Indian J Physiol Pharmacol 2015; 59(2) : 189–193

Original Article

Sphygmomanometric Blood Pressure Drop on Consecutive Measurements : The Search for a Cause

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Abstract

This study was inspired by our oft-noted observation that the first sphygmomanometric reading of blood pressure (BP) is invariably higher than the subsequent ones recorded immediately thereafter. The objectives of this study were to establish the statistical validity of this observation and further, to probe the possible causes of the same. The sphygmomanometric BP was recorded in 30 non-obese young adults using two different protocols. In protocol-1, BP in the left arm was repeated thrice in quick succession, both in standing and supine postures. In protocol-2, BP was recorded in the supine position six times in quick succession, thrice in the left arm and immediately thereafter, thrice in the right arm. Data was compiled and analysed using appropriate statistical tests. In protocol-1, a statistically-significant drop in the blood pressure was consistently noted between quickly consecutive measurements in both standing and supine postures. Importantly, this pressure drop was not significantly affected by posture. In protocol-2, significant pressure drop was recordable from both arms. These findings rule out baroreflex as a cause of the pressure-drop on consecutive measurements and suggest a likely role of tissue compaction in the same.

Introduction

Sphygmomanometry is an important clinical procedure that indirectly measures blood pressure and thereby provides information about the cardiovascular system in normal and diseased states. It estimates the blood pressure by noting the pressure that has to be applied circumferentially on the arm to occlude the blood flow in the underlying brachial artery.

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(Received on March 14, 2014)

Over the past several years, we have observed that when the blood pressure is measured in quick succession, the second and third readings are lower than the first reading. A literature survey revealed articles that report such observation (1, 2). We surmised two possible reasons for the norm, which is referred hereon as PDCM, i.e., (sphygmomanometric) pressure drop on consecutive measurement for convenience. For one, it could be due to the baroreceptor reflex, which is presumably triggered by an increase in systemic blood pressure resulting from the obliteration of the blood flow through the arm. The other putative reason is the compaction of the subcutaneous tissue of the arm by the cuff-pressure during the first reading, leading to a more effective transmission of the compressive pressure to the brachial artery during subsequent readings.

We reasoned that: (1) the *first possibility*, that of baroreceptor stimulation, could be substantiated if the PDCM is less in supine position, since the supine position itself would stimulate the baroreceptors strongly enough to reduce the margin for further stimulation by the compression of the brachial artery. Conversely, if the PDCM is not significantly affected by posture, it would rule out baroreflex as a cause and indirectly implicate tissue compaction (*See Fig:* Algorithm-1). (2) The *second possibility*, that of tissue-compaction, can be directly proved if the PDCM in sitting posture is recordable in both arms (first in one arm, then in the other arm) within a short interval (*See Fig:* Algorithm-2). Our experiments are designed accordingly.

Methods

This observational study was conducted in the department of Physiology at AIIMS, Jodhpur on thirty non-obese adult volunteers after obtaining ethical clearance from the institutional ethical committee. The blood pressure was measured in all subjects using an oscillometric sphygmomanometer. Since oscillometric devices are declaredly unreliable in persons with arrhythmias and those with mid-upper arm circumference > 42 cm, such subjects were not included in this study. Measurements were done in conformity with the updated American Heart Association guidelines for office BP measurements (3). Informed consents were obtained from all subjects, who were told that these recordings were a part of a study. Subjects were especially instructed not to move much during the measurements. To stabilize the blood pressure, subjects were rested for 5 min before starting the experiment.

The experiments in each subject comprised two protocols (Fig. 1) separated by an interval of 15 minutes during which the subject remained seated comfortably.

Statistical analysis was done using SPSS version 17 and Graph Pad Prism 5. Paired t-test was done to compare the three consecutive readings and the significance in differences in blood pressure with posture was analysed using one way ANOVA. A p valve <0.05 was taken as significant.

Results

Protocol-1: The three consecutive SBP, DBP (mmHg) and HR (bpm) in sitting and supine positions are given in Table Ia. Significant systolic and diastolic PDCMs were observed in both sitting and supine positions ($p<0.05$). Importantly, however, there was

TABLE Ia : Systolic and diastolic blood pressures (mmHg) and heart rate (bpm) recorded on three consecutive readings, in sitting and supine positions.

Blood pressure & heart rate in sitting posture								
1st reading			*2nd reading*			*3rd reading*		
Systolic	*Diastolic*	*HR*	*SBP*	*DBP*	*HR*	*Systolic*	*Diastolic*	*HR*
131.4±15.4	84.7±9.9	8884±14.68 p>0.05 (ns)	125.8±11.3 p<0.01 (0.0018)	82.2±9.3 p<0.05 (0.01)	90.88±15.10 p>0.05 (ns)	123.5±11.5 p<0.001 (0.0001)	81.8±10.5 p<0.001 (0.0001)	91.80±15.59 p>0.05 (ns)
Blood pressure & heart rate in supine posture								
1st reading			*2nd reading*			*3rd reading*		
Systolic	*Diastolic*	*HR*	*Systolic*	*Diastolic*	*HR*	*Systolic*	*Diastolic*	*HR*
119.0±8.1	72.0±7.7	80.4±11.64 p>0.05 (ns)	116.5±8.7 p<0.05 (0.029)	70.0±7.0 p<0.05 (0.0144)	82.12±10.79 p>0.05 (ns)	114.8±7.7 p<0.01 (0.0012)	67.0±8.9 p<0.001 (0.0001)	81.92±10.70 p>0.05 (ns)

All values are expressed as mean±SD. The p-value given in the 2nd and 3rd readings refer to the significance of the PDCM (pressure drop on consecutive measurements) as compared to the *first* reading, which is taken as the control. The difference between 2nd and 3rd readings (systolic and diastolic) in both sitting and lying position was non-significant (p<0.05) and is not shown in the table.

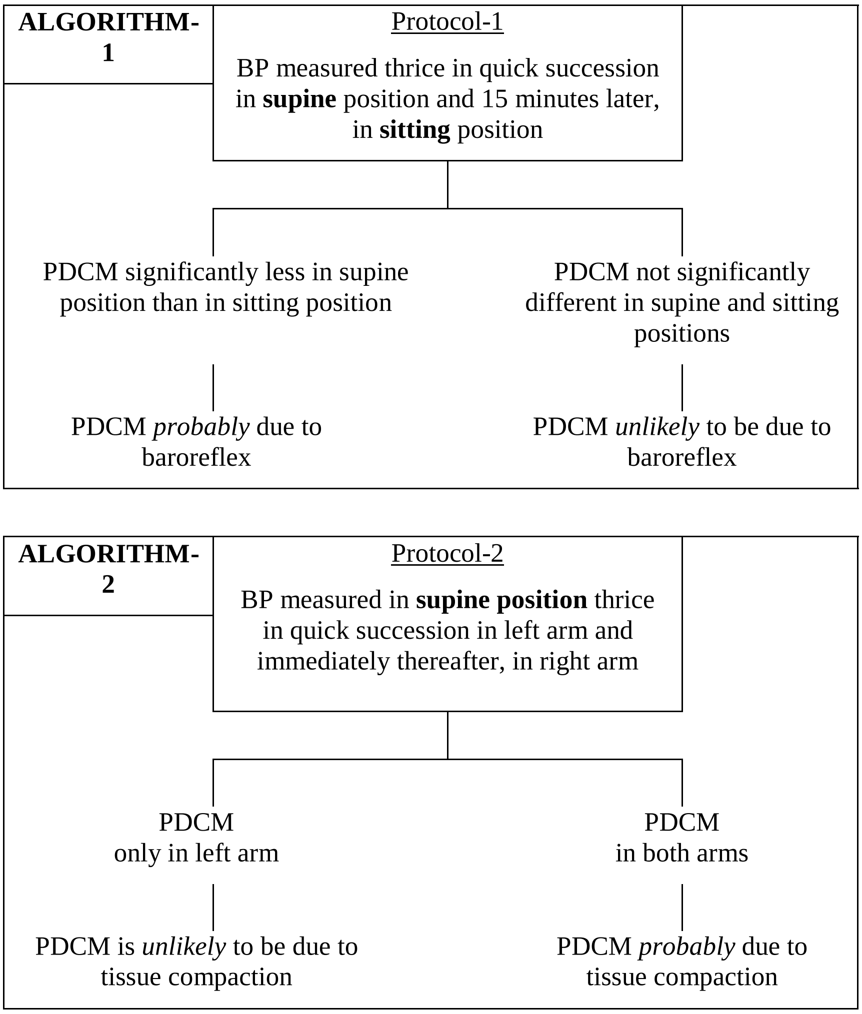

Fig. 1: Algorithms 1 and 2 for consecutive recordings of blood pressure.

no significant difference in the PDCM during sitting and the PDCM during supine position (Table Ib, $p>0.05$).

Protocol-2: The results of consecutive BP measurements, thrice on the right arm followed immediately by thrice on the left arm, are given in Table II. The PDCMs in each arm were statistically significant ($p<0.05$).

All values are expressed as mean±SD. The p-value given in the 2nd and 3rd readings refer to the significance of the PDCM as compared to the *first* reading, which is taken as the control. The difference between 2nd and 3rd readings in all parameters in both arms was non-significant ($p<0.05$) and is not shown in the table.

Discussion

Our results of Protocol-1show the presence of statistically significant PDCM, systolic as well as diastolic, in both sitting and supine positions (Table 1a). What is important in the present context is that the effect of posture (sitting versus lying) was statistically insignificant (Table Ib). Thus, according to algorithm-1 (Fig. 1), the results of protocol-1 rule out baroreflex as a possible cause of the observed PDCM and by elimination, implicate tissue compaction as the probable cause.

Protocol-2 validates the above results and furthermore, directly implicates tissue compaction, as deduced from Algorithm-2. In this protocol, all measurements were made in the supine position,

TABLE Ib : Difference between PDCM [I minus II] and PDCM [I minus III] in both sitting and supine postures.

Parameters	*Position*	*PDCM (I-II) (Mean±S.D)*	*PDCM (I-III) (Mean±S.D)*	*Difference in PDCM in supine and sitting posture (II vs I) Mean±S.E*	*Difference in PDCM in supine and sitting posture (III vs I) Mean±S.E*
SBP	Sitting (n=30) Supine (n=30)	5.60±8.9 2.50±5.9	7.93±8.8 4.20±6.4	3.10±1.9 (p>0.05)	3.7±1.9 (P>0.05)
DBP	Sitting (n=30) Supine (n=30)	2.47±4.9 2.03±4.3	2.03±4.3 5.03±5.8	0.43±1.2 (P>0.05)	–2.2±1.5 (P>0.05)

The systolic and diastolic PDCM were non-significant (P>0.05) in both sitting and supine postures.

TABLE II : Systolic and diastolic blood pressures (mmHg) and heart rate (bpm) recorded on six consecutive readings in supine position, three on *right* arm followed by three on *left* arm.

Right arm BP								
1st reading			*2nd reading*			*3rd reading*		
Systolic	*Diastolic*	*Heart Rate*	*Systolic*	*Diastolic*	*Heart Rate*	*Systolic*	*Diastolic*	*Heart Rate*
123.3±16.0	74.73±12.87	80.84±11.93	117.5±17.77 p<0.05) (0.0021	71.85±12.49 p<0.05 (0.027)	80.92±11.33 p>0.05 (ns)	115.7±15.13 P<0.05 (0.0001)	70.38±13.39 p>0.05 (ns)	81.08 ±11.1 p<0.05 (0.0037)
Left arm BP								
1st reading			*2nd reading*			*3rd reading*		
Systolic	*Diastolic*	*Heart Rate*	*Systolic*	*Diastolic*	*Heart Rate*	*Systolic*	*Diastolic*	*Heart Rate*
117.3±16.38	74.04±12.15	83.08±11.43	112.2±12.0 p<0.05	72.62±11.55 p>0.05 (ns)	82.68±11.32 p>0.05 (ns)	111.5±13.69 p<0.05	70.92±11.85 p<0.05	79.52±12.05 p>0.05 (ns)

stimulating the baroreceptors maximally and virtually "decapacitating" them by reducing their margin for further stimulation. The results show significant PDCM in both arms, clearly pointing to tissue compaction as the possible cause. Arguably, the high cuff pressure squeezes out fluid from the underlying tissues during the first reading that spans a minute or two. Hence, the transmission of the cuff pressure to the underlying artery is more effective and therefore less pressure is required to occlude the artery on the second reading, as reflected in the data. The third reading is only marginally less than the second indicating, expectedly, that there is little margin for further compaction of the tissue.

There have been little research on the influence of repeated measurements of BP in a single sitting; the objectives of most studies, like those by Kuwabe 2005 and 2012 (1, 2) and de Gaudemaris, 1994 (4), were related to standardization of home monitoring of blood pressure. Similar to our findings, Kawabe et al (1, 2) recorded significant fall in SBP and DBP on 2nd and 3rd consecutive measurements in comparison to the first. However, the interval between the 2 consecutive readings was not mentioned and the possible mechanism involved was not discussed. Other studies were done to standardize the BP measuring device, number and timing of BP measurement and inter-individual visit to visit variability (5-7). Meyers et al demonstrated the optimum frequency of office BP measurement using an automated sphygmomanometer; they recorded BP at intervals of 1 and 2 minutes and concluded that a minimum interval of 1 minute before the next recording is necessary if the accuracy of the latter is not to be affected by the preceding procedure (8). In a way, their study complements ours, which has studied the effect of minimum interval between consecutive readings.

We conclude that quickly-consecutive sphygmomanometric measurements of blood pressure will inevitably show pressure drop between readings. The pressure drop most likely occurs due to the tissue compaction caused by the cuff pressure.

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