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Role of pulse wave velocity (PWV) and central aortic pressure (CAP) in evaluating hypertension using sphygmocor

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Abstract
These days, hypertension has become very serious health issue as it is estimated that over 1 billion people are suffering from this disease worldwide. It has been estimated that by the year 2025, this will reach to about 1.56 billion people. It is also estimated that in future, almost 1 out of 3 adults having age more than 20 will be suffering from hypertension.
One of the reports of World Health Organization has suggested that blood pressure is the number one attributable risk for the death throughout the world. For the current study, 33 patients were included to measure hypertension by using Sphygmocor device. The age of included patients was between 40 to 85 years. The evaluation of hypertension was performed by using Sphygmocor device.

Keywords: Heartburn, Regurgitation, reflux disease, Bronchial asthma, GERD

1. Introduction
Hypertension is believed to be the most prevalent risk factor for cardio-vascular diseases. The probability of high blood pressure tends to increase in an individual suffering from hypertension [1]. To prevent the risks of hypertension, one needs to maintain control of hypertension as there are no significant symptoms of high blood pressure.
Hence, the most significant way to improve outcomes for hypertensive patients is to identify the patients who are at a risk of cardio-vascular disease and monitor the effects of treatment. According to a report published in United States of America, about 76.4 million adults having age more than 20 are suffering from hypertension at present. Among these, 78% have an idea about their condition and are taking appropriate steps to recover. And 68% are taking anti-hypertensive medicines to prevent themselves from hypertension.
Among the patients who are under the treatment, only 64% patients have their hypertension under control, thus, leading to a suggestion that there needs to be some kind of improvement in current methods of monitoring anti-hypertensive treatment [2]. High blood pressure is occurred when a systolic blood pressure (SBP) above 140 mmHg or a diastolic blood pressure (DBP) of 90 mmHg is observed [2].
There are two types of hypertension – Primary Hypertension and Secondary Hypertension.

(i) Primary Hypertension
About 90-95% of people suffering from hypertension come under the category of primary hypertension as there is no significant reason of the high blood pressure. There are many factors which help to increase the risk of occurring hypertension. Some of these factors are smoking, high stress, obesity and high alcohol consumption.

(ii)Secondary Hypertension
As compared to primary hypertension, secondary hypertension is found in only approximately 5% of patients suffering from hypertension. It is less common than primary hypertension. It means that the probability of existence of secondary hypertension is very less among the hypertensive patients. It is caused by endocrine diseases, kidney diseases or pregnancy.
The severity of hypertension is based on systolic and diastolic blood pressure ranges as follows:

Table 1

	SBP (mmHg)	DBP (mmHg)
Normal	90-119	60-79
Pre-hypertension	120-139	80-89
Stage 1	150-159	90-99
Stage 2	≥ 160	≥ 100
Isolated systolic hypertension (ISH)	≥140	< 90

Hypertension is also supposed to be responsible for many other diseases like cardio-vascular diseases, heart failure etc. According to a report, hypertension reduces the lifetime of an individual approximately by 5 years. It is also estimated that 29% of the population have pre-hypertension and there is more probability in these individuals to suffer from cardio-vascular diseases in the future. Hence, effective steps need to be taken in order to prevent them from these kinds of diseases.
It is observed that the individuals suffering from pre-hypertension have the cholesterol levels above normal and these people are at a high risk of cardio-vascular events [3]. In some cases, it may lead to the occurrence of diabetes in the patients. In hypertensive patients, aortic stiffness is supposed to be a powerful predictor of cardio-vascular events.
Aortic stiffness is measured by aortic pulse wave velocity (PWV) and it is considered to be the gold standard of the measurement of arterial stiffness [4]. The arterial pulse waves travel along the aortic and Aorto-iliac pathway with a very high speed and this speed is measured with the help of Aortic PWV. At the carotid and femoral arteries, the pressure waves are recorded along this pathway.

According to European Society of Hyper-Tension, an individual with a PWV of 12 m/s or greater is said to be a hypertensive patient. A high pulse wave velocity (PWV) is also responsible for CV risk. Aortic PWV is supposed to be an independent predictor of coronary events in patients with essential hypertension [5].

1.1 Objectives of the study

The objectives of the current research work are as follows:

- To study about Pulse Wave Velocity (PWV) and Central Aortic Pressure (CAP).
- To study the role of Pulse Wave Velocity (PWV) and Central Aortic Pressure (CAP) in evaluating hypertension using sphygmocor.

1.2 Review of related literature

In a study conducted by Robert *et al*. (2006), a group of 145 patients suffering from hypertension were monitored for few months. It was observed that the risk of occurring cardio-vascular events increased with an increase in pulse wave velocity. It was observed that the RR was found to be 1.41 for each 3.5 m/s increase in pulse wave velocity. This report confirms the fact that an increase in Aortic PWV is responsible for Atherosclerosis in hypertensive patients.

Alberto *et al*. (2010) [1] conducted a research and described about the usage of the technique which accesses Sphygmomanometer used for the analysis of the central arterial pressure waveform. He specified that pulse wave velocity and central aortic pressure play an important role in evaluating hypertension if sphygmocor is used. The CVProfilor device was used to analyze the pulse wave in this research.

Satoru Sakuragi *et al*. (2009) [12] conducted a research and highlighted the various methods to measure arterial stiffness. He also described the physiological mechanisms that accesses arterial stiffness as a significant factor of cardio-vascular diseases. He also explained through his study that arterial stiffness can be used to predict cardio-vascular events and mortality.

Agarwal *et al*. (2012) [2] described that aortic stiffness can be directly measured by using aortic pressure wave velocity. The speed of the arterial pressure waves can be measured by pulse wave velocity. He further stated that stiffer arteries occurred due to high arterial pressure wave velocity.

Sinha *et al*. (2012) [14] described that measurements are performed by recording pressure waveforms at the carotid artery and femoral artery. This is done with the help of an ECG signal being recorded simultaneously. He further described that pressure wave velocity is calculated by using the mean time difference and the arterial path length between two recording sites.

Singh *et al*. (2010) [13] conducted a study to describe that the pressure waves travel through the arterial tree and these waves are reflected at multiple sites. Consequently, the forward travelling wave form merge with each other and thus, considered as the arterial pressure waveform at any site. The two waveforms merge during diastole.

He also explained that the pressure waves start travelling faster when the arterial wall thickens and stiffer is occurred at the arteries. As a result of this process, the reflected pressure wave returns during the systolic phase. Thus, Aortic systolic pressure is increased which further enhances the load of left ventricular.

Mehta *et al*. (2013) [8] conducted a research and stated that the analysis of aortic pressure waveform can be proved to be a good measure of central blood pressure and indices of arterial stiffness like Augmentation Pressure (AP) and Augmentation Index (AIx) as shown in figure.

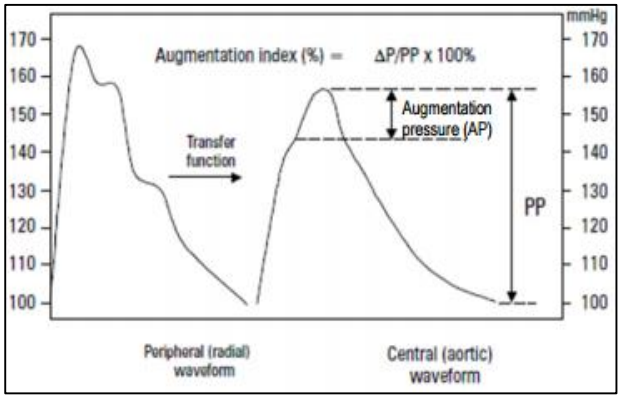

Fig 1

These indices are associated with the reflected pressure waves from the arterial system, either as in a direct increase in pressure at the heart from the reflected wave (AP) or as a percentage of pulse pressure (AIx). AIx represents a complex measure of wave reflection and includes a component of arterial stiffness.

Chetan *et al*. (2012) [3] described that sphygmocor is a device which is very useful for the analysis of pressure waves. It can also be used to measure the arterial pressure waveform at the radial artery. This device also applies a validated transfer function to provide the central pressure waveform.

1.3 Research Methodology

The sphygmocor device has been commercially utilized for more than a decade and is extensively used for clinical studies. It is used to obtain central aortic pressure waveform by directly recording radial pulse waveform using tonometry which further employs a transfer function. Radial pulse waveforms are merged with Brachial blood pressure with the help of a sphygmomanometer and hence, is helpful for the estimation of central blood pressure.

2. Method

For the current study, 33 patients were included to measure hypertension by using sphygmocor device. The age of included patients was between 40 to 85 years. The non-invasive and invasive central systolic blood pressures were highly correlated. Sphygmocor device was used to provide accurate assessment of aortic pressure values. In this study, the estimated central systolic blood pressure of 33 patients was observed to be 12 mmHg.

2.1 Data analysis

The evaluation of hypertension was performed by using Sphygmocor device among the selected patients. The patient was lying on the catheterization table with the left arm stretching out and the palm up. Then, the SphygmoCor device was used to record the radial arterial pulse wave. To estimate the central blood pressure, the above described procedure was repeated for each and every patient.

The patients were treated one after another in a sequence and their characteristics like age, body height, Body weight, body mass index, systolic blood pressure, diastolic blood pressure, pulse rate, hypertension were noted. After the completion of the whole procedure, the mean of all body characteristics mentioned above, was evaluated.

The mean systolic blood pressure was observed to be 132 (±16) mmHg and mean diastolic blood pressure of 33 patients was found to be 78 (±8) mmHg by using the SphygmoCor device. The average pulse rate of included patients was noted to be 77 (±8) beats/minute. And the mean of hypertension of 33 patients was observed to be 23(±69.7) %.

33 patients were included for the research study. Overall, age (± s.d.) averaged 60.1 (± 8.7) years and ranged from 45 to 83 years. Mean body mass index was 25.5 (± 2.9) kg/m^2.

In the research work, good measurements of cSBP, were found with the help of noninvasive device (SphygmoCor). Non-invasvive brachial measurements rather than invasive BP should be taken for calibration since such an approach reflects the clinical situation for which the device was designed.

Previously, Smulyan and colleagues have shown similar results, namely a high correlation of invasive and noninvasive (SphygmoCor) estimated cSBP (r=0.89), as well as a mean difference of only 1.5 mm Hg, but with a large scatter (SD= 11.13 mm Hg).

In accordance with our study, calibration of the noninvasive device has been carried out with oscillo-metric measurements of brachial BP. In accordance, Zuo and associates found a non-significant difference between estimated cSBP (SphygmoCor) and invasively measured cSBP but a high SD of about 17 mm Hg.

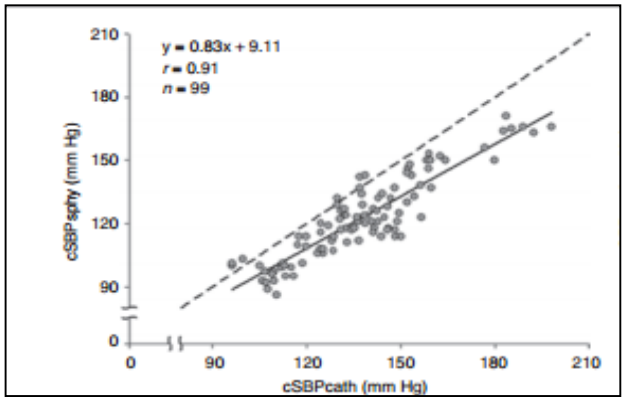

Fig 2

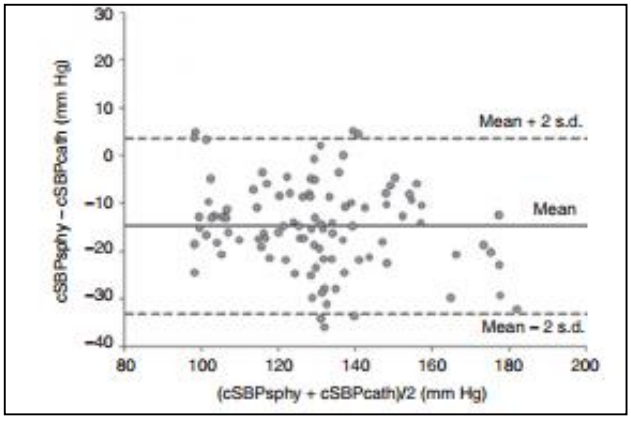

Fig 3

In the study, the central systolic blood pressure was estimated to be p<0.001 and closely correlated with the catheter measurement with an intra-class correlation co-efficient of 0.91. The device estimated central systolic blood pressure about −15mmHg (95% CI, −17 to −13mmHg, P < 0.001).

The device also estimated diastolic blood pressure and pulse pressure to be P < 0.001 and closely correlated with the invasive measurements, with an intra-class correlation coefficient of 0.74. The correlation coefficient for the differences between and the mean values of the pulse pressures was −0.18 (P < 0.001).

Table 2

	Noninvasive devices	Invasive catheter[a]	Difference from the catheter (95% confidence interval)	P value
Central pressure (n = 99)				
SphygmoCor				
Systolic blood pressure (mm Hg)	123 ± 20	138 ± 22	−15 (−17 to −13)	<0.001
Diastolic blood pressure (mm Hg)	78 ± 11	78 ± 10	0 (−2 to +1)	0.91
Pulse pressure (mm Hg)	45 ± 14	60 ± 16	−15 (−16 to −14)	<0.001

2.2 Significance of the study

Of course, without invasive catheter measurements in this study, it is difficult to judge which device is more accurate. These similar findings across populations suggest that the difference in the estimation of central systolic BP is inherent with their technological differences, and that central BP values are not exchangeable between the two devices, and device specific reference values would be required for clinical decisions, if any.

Our finding on the comparison between the SphygmoCor device and the catheter measurement is also in keeping with the results of previous studies in two different populations. Whenever the sphygmomanometrically measured brachial BP was used for the calibration, the SphygmoCor device substantially underestimated central systolic BP.

3. Conclusion

Aortic pressure wave velocity is supposed to be a significant therapeutic factor. It is observed that the patients whose reports suggest that there is an improvement in aortic pulse wave velocity leads to the reduction in mortality. It also improves the survival rate of the patients. It is also observed that, in treated hypertensive patients, reduction in aortic PWV is observed.

Over a period of 5 years, a group of treated hyper-tension patients was monitored. And in that study, it was concluded that the biggest reason for these patients to be cured from hypertension was sustained decrease in aortic PWV, central systolic blood pressure as well as pulse pressure.

There are many anti-hypertensive drugs are available in the market which are used to decrease aortic PWV in hypertensive patients.

Some of these drugs are beta blockers, calcium channel blockers, angiotensive II receptor antagonists and ACE inhibitors. Two different beta blockers, atenolol and nebivolol were given to the patients suffering from hypertension and this results into the decrease in aortic PWV in those patients.

In a different study, Atenolol and Indapamide were given to hypertensive patients which further resulted in the reduction of aortic PWV being monitored for twelve months.

According to a report, a BP device is supposed to be similar to a reference device if the mean difference is found to be 5 mm Hg and the SD 8 mm Hg. In the similar way, a reference device is supposed to be similar to a BP device if the mean difference is found to be 5 mm Hg and the SD 8 mm Hg. For the current study, we used SphygmoCor device with the catheter manometer system.

In a previous study comparing peripheral BP values obtained with the noninvasive device for the assessment of central hemodynamics and measured brachial BP, a high correlation of peripheral systolic BP ($r=0.81$, $P<0.001$) was found, but the agreement with mean difference of 4.9 mm Hg and an SD of about 11 mm Hg was relatively poor.

Results from the J-CORE study showed that along with a significant reduction in central systolic blood pressure from a combined ARB / CCB combination, aortic PWV in the combination therapy group was significantly lower than when combined with a diuretic, even after adjustment for mean pressure. The combination of lowered central systolic pressure and aortic PWV, both independent predictors of cardiovascular morbidity in hypertensive patients, allowed for suggestions that ARB / CCB therapy may lead to a favorable effect on cardiovascular outcomes beyond that achieved by ARB / diuretic treatment.

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