Blood Pressure Difference between the Measurements taken during Cuff Inflation and Deflation

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Abstract

There is little quantitative clinical data available to support blood pressure measurement accuracy during cuff inflation. This study aimed to provide these data.

Manual auscultatory systolic and diastolic blood pressures (SBP and DBP) were obtained from 15 subjects during cuff inflation and deflation. During the measurement, the oscillometric cuff pressure was inflated and deflated linearly at the same rate of 2-3 mmHg/s, and was recorded digitally for off-line analysis. Automated mean arterial pressures (MAPs) were then determined from both cuff inflation and deflation, corresponding to the cuff pressures at the peak of the 6th order polynomial model envelope fitted to the sequence of oscillometric pulse amplitudes. The manual SBP, manual DBP and automated MAP measured during cuff inflation and deflation were finally compared.

The manual SBP measured during cuff inflation was significantly lower by 4.3 mmHg (mean±SD: 110.6±9.7 vs 114.9±9.0) than that measured during cuff deflation (P<0.001). However, the manual DBP from cuff inflation was significantly higher by 3.0 mmHg (76.7±7.8 vs 73.6±7.2) than that from cuff deflation (P<0.01), and the automated MAP from cuff inflation was also significantly higher by 4.5 mmHg (88.3±7.4 vs 83.9±8.7) (P<0.01).

In conclusion, this study quantitatively showed that blood pressures measured during cuff inflation and deflation were different.

1. Introduction

Measurement of blood pressure (BP) is one of the most common and important clinical and diagnostic measurements made by family doctors, hospital physicians and other healthcare providers [1]. Automatic non-invasive BP (NIBP) measurement devices are used frequently in many health care institutions because they are easy to operate.

The most common automatic BP devices use the oscillometric technique [2,3]. Technically, these automatic BP devices analyse the small pressure pulse changes (oscillometric pulses) induced in a pressurized cuff wrapped round the upper arm. Traditionally, the cuff is rapidly inflated to a peak inflation level (normally 30 mmHg above the cuff pressure where the radial pulse disappears), and automated BPs are then determined during cuff pressure deflation.

To reduce the measurement time, some automatic devices measure BP during cuff pressure inflation. Since the measurement principle is the same, theoretically, the measured BP should be similar. However, there is little quantitative clinical data available to support the BP measurement accuracy during cuff inflation. This study aimed to provide these data by comparing the BP difference between the measurements taken during inflation and deflation.

2. Methods

2.1. Subject

Fifteen healthy subjects (9 male and 6 female; age from 28 to 64 years) were studied. They had no known cardiovascular disease before this study. The detailed subject demographic information including age, height, weight and arm circumference are summarized in Table 1. This study received ethical permission, and all subjects gave their written informed consent to participate in the study.

Table 1. General data information for the subjects studied. Their means and standard deviations (SDs) are presented.

Subject information		
No. subjects	15	
No. male	9	
No. female	6	
	Mean	**SD**
Age (years)	41	12
Height (cm)	172	10
Weight (kg)	76	13
Arm circumference (cm)	29	4

2.2. Blood pressure measurement

BP measurements were undertaken in a quiet clinical measurement room. Prior to the measurement, the subject was asked to have at least 5 min rest to allow cardiovascular stabilization. The whole BP measurement was performed under resting condition. The subject was seated in a chair with their feet on the floor and with the arm supported at heart level.

Manual auscultatory systolic and diastolic blood pressures (SBP and DBP) were obtained during both cuff inflation and deflation by a trained observer using a clinically validated electronic sphygmomanometer (Accoson Greenlight 300 from AC Cossor & Son (Surgical) Ltd) [4]. For each subject, three repeat measurements were performed. The whole BP measurement procedure followed the guidelines recommended by the American Heart Association and British Hypertension Society [5].

During the measurement, the oscillometric cuff pressure was inflated and deflated linearly at the same rate of 2-3 mmHg/s, and was recorded digitally at a sample rate of 2000 Hz for off-line oscillometric waveform analysis. Figure 1 shows one example of the digitally recorded cuff pressure and the extracted oscillometric pulse waveforms during cuff inflation and deflation.

2.3. Automated mean arterial pressure determination

Automated mean arterial pressures (MAPs) were determined from both cuff inflation and deflation using interactive software developed with Matlab 7.1 (MathWorks Inc. USA). They corresponded to the cuff pressures at the peak of the 6th order polynomial model envelope fitted to the sequence of oscillometric pulse amplitudes. This model-based automated MAP determination technique has been described in our previously published study [6].

2.4. Data and statistical analysis

The average manual SBP, manual DBP and automated MAP from the three repeat measurements were used as the reference values for that subject. The mean and SD of the manual BPs and automated MAP across all subjects were calculated, separately for both cuff inflation and deflation.

The SPSS Statistics 17 software package (SPSS Inc, USA) was then employed to perform paired t-tests to statistically quantify the BP differences between the measurements from cuff inflation and deflation. A P value below 0.05 was considered statistically significant.

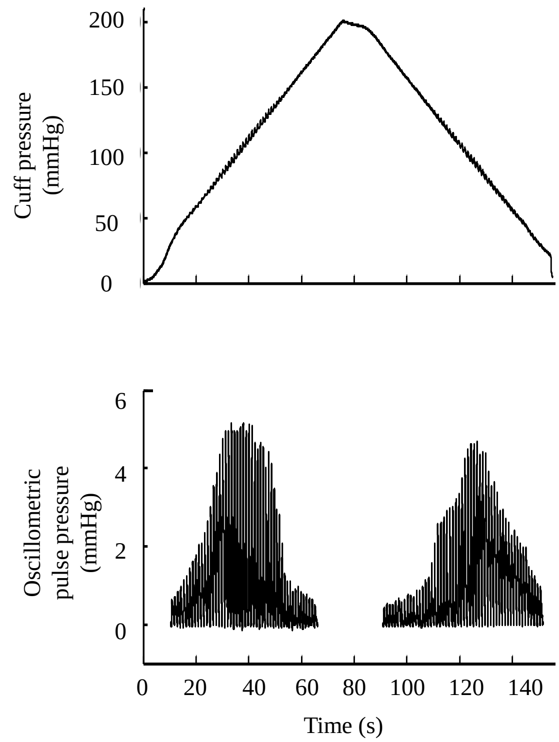

Figure 1. Oscillometric cuff pressure during inflation and deflation (top). The extracted oscillometric waveforms from cuff inflation and deflation are also shown (bottom).

3. Results

3.1. Manual blood pressures during cuff inflation and deflation

Figure 2 shows the manual SBP and DBP measured during cuff inflation and deflation for each individual subject. It can be seen that their overall means (marked with horizontal lines) were different.

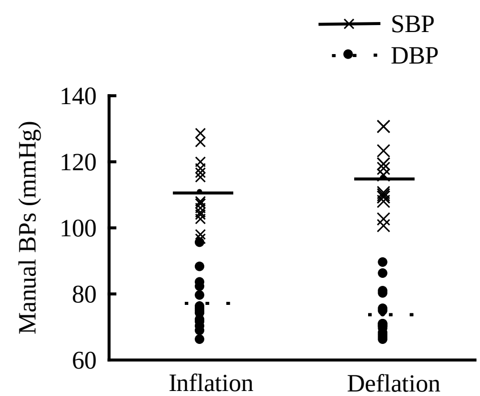

Figure 2. Manual SBP and DBP measured during cuff inflation and deflation for each individual subject.

3.2. Comparison of manual blood pressures during cuff inflation and deflation

As shown in Figure 3, the manual SBP measured during cuff inflation was significantly lower by 4.3 mmHg (mean±SD: 110.6±9.7 mmHg vs 114.9±9.0 mmHg) than that during cuff deflation (P<0.001). However, the manual DBP from cuff inflation was significantly higher by 3.0 mmHg (76.7±7.8 mmHg vs 73.6±7.2 mmHg) than that from cuff deflation (P<0.01).

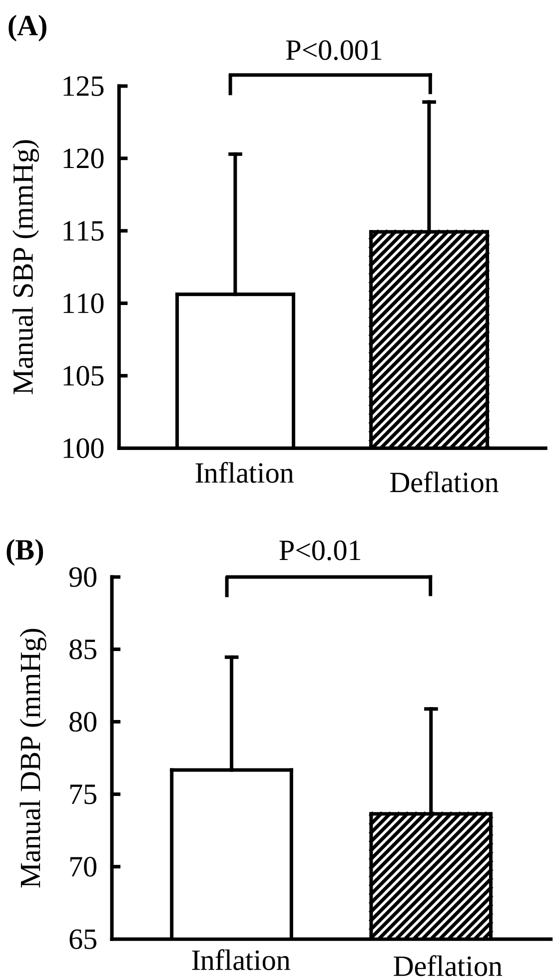

Figure 3. Overall mean±SD of manual SBP (A) and manual DBP (B) measured during cuff inflation and deflation.

3.3. Comparison of automated mean arterial pressure during cuff inflation and deflation

As shown in Figure 4, the automated MAP from cuff inflation was also significantly higher by 4.5 mmHg (88.3±7.4 mmHg vs 83.9±8.7 mmHg) (P<0.01).

To visualise the underlying principle of the automated MAP increase during cuff inflation, Figure 5 gives one oscillometric waveform example showing a shift of the peak of the modeled 6th order polynomial curve to higher pressures when the automated MAP was calculated during cuff inflation, hence the higher MAP was obtained.

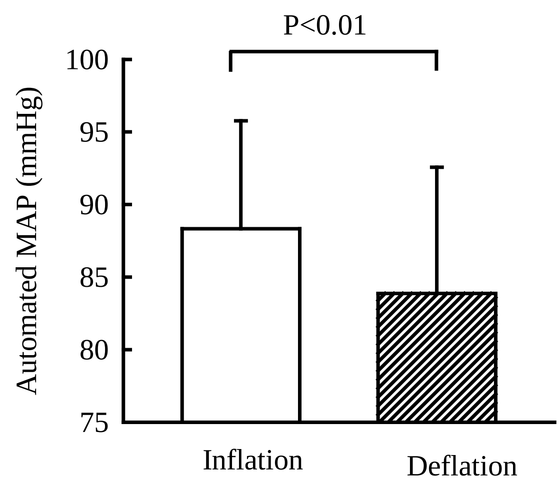

Figure 4. Overall mean±SD of automated MAP measured during cuff inflation and deflation.

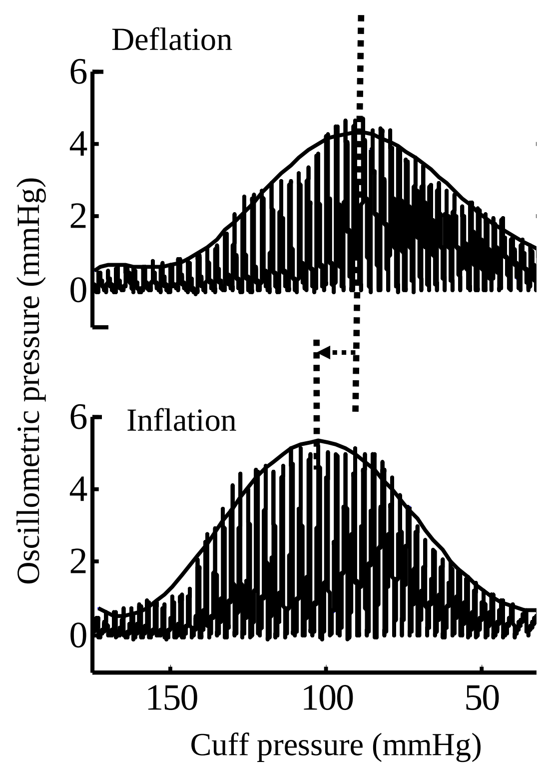

Figure 5. Illustration of oscillometric pulse waveform envelope peak shift to higher pressures during cuff inflation.

4. Discussion and conclusion

Our study quantitatively showed that BPs measured during cuff inflation and deflation were different. Since the measurement accuracy is always the key issue for patients, further investigation needs to be followed up to better understand the reasons causing the difference.

Furthermore, these different quantitative findings in BPs taken from cuff inflation and deflation also emphasize that when developing BP determination algorithms for devices measuring BP during cuff inflation, some correction should be considered to achieve clinical measurement consistency and accuracy.

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