers great help in the acute-phase monitoring of the intensive care unit stay[2-4]. Otherwise, the invasive systemic arterial blood pressure measurement can be associated with unnecessary blood collection, blood stream infections, and arterial thrombosis[5,6] if the catheter remains in place for a long time. In non-hypotensive patients, after the acute-phase of the intensive care unit stay, the oscillometric noninvasive technique to measure systemic arterial blood pressure can be used taking into account that it correlates well with direct measurement, but the real value probably is lacking, mainly in thin and hypertensive patients, at least when the oscillometric measurement is used in the contralateral arm of the invasive arterial catheter.

RESUMO

JUSTIFICATIVA E OBJETIVOS: O método invasivo ou direto de mensuração da pressão arterial sistêmica é usado com freqüência na monitorização de pacientes críticos, mas tem efeitos adversos como coletas excessivas de amostras de sangue, infecções de corrente sangüínea e trombose local. A técnica não-invasiva automatizada oscilométrica pode ser uma alternativa após a fase aguda em pacientes críticos não hipotensos, possivelmente reduzindo a incidência de complicações. O objetivo deste estudo foi comparar as medidas invasivas e não-invasivas de pressão arterial sistêmica.

MÉTODO: Dados de 27 pacientes não recebendo vasopressores ou inotrópicos foram prospectivamente coletados. Dez medidas invasivas e não-invasivas da pressão arterial sistêmica foram realizadas a cada 10 minutos.

RESULTADOS: A correlação entre os dois métodos foi boa, r = 0,75 para pressão sistólica, r = 0,72 para pressão diastólica e r = 0,73 para pressão média, mas a concordância entre os métodos foi ruim, bias = - 5 mmHg para pressão sistólica, 7 mmHg para a pressão diastólica e 6 mmHg para a pressão média. O IMC e o peso reduzido, assim como a pressão arterial altos foram indentificados como possíveis fatores associados ao maior erro.

CONCLUSÕES: A técnica não-invasiva oscilométrica pode ser usada para medir a pressão arterial sistêmica em pacientes críticos não hipotensos levando em conta que esta técnica tem boa correlação com a mensuração invasiva, mas o valor real da medida pode não ser tão exato, principalmente em um subgrupo especial de pacientes.

Unitermos: Pressão arterial, monitorização fisiológica, terapia intensiva.

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