Estimation of Mean Blood Pressure from Oscillometric and Manual Methods

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Abstract

The aim of this study was to estimate mean blood pressure from oscillometric and manual methods.

Ten healthy subjects were studied with three repeat blood pressure measurements. Manual systolic and diastolic blood pressures (SBP and DBP) were obtained by two trained observers. During the measurement the oscillometric cuff pressure waveform was recorded digitally. The cuff pressure corresponding to the largest oscillometric pulse pressure was taken as the mean arterial pressure (MAP). MAP was also estimated from manual DBP plus one third the pressure change from DBP to SBP. Blood pressure measurement variability and the difference between automated and manual MAP were quantified.

The overall coefficients of variability for manual SBP and DBP were 2.2% and 4.5%. Corresponding values for manual and automated MAP were 3.1% and 3.7%. The automated MAP, as a percentage of the difference between manual DBP and SBP was 28±14% (mean ± SD), which was lower than the classically assumed mean value of 33 %.

In conclusion, the relationship between MAP and SBP and DBP is complex with a large between-subject SD variability of 14%.

1. Introduction

Blood pressure determination is one of the most important clinical and diagnostic measurements. Despite the importance of blood pressure measurement and its very widespread use, it is accepted that it is one of the most poorly performed diagnostic measurements in clinical practice [1].

The gold standard for clinical arterial blood pressure measurement has always been readings taken by a trained observer using manual sphygmomanometry and the Korotkoff sound technique [2]. Blood pressure measurement with an automated, non-invasive device is also taken frequently in many health care institutions, but is highly variable and often inaccurately performed [2, 3].

The majority of these automated devices use the oscillometric techniques, which can readily determine mean arterial blood pressure (MAP), and can be used as a first step in estimating systolic and diastolic blood pressures (SBP and DBP) [4]. However, little is known about the relationship between these pressures.

The aim of this study was to compare the estimation of MAP from oscillometric and manual methods, and to determine the blood pressure measurement variability for these two methods.

2. Methods

2.1. Subjects

Ten healthy subjects, with no known cardiovascular disease, were studied. There were 8 male and 2 female subjects, with ages in the range 22 to 63 years. This study received ethical permission, and all subjects gave their written informed consent.

2.2. Blood pressure measurements

Blood pressure measurements were undertaken in a quiet room. The subject was seated in a chair with their feet on the floor and with arm supported at heart level. There was a 5 min rest period before measurements to allow cardiovascular stabilization.

Manual SBP and DBP were obtained with a manual sphygmomanometer, simultaneously by two trained observers. Three repeat measurements were performed for each subject.

During each measurement, the oscillometric cuff pressure waveform was recorded to a data capture computer at a sample rate of 2000 Hz for subsequent off-line analysis. After oscillometric pulses were pre-processed by filtering, the largest oscillometric pulse pressure was determined using software developed with Matlab 7.0. The cuff pressure corresponding to the largest oscillometric cuff pressure pulse was taken as MAP, as shown in Figure 1. MAP was also estimated from manual DBP plus one third the pressure change from DBP to SBP.

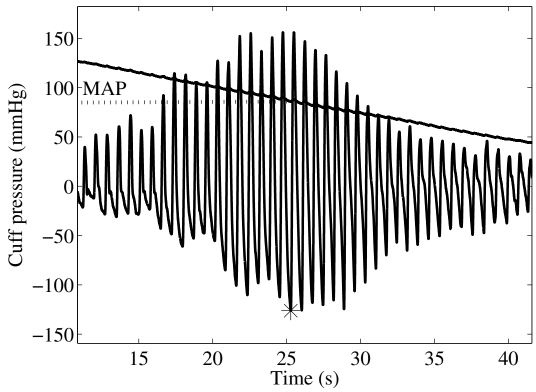

Figure 1. One typical example of cuff pressure and extracted oscillometric waveforms.

2.3. Data analysis

SPSS software package (SPSS Inc.) was employed to perform analysis of Variance (ANOVA) for determining the repeatability and the effect of observer on manual blood pressure measurement.

The average value of manual SBP and DBP from the two observers was then calculated for the three repeat recordings. Within-subject blood pressure variability was calculated from the standard deviation (SD) of the three repeat measurements, and also expressed as a coefficient of variability (100×SD/mean, %).

Finally, the regression analysis and Bland-Altman analysis were performed on all the MAPs from manual and oscillometric methods. And the automated MAP, as a percentage of the difference between manual DBP and SBP, was compared with the classical mean value of 33%.

3. Results

3.1. Variability of manual SBP and DBP

ANOVA analysis shows that there was no significant difference between the two trained observers and the three repeat readings for SBP and DBP (both $P>0.1$). As shown in Figure 2, the mean within-subject SD variabilities for SBP and DBP were 2.6 and 3.3 mmHg, with coefficients of variability of 2.2% and 4.5%.

3.2. Variability of manual and automated MAP

The overall mean MAPs from manual and oscillometric methods are shown in Figure 3. The mean within-subject SD variabilities for MAP are also given, with 2.7 and 3.2 mmHg from manual and automated methods and with corresponding coefficients of variability of 3.1% and 3.7%.

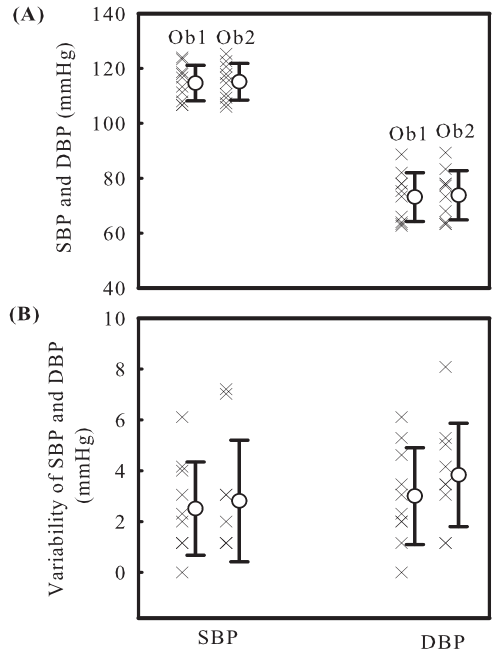

Figure 2. Mean manual SBP and DBP (A) and their variabilities (B) for each subject, which were calculated from the three repeat recordings. The values from the two observers are given.

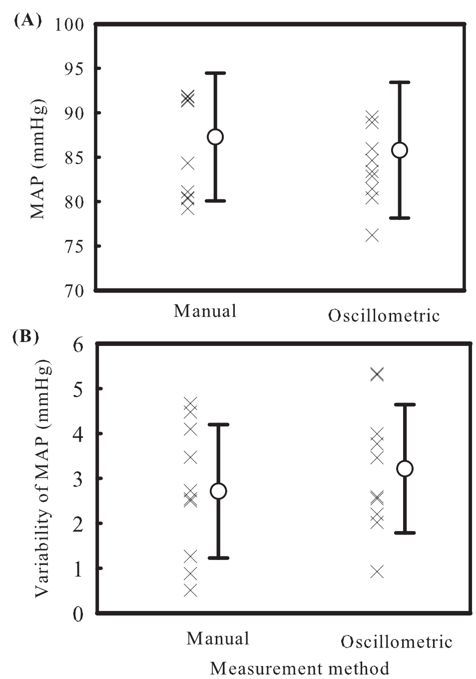

Figure 3. Mean MAP (A) and its variability (B) for each individual subject obtained from the manual and oscillometric technique, which was calculated from the three repeat recordings.

3.3. Comparison between manual and automated MAP

Figure 4 shows the comparison of MAP obtained from manual and oscillometric methods. The linear regression analysis showed that the correlation of MAP from the two methods was significant (P<0.001), with the regression slope of 0.75 and the R square of 0.5. Their overall mean MAP differences were very close to zero (1.5mmHg) and the majority of the MAP fell within the limits of agreement (2×SD=12mmHg).

Figure 5 shows the automated MAP, as a percentage of the difference between manual DBP and SBP. The overall mean ± SD value was 28±14%, which was lower than the classically assumed mean value of 33%.

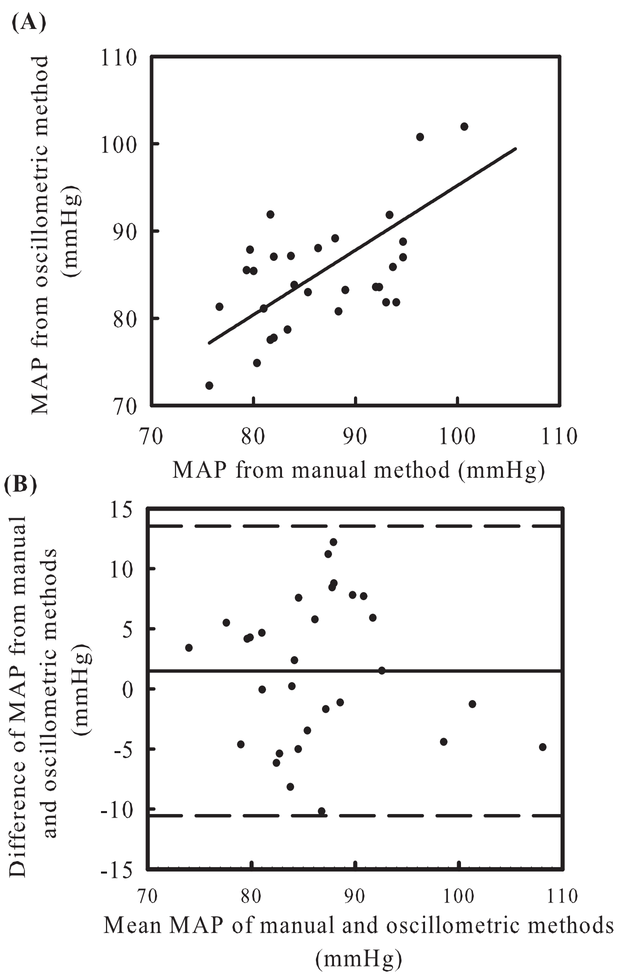

Figure 4. (A) Regression analysis results of MAP from the manual and oscillometric methods. (B) Bland-Altman plot of MAP difference from the two methods.

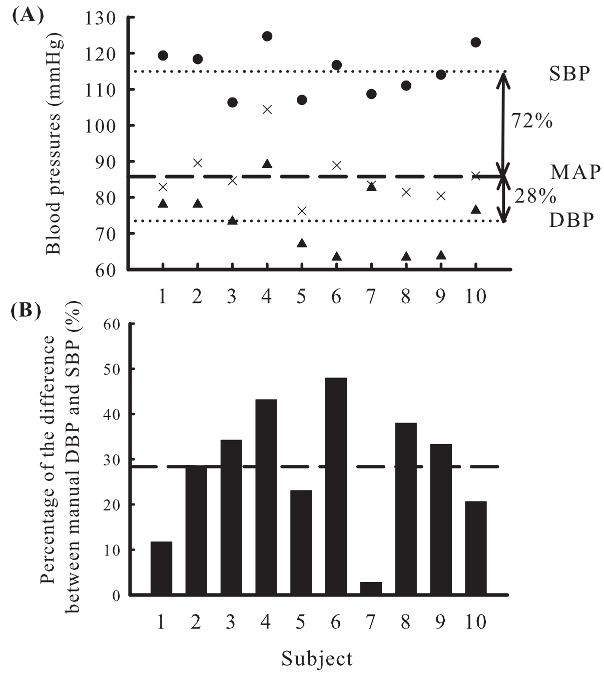

Figure 5. (A) Mean SBP and DBP from all manual recordings and average MAP from oscillometric technique for each subject. (B) Automated MAP, as a percentage of the difference between manual DBP and SBP for each individual subject. A virtual line is drawn with mean value.

4. Discussion and conclusions

The most noted comment from clinicians and nurses is that consecutive blood pressure measurements in the same individual vary significantly, whether the measurements are taken manually or automatically. In this study, the short term blood pressure measurement variability from manual and oscillometric methods was less than 4 mmHg. This variability is associated with conditions during the measurement, including patient posture, arm position, the cuff size and the environment in which blood pressure measurements are made [3, 5, 6]. These factors are required to be carefully controlled in order to improve the measurement accuracy. And this work needs to be followed up to determine the effect of longer periods between measurements.

Other disturbances, including heart rate changes, frequent ectopic beats, arrhythmias, patient movement, respiratory disturbances, coughing, talking and muscle tension, associated with changes in the oscillometric pulses in the cuff pressure for the oscillometric technique, can also influence clinical blood pressure measurement variability [7-10]. Thus, the quantification of the relationship between manual blood pressure measurement variability and the characteristics of the oscillometric cuff pressure waveform needs to be further investigated.

Interestingly, this study has shown that the automated MAP, as a percentage of the difference between manual DBP and SBP was lower than the classically assumed mean value of 33 %, and the relationship between MAP and SBP and DBP is complex with a large between subject SD variability of 14% in normals. In a patient population this can be expected to be higher. These values are relevant for developing new automated techniques to achieve accurate blood pressure measurement and for validating automated blood pressure devices for clinical use.

Acknowledgements

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