CONCURRENCE OF MANUAL AUSCULTATORY AND AUTOMATIC OSCILLOMETRIC TECHNIQUES ON INFLUENCE OF DEEP BREATHING ON MEAN ARTERIAL PRESSURE (MAP)

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Abstract

This study provides quantitative clinical data oneffect of deep breathing on Mean ArterialPressure (MAP) measurement, with emphasis on comparison of its effect on simultaneous manual auscultatory and automatic oscillometricmeasurements. Thirty-nine healthy subjects were studied. Manual Systolic Pressure (SBP) and DiastolicBlood Pressures (DBP) were measured from each subject under both resting and deep breathing conditions. The Manual Mean Arterial Pressure (MMAP) was computed from the empirical equation [DBP+1/3(SBP - DBP)]. Simultaneously, during the manual Blood Pressure (BP)measurement, the oscillometric cuff pressure was digitally recorded. Automated Mean Arterial Pressure (AMAP)was determined from the oscillometriccuff pressures corresponding to100%, peak of the envelopewaveform fitted to the sequence of oscillometric pulse amplitudes. Finally, the effect of deep breathing on MMAP and AMAP wereanalysed and compared. Experimental results showed that deep breathing significantly (all p<0.001) reduced MMAP by 3.7mmHg when compared with the resting condition. Correspondingly, AMAP wassignificantly reduced by 3.4mmHg with deep breathing (all p<0.001). In addition, it is observed that 67% of subjects showed MAP reductions with deep breathing in both manual auscultatory and automatic oscillometric techniques. In summary, both MMAP and AMAP were significantly decreased with deep breathing. Over half of the normal healthy subjects achieved significant MAP reductions with deep breathing in both manual and automatic techniques.

Keywords: Concurrence Manual Auscultatory, Automatic Oscillometric Techniques, Deep Breathing, Mean Arterial Pressure

1 Introduction

Blood pressures(BPs) have been regularly measured for clinical and research use by two non-invasive ways: manual auscultatory and automatic oscillometric techniques. The manual auscultatorytechnique uses a sphygmomanometer and stethoscope, whichis the gold standard for clinical BP measurement when it is performed by a well-trainedoperator [Zheng, 2011], while the automatic oscillometrictechnique analyses thepressure oscillations in a sphygmomanometer cuff during cuff deflation[ISO, 2009].

Accurate BP measurement is essential for medical diagnosis and is necessary for the prevention and treatment of various diseases including hypertension, kidney failure, stroke and other cardiovascular conditions which have been considered as globally leading factors for death and disability [Smith, et al., 2005]. Automated oscillometric devices are widely used because they are easy to operate and have the capability of reducing human error in comparison with the manual auscultatory technique especially when it is not performed by a trained observer.However, there have been debates over the accuracy of BPreadings obtained fromautomatic oscillometricdevices. This has raised concerns, andBP readings obtainedfrom manual auscultatory techniques arerecommended for clinical use. To achieve accurate BP measurement, several international organisations, including the American Heart Association (AHA) [Pickering, et al., 2005], British Hypertension Society (BHS) [Williams, et al., 2004] and European Society of Hypertension (ESH) [O'Brien, et al., 2003], have highly recommended that subjects should remain calm during BP measurement notwithstanding which technique is involved in obtaining the measurement.

It has been widely accepted that respiration is one of the key factors affecting physiological changes in BP [Meles, et al., 2004; Grossman, et al., 2001; Elliot, et al., 2004; Mori, et al., 2005; Parati and Carretta, 2007; Zheng, et al., 2011; Mason, et al., 2013; Ravi, Narasimhaswamy and Anad, 2015; Drodz, et al., 2016]. The effect of deep breathing on manual auscultatory BPs has been quantified, with decreased manual auscultatory systolic and diastolic blood pressures (SBP and DBP) observed [Rosenthal, et al., 2001; Meles, et al., 2004; Smith, et al., 2005; Pickering, et al., 2005; Zheng, et al., 2011].Automated BP decreases with deep breathing have also been reported with the measurements taken from different automatic BP devices[Grossman, et al., 2001; Elliot, et al., 2004; Zheng, et al., 2011; Ravi, Narasimhaswamy and Anad, 2015].However, those automatic BP devices are not validated for non-resting measurement conditions. Additionally, there is little quantitative clinical data available on the simultaneous comparison of the effect of respiration on both manual and automatic BPs.

This study aimed to provide quantitative clinical data on the magnitude of deep breathing on MAP measurements with emphasis on the comparison of its simultaneous effect on manual auscultatory and automatic oscillometric techniques.

2 Methods

2.1. Subjects

Thirty-nine healthy subjects (24 male and 15 female; 18 to 75 years old) with no known cardiovascular disease were recruited to participate in this study. An ethical permission was received from the Newcastle & North Tyneside Research Ethics Committee. The investigation conformed tothe Declaration of Helsinki, and all subjects gave their written informed consent to participate in the study.Table 1 summarizes the detailed subject demographic information including age, arm circumference, height and weight.

Table 1: Demographic data for the subjects studied with their means and standard deviation presented.

Subjects Information	Minimum	Maximum	Mean	Standard Deviation
No of Subjects	39			
No of Male	24			
No of Female	15			
Age (Years)	18	75	47	40
Height (cm)	152	192	172	28
Weight (kg)	50	105	78	39
Arm circumference (cm)	24	33	29	6

2.2. Blood pressure measurement protocol

The manual BP measurements were taken in a quiet clinical measurement room by a trained observer using a clinically validated electronic sphygmomanometer (AccosonGreenlight 300 from AC Cossor & Sons (Surgical) Ltd [Graves, et al., 2003]. The subjects wereasked to be seated comfortably on a chair with feet placed on the floor, and the measurement arm supported at heart level. They then had a 5-minute rest period before the measurement to allow for cardiovascular stabilization. The whole measurement procedure followed the guidelines recommended by the British Hypertension Society and the American Heart Association [Williams, et al., 2004].

During the manual BP measurement, the oscillometric cuff pressure was recorded digitally to a data capture computer with cuff pressure deflating from 200 mmHg at the recommended deflation rate of 2-3 mmHg/s and with a sample rate of 2000Hz for off-line automated BP determination. Figure 1 shows the schematic representation of BP measurement in this study.

For each subject,there were two repeat sessions. With the first session, two BP measurements were undertaken under resting and deep breathing conditions at his/her own comfortable respiratory rate. The order was randomised between subjects. This was repeated, giving a total of 4 BP measurements for each subject. A time interval of at least 4 min was given between sessions, and at least 1 min between the twoBP measurements within a session, allowing recovery of cardiovascular haemodynamic.

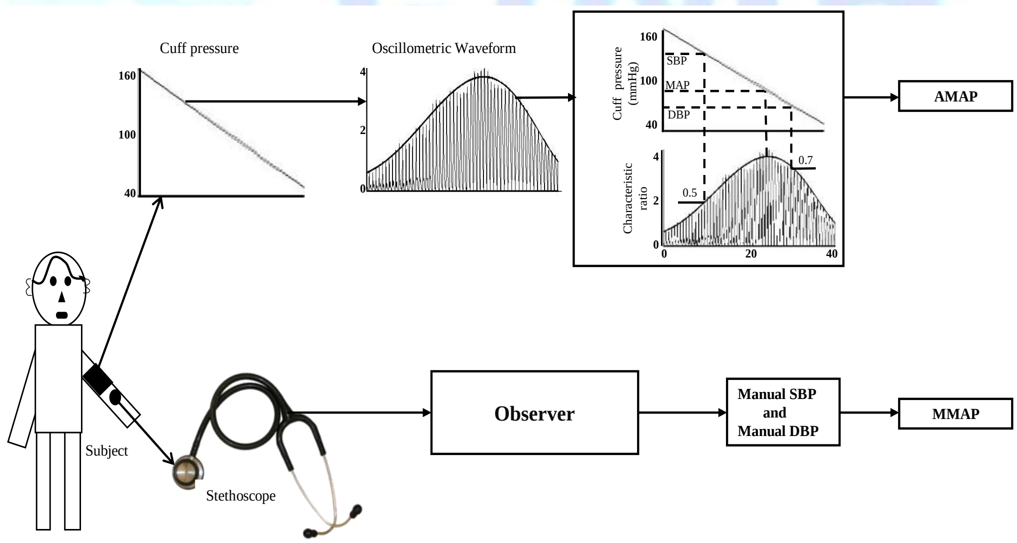

Figure 1: Schematic representation of BP measurement on a subject.

2.3. Blood Pressure determination

2.3.1 Manual auscultatorytechnique

Manual SBP and DBPwere obtained by a trained operator during the measurement. Manual Mean Arterial Pressure (MMAP) was estimated from the manual DBP plus one third of the absolute difference betweenSBP and DBP (DBP+1/3(SBP‑DBP).

2.3.2 Automatic oscillometrictechnique

The analysis of automated BPs was performed on anonymised data. AMAP was determined from the recorded cuff pressure signal usinginteractive software developed with Matlab 7.1 (MathWorks Inc. USA). A 6th order polynomial curve was used to fit the sequence of oscillometric pulse peaks. AMAP was then determined from the cuff pressure corresponding to the peak of the fitted curve (see Figure 1).

2.4. Data and statistical analysis

The mean and standard deviation (SD) of both MMAP and AMAP across all subjects were calculated separately for resting and deep breathing conditions. The SPSS Statistics 17 software package (SPSS Inc., USA) was then employed to perform ANOVA analysis for the measurement repeatability and the effect of deep breathing on both MMAP and AMAP. Bland-Altman analysis was then performed to demonstrate MAP changes with deep breathing. Regression analysis was finally performed to investigate the changes due to deep breathing for MMAP in relation to the changes forAMAP with the regression slope and the correlation coefficients (R square) obtained. A *P*-value below 0.05 was considered statistically significant.

3 Results

3.1 Measurement repeatability on manual and automated BP measurements

The repeatability test showed that MMAP and AMAPwere not statistically significant with p-values of 0.64 and 0.51 respectively.The average MAP values from the two repeats were then used as reference values for each subject.

3.1. Effect of deep breathing on manual and automatedmean arterial pressures (MMAP and AMAP)

Figure 2 gives the overall mean and standard deviation (mean ± SD) of MAP under resting and deep breathing conditions for both manual auscultatory andautomatic oscillometric techniques. MMAP and AMAP changes with deep breathing in comparison with resting condition are clearly shown.

To be specific, MMAP decreased significantly ($p<0.001$) with deep breathing by 3.7 ± 3.7 mmHg (85.3 ± 6.4 vs. 89.0 ± 7.4 mmHg). Similarly, AMAP also decreased significantly ($p<0.001$) by 3.4 ± 4.7 mmHg (85.5 ±7.1 vs. 89.0 ± 8.3 mmHg)

Figure 3 gives their Bland-Altman plots to illustrate the level of MAP reduction with deep breathing measured simultaneously by manual and automated techniques.

To visualize the underlying principle of how AMAP decreased with deep breathing in comparison to that under resting conditionFigure 4 gives an example of oscillometricwaveforms under both resting and deep breathing conditions and shows a clear shift ofMAP toward lower pressure region when the waveforms were recorded with deep breathing.

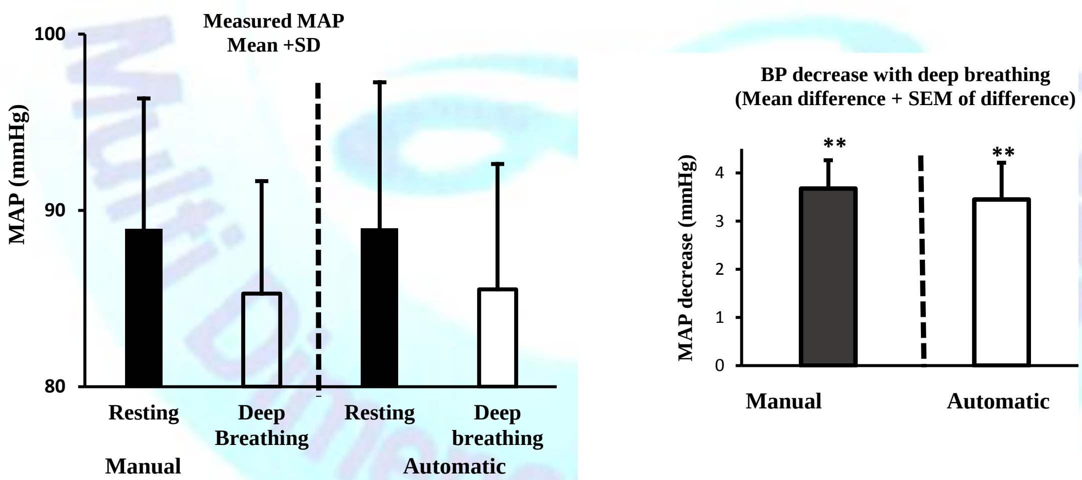

Figure 2: Left: Manual and automated Mean Arterial Pressure (MAP) measured under both resting and deep breathing conditions. Error bars are from between subject Standard Deviation (SD).

Right: BP decreases with deep breathing using mean BP decrease and Standard Error Mean (SEM) of BP decrease (** indicates $p < 0.001$ in comparison with resting condition , from one way ANOVA with repeated measures).

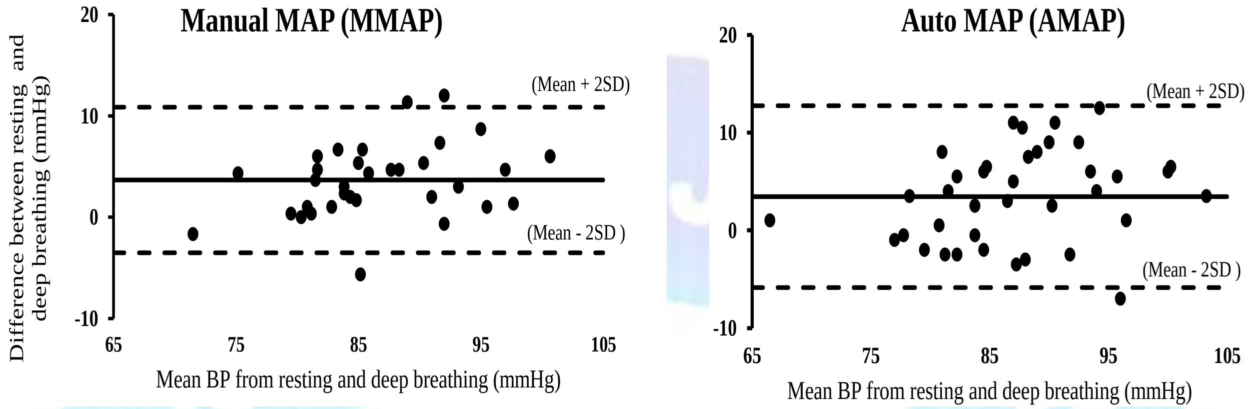

Figure 3: Bland-Altman plotsshowing MAP(MMAP and AMAP) changes with deep breathing separately for manual and automatic techniques. The limit of agreement (mean ± 2SD) is shown.

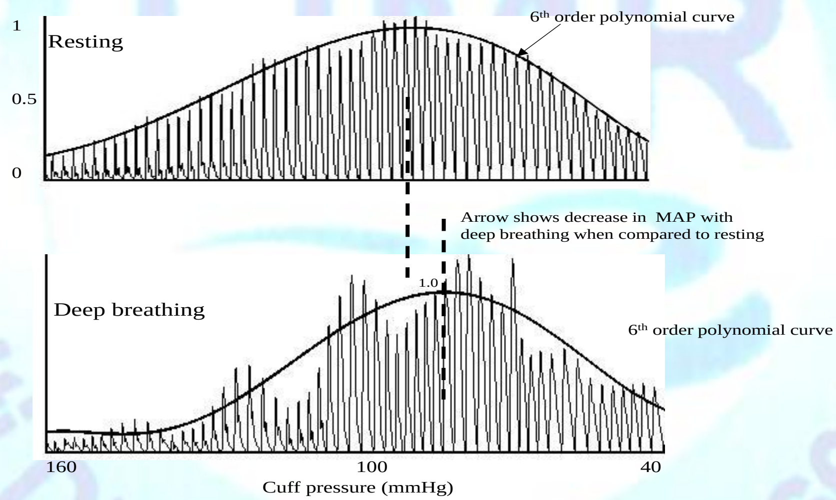

Figure 4. Example of oscillometric waveforms to illustrate decreased automated MAP with deep breathing in comparison with resting condition.

3.2. Comparison ofmanual and automated BP decreases with deep breathing

Figure 5 shows the manual MAPdecrease against automatic MAP decrease with deep breathing. The result as shown in the shaded area shows that 67% of subjects had their MAP reduction from both manual and automatic techniques.

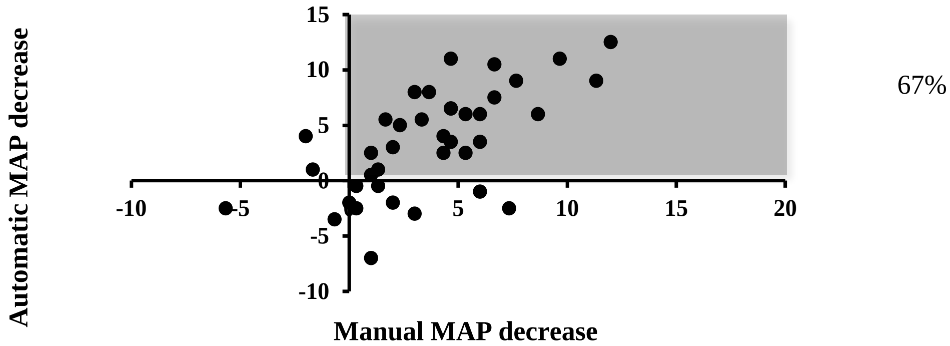

Figure6. Comparison of manual and automatic MAP decreases with deep breathing 67% of subjects had MAP reduction in both manual and automatic oscillometric techniques.

4 Discussion and conclusion

This study quantitatively demonstratedthat both manual and automated MAP decreased significantly with deep breathing when compared to resting condition.This is in agreement with previous studies that BPs reduced with consistent practical period of slow and regular breathing [Meles, etal., 2004; Grossman, etal., 2001; Mori, etal., 2005;Parati and Carretta, 2007;Zheng, et al.,2011; Ravi, Narasimhaswamy and Anad, 2015; Drodz, et al 2016].The underlying mechanisms forthe effect of deep breathing onBP include: firstly, it has been attributed to reflexes from mechanoreceptors in the lungs. When the lungs expand during deep breathing, these receptors initiate the Hering Breuer reflex (reflex triggered to avoid over-inflation of the lungs) that reduces respiratory rate which eventually leads to autonomic cardiovascular inhibition [Jerath, et al., 2006]. Secondly, it is observed that deep and slow breathing causes the increase of blood flow in the blood capillaries which decreases the peripheral resistance and regulates heart rate, resulting in BPreduction [Hubard and Falco, 2015; Sharma and Gupta, 2016].Thirdly, it is noted that deep breathing triggers the body to absorb full oxygen quota.In that process, carbon-dioxide is being exhaled out, thus slowing heartbeat and stabilizing BP [Hubard and Falco, 2015; Suckling, et al., 2016]. Fourthly, during deep breathing, there is an increase in transmission of nitric oxide. Endothelium cells use nitric oxide to communicate to muscles around them to unwind and relax during vasodilation, leading to reduced blood pressure [Hubard and Falco, 2015;].

Moreover, this study showed that automatedMAP (AMAP) decreased with deep breathing. This agreed with published studies using automatic BP device [Grossman, et al., 2001; Elliot, et al., 2004; Zheng, et al., 2011; Ravi, Narasimhaswamy and Anad, 2015]. However, our study was based on the analysis of originally recorded oscillometric cuff pressure waveform, alleviating the potential uncertainty of the results from these un-validated BP devices for non-resting conditions.

More interestingly, it has been shown that a decrease in manual auscultatoryMAPs with deep breathing has been confirmed with a shift of the peak of the oscillimetric pulse waveform envelope to lower pressures. The AMAP (MAP decreases observed in manual auscultatory technique) were moderately correlated with the decreases of AMAP (automated MAP determined from oscillometric technique), demonstrating a good agreement on the effect of deep breathing measured by both manual and automatic techniques. It is noted that the study was limited to healthy subjects. More subjects with the inclusion of hypertensive patientscould be considered in a future study.

Nevertheless,by analysing the recorded oscillometric pulse waveform, this study has quantitatively confirmed that there was a good agreement in BP decrease with deep breathing when there were simultaneously measured by manual auscultatory and automatic oscillometric techniques. This is an important step to better understand the underlying mechanism of the BP decrease with deep breathing.

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