Research Article

Association of central blood pressure profile, ambulatory blood pressure parameters with 2D echocardiographic diastolic dysfunction and carotid intima-media thickness in patients with coronary artery disease

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Abstract

Introduction: Blood Pressure (BP) and its diurnal variability are linked to endothelial dysfunction and arterial stiffness, promoting atherosclerosis which can be observed as intimal thickening in carotid arteries and atherosclerotic lesions in coronary angiograms.

Objectives: To evaluate the association of Diastolic Dysfunction (DD) in patients with Coronary Artery Disease (CAD) with central and Ambulatory Blood Pressure Monitoring (ABPM) indices and to assess Carotid Intima Media Thickness (CIMT) in different CAD score groups and then to compare the results with individuals having normal coronaries.

Methodology: A descriptive cross-sectional study was conducted at Cardiology Unit Kandy in 2017/18. Patients undergoing elective coronary angiography were categorized into low, intermediate and high SYNTAX score group. Invasive BP was recorded and Pulsatility Index (PI) was derived. Carotid ultrasound was used to assess CIMT and diastolic function was assessed by 2D echocardiogram. Patients had their 24-hour ABPM recorded. Results were compared with individuals having normal coronary arteries on angiogram.

Results: There were a total of 60 subjects out of which 40 (Mean age=59.77±8.73years) had angiographically proven CAD and 20 subjects had no CAD on angiogram. Amongst the CAD group the calculated PI was 0.82±0.36. The ratio of early diastolic mitral inflow velocity to annular velocity (E/e') which denotes diastolic dysfunction, had strong positive correlation with PI (r=0.942, p=0.002).

The mean CIMT for right and left carotid arteries were 0.62±0.11mm and 0.65±0.13mm respectively. A higher but statistically insignificant (p=0.087) CIMT value was noted among patients with SYNTAX score ≥ 23 (7.55±3.01) than in SYNTAX score ≤ 22 (6.87±1.93).

Low SYNTAX score group had 45%, (n=18) abnormal dipping pattern in ABPM whereas only 12.5%, (n=5) in the intermediate to high score group showed this pattern, which was statistically highly significant (X²=30.7, p=0.004).

Between the CAD group and subjects having normal coronary arteries, the following parameters did not show statistically significant difference. Invasively derived PI (0.76±0.17 and 0.78±0.16, p=0.318), ABPM-derived atherogenic index (r=0.005, p=0.659 and r=0.003, p=0.554), CIMT value (0.63±0.10 mm and 0.52±0.19 mm, p=0.196) and the mitral annular E/e' velocity (9.56±5.40 and 10.81±3.22, p=0.372).

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Introduction

Coronary vascular disease, being the number one cause of death globally, had caused an estimated 7.4 million deaths in the year 2012 [1]. The latest updates (WHO fact sheet, 2016) state that over three quarters of cardio vascular deaths take place in low and middle income countries [1]. It is known that atherosclerosis is the main cause of ischaemic coronary artery disease [2], and accounts for approximately 90% of myocardial infarctions [2].

Patients may present with a wide spectrum of symptoms in ischaemic heart disease varying between stable angina and acute ST segment-elevation myocardial infarction. The gold standard investigation for assessing atherosclerotic coronary artery disease is invasive conventional coronary angiography. However this procedure requires hospital admission, highly skilled operators and cardiac catheterization laboratory facilities in addition to having a 1.7% risk of developing relevant complications [3], as well as radiation exposure to both patients and operators. The selection process of suitable candidates undergoing invasive conventional coronary angiography therefore requires much deliberation.

Multiple studies have been conducted worldwide assessing the effectiveness of numerous non-invasive investigations that may be helpful in estimating the extent of atherosclerotic plaque burden. Discovery of such effective methods will invariably help narrow down the selection process for invasive coronary angiography. Ambulatory Blood Pressure Monitoring (ABPM) is one such non-invasive method which may be used for evaluation of this purpose. Previous studies have shown that cardiovascular events are better correlated with abnormalities detected on 24 hour ambulatory blood pressure monitoring [1] than manual clinic blood pressure measurements, and there is evidence that occurrence of target organ damage is higher with increased blood pressure variability [4].

However it has also been found that central blood pressure values, which are lower than the corresponding peripheral values [5], give a better projection of cardiovascular morbidity and mortality than ambulatory blood pressure values [4,5]. This is in support of the fact that indices such as femoral carotid pulse wave velocity (gold standard test for assessing arterial stiffness), central blood pressure and augmentation index which can be derived from central blood pressure monitoring during coronary angiography are known to predict mortality and morbidity better [4]. Therefore it is worthwhile finding out if results of ABPM and then correlate with those of central blood pressure monitoring.

Furthermore, case control studies done with both invasive as well as non-invasive monitoring have shown that indices such as aortic fractional pulse pressure and pulsatility index showed significantly greater values among patients with Coronary Artery Disease (CAD) compared to those with normal coronary arteries [6]. Additionally it has been found that both aortic pulse pressure and aortic pulsatility are associated with angiographic coronary artery disease regardless of age and other cardiovascular risk factors [7]. The use of echocardiography in detecting an independent association between aortic stiffness and left ventricular diastolic function had been proven in previous studies as well [8]. Since aortic stiffness is an independent predictor of cardiovascular outcome once adjustment has been made for traditional cardiovascular risk factors [9], it is beneficial to find out if there is an association between echocardiographic parameters and the extent of atherosclerotic plaque disease.

Studies in animal models have shown that increased aortic afterload results in LV diastolic dysfunction, characterized by impaired LV relaxation and increased LV end-diastolic pressure [10]. Consequently, elevated central aortic blood pressure may contribute to LV diastolic dysfunction in humans as well. This becomes clinically significant given the high prevalence of LV diastolic dysfunction in patients with hypertension, type 2 diabetes mellitus, obesity, and others diseases [10]. However, studies investigating the association between central aortic pressures and diastolic function have been limited. The present study was designed to test the hypothesis that the pulsatile component of central aortic pressure significantly contributes to left ventricular diastolic function.

In modern cardiology, an increasing number of novel indices, non-invasive measurements are appearing for the estimation of the extent and mortality in coronary artery disease [11].

Material and methods

Study design and setting

A descriptive cross-sectional study was conducted at the Cardiology unit, National (Teaching) Hospital Kandy. The study population consisted of all the consecutive patients fulfilling the inclusion criteria who were subjected to coronary angiography from January 2017 onwards. The control group was patients suspected of having ischaemic heart disease and underwent coronary angiogram but having no demonstrable coronary artery disease on angiography.

Inclusion criteria

Patients with a past history of myocardial infarction or with a positive exercise stress test as evidence of ischaemic heart disease who underwent elective coronary angiography for the diagnosis of CAD were included in the study. Significant coronary artery disease is defined as ≥70% stenosis in at least one major epicardial coronary artery.
2D echocardiography was carried out the following day by two well experienced echocardiography operators individually using the Philips Epic 7 Echocardiography machine with standard in–build software for tissue Doppler studies.

Ambulatory blood pressure monitoring was performed on discharge using the Oscar 2 Ambulatory Blood Pressure Meter and Accuwin Pro® software for documentation and analysis. All instruments and softwares underwent independent validation.

A pre–tested interviewer administered questionnaire and the relevant medical records were used to obtain information about demographic data, patient characteristics, co–morbidities and investigation findings.

Manual blood pressure was assessed using conventional sphygmomanometer wherever appropriate.

### Statistical analysis

Values will be expressed as mean ±1 SD. Mean values between two groups will be compared by Student’s t–test. Categorical variables will be compared using chi–square test. Changes of haemodynamic parameters will be evaluated by paired t–test. A p value <0.05 will be considered statistically significant. The association between dependent variables and independent variables will mainly be presented in terms of percentage frequencies. All statistical analyses will be performed using the Statistical Package for Social Science (SPSS) for windows version 17 (SPSS Inc. Chicago, IL, US).

### Ethical clearance

Ethical clearance was obtained from the ethical review committee of Teaching Hospital Kandy, Sri Lanka (M/02/A/73). Informed written consent was obtained from all patients.

### Results

#### Demographic characteristics

There were 40 patients and 20 controls in the study sample. Out of the patients, there were 77.50% (n=31) of males. The mean age of the sample was 59.8± 8.7 years. The control group contained 20 subjects (Mean age= 51.90±13.08 years) with 55.00% (n=11) of males. Baseline characteristics and co–morbidities of the patient (diseased) group and control group are demonstrated in Table 1.

Correlation between invasively derived blood pressure indices vs. non–invasive echocardiographic diastolic function in diseased group.

In the diseased group, there was a strong negative correlation of the early diastolic mitral annular velocity (e') to PI which was derived from invasive BP measurements (r= -0.913, p=0.003).

Similarly, the ratio of early diastolic mitral inflow velocity to annular velocity (E/e') which denotes diastolic dysfunction also had strong positive correlation with PI (r=0.942, p=0.002).
Classification of diseased group according to SYNTAX score and subgroup analysis

There were 75.00%, (n=30) had SYNTAX score 0 to 22 (low), 20.00%, (n=8) had 23 to 32 (intermediate) and 5.00%, (n=2) had >32 (high) according to extent of involvement of coronary arteries in the angiogram amongst the diseased group Figure 1.

CIMT in different SYNTAX score group

The mean CIMT for right and left carotid arteries were 0.62±0.11mm and 0.65±0.13mm respectively Higher CIMT value was noted among the patients with SYNTAX score ≥ 23 (7.55±3.01) than patients with SYNTAX score ≤ 22 (6.87±1.93) in the diseased group, the difference was not statistically significant (p=0.087) Table 2.

Different ABPM patterns in different SYNTAX score groups

In patients with low SYNTAX score had 45%, (n=18) abnormal dipping pattern in ABPM whereas only 12.5%, (n=5) in the intermediate to high score group showed this pattern, which was statistically significant (X²=30.7, p<0.004).

When considering the diseased group, the group with low score (SYNTAX ≤ 22) vs intermediate to high score (SYNTAX ≥ 23) had their invasive BP derived Pulse Pressure [PP] (57.70±27.60 vs 62.40±15.01mmHg, p=0.201), Fractional pulse pressure [PP/Mean BP] (0.60±0.21 vs 0.67±0.19, p=0.850) and Pulsatility index [PP/Diastolic BP](0.81±0.38 vs.0.88±0.32, p=0.707) respectively denoting that PP, fractional PP or PI did not differ among different syntax score groups.

Invasive blood pressure indices amongst diseased vs. control group

In the diseased sample, the invasive BP derived Systolic BP (SBP), Diastolic BP (DBP), Mean BP, Pulse Pressure (PP) and Pulsatillity Index (PI) was 117.50±15.80mmHg, 67.03±7.78mmHg, 83.85±9.71mmHg, 50.48±11.49 and 0.76±0.17 respectively.

In the control sample, the invasive BP derived Systolic BP (SBP), Diastolic BP (DBP), Mean BP, Pulse Pressure (PP) and Pulsatility Index (PI) was 111.05±9.47mmHg, 62.80±7.14mmHg, 78.88±7.30mmHg, 48.25±06.91 and 0.78±0.15 respectively (Table 3).

Thus statistically, the invasively derived pulsatility index showed no significant difference between the diseased and control group (0.76±0.17 and 0.78±0.15, p=0.318).

Mean CIMT diseased vs. control

The mean CIMT in the diseased group and control group were 0.63±0.10 mm and 0.52±0.19 mm respectively (p=0.196) Figure 2.

Although the mean CIMT showed a lower value in the control group with no CAD, the difference was not statistically significant.

Diastolic dysfunction (E/e’) patients vs. controls

The E/e’ in the diseased group and control group were 9.56±5.40 and 10.81±3.22 respectively (p=0.372) which was not statistically significant Figure 3.

Ambulatory BP comparison

In addition, the ambulatory BP derived atherogenic index did not have any correlation with invasively derived PI both in the diseased group (r=0.005, p=0.658) and control group (r=0.003, p=0.554).

Discussion

Our study has shown the association between the pulsatile components of afterload also known as the aortic pulsatility, which is derived by the pulsatility index on invasive BP measurements and the left ventricular diastolic dysfunction. Studies in animal models have shown that increased aortic afterload results in LV diastolic dysfunction, characterized by impaired LV relaxation and increased LV end-diastolic pressures [13]. Consequently, elevated central aortic blood pressure may contribute to LV diastolic dysfunction in humans as well. This becomes clinically significant given the high prevalence of LV diastolic dysfunction in patients with hypertension, type 2 diabetes mellitus, obesity, and other related diseases [13,14]. However, studies investigating the
The clinical importance of this finding rests in the potential for it to be considered a standard parameter [18-20]. On the contrary, the role of ABPM on CV mortality has not been investigated sufficiently in clinical practice for it to be considered a standard parameter [18-20].

Interestingly, a significant proportion of patients with abnormal dipping pattern in Ambulatory Blood Pressure Monitoring (ABPM) was observed in the low SYNTAX score group compared to intermediate and high score group. Abnormal dipping pattern or reverse dipping in ABPM is an independent cardiovascular CV risk factor. However, emerging strong evidence from recent meta-analyses and systematic reviews suggest that its clinical usefulness may be limited because the variable CIMT measurements inconsistent with underlying CAD [16]. This is also reflected in our study where CIMT did not show significant difference between patients with CAD and control group. The measurements between the three SYNTAX score groups amongst patients with angiographically evident CAD was not significant either. These finding can partly be explained by the fact that CIMT has association with other traditional risk factors namely age, hypertension, dyslipidaemia, abdominal obesity, smoking and glucose intolerance. The impact of these risk factors on CIMT has previously been well described [17].

Sharman et. al., investigated the relationship between arterial wave properties and diastolic function and found an association between central aortic pulse pressure and diastolic function [14]. However, this analysis was limited to a diabetic cohort and found that the partial contribution of PI to E/e' in multivariate analysis was rather small. The present study not only validated the finding that PI contributes to high E/e' in diabetics and non-diabetics, but also in subjects with other comorbidities such as hypertension, dyslipidaemia, and smoking. Analysis of Myocardial Performance Index (MPI) would have been a better predictor of global LV function since it is considered as a sum of an index reflecting LV systolic function as well as an index reflecting LV diastolic function [15]. The MPI is derived by dividing the sum of isovolumetric relaxation time and isovolumetric contraction time by ejection time. Ejection time is usually obtained by measuring the timing of the transaortic valve flow velocity or LV outflow velocity by continuous-wave Doppler. This measurement is observer dependent and has substantial intra-observer as well as inter-observer variability on repeated estimation [15]. Thus MPI was not in cooperated as a measurement of interest in our study. However, in future with the advent of real time three dimensional (3D) echocardiography, precise measurement of ejection time is possible and will then be a valuable tool to assess global LV function and risk stratify cardiovascular morbidity.

One of the aims of our study was to see whether increased Carotid Intima-Media Thickness (CIMT) has an association with the extent coronary artery disease and its severity. The severity and extent of CAD is measured by the SYNTAX scoring system which has world-wide acceptance [12]. Traditionally CIMT has been associated with coronary artery disease and stroke; However, emerging strong evidence from recent meta-analyses and systematic reviews suggest that its clinical usefulness may be limited because the variable CIMT measurements inconsistent with underlying CAD [16]. This is also reflected in our study where CIMT did not show significant difference between patients with CAD and control group. The measurements between the three SYNTAX score groups amongst patients with angiographically evident CAD was not significant either. These finding can partly be explained by the fact that CIMT has association with other traditional risk factors namely age, hypertension, dyslipidaemia, abdominal obesity, smoking and glucose intolerance. The impact of these risk factors on CIMT has previously been well described [17].

Interestingly, A significant proportion of patients with abnormal dipping pattern in Ambulatory Blood Pressure Monitoring (ABPM) was observed in the low SYNTAX score group compared to intermediate and high score group. Abnormal dipping pattern or reverse dipping in ABPM is an independent cardiovascular CV risk factor. However, its impact on CV mortality has not been investigated sufficiently in clinical practice for it to be considered a standard parameter [18-20].

Conclusion

In patients with CAD the diastolic dysfunction which is reflected by E/e’ positively correlated with invasively derived PI.
which indicate incipient arterial stiffness. Therefore E/e’ could be used as a non-invasive reproducible tool to assess arterial stiffness indirectly. CIMT showed a higher value in patients with high SYNTAX score group compared to low score group and control group without CAD, reflecting the generalized atherosclerotic process in the studied arteries although the values were not significant statistically. Statistically significant abnormal dipping pattern was observed in low SYNTAX group compared to high group which demonstrates the difference in BP variability and haemodynamic diversity amongst CAD patients with different atherosclerotic disease burden, categorized by means of SYNTAX score. These findings need further detailed evaluation to estimate the extent and severity of CAD in a non-invasive manner.

Limitations

The present study was observational and cross-sectional, and thus causality cannot be accurately determined; furthermore, long-term clinical events and outcomes were not collected. Left Ventricular (LV) diastolic function (LV filling pressure and LV relaxation) was assessed by echocardiographic tissue Doppler study rather than by invasive measurement which is the gold-standard method. LV systolic function estimation by M-mode echo may be erroneous and the 3D assessment of left ventricular ejection fraction would have been a more precise estimation of the true LV systolic function. Some patients may have sleep apnoea, which has been associated with increased aortic stiffness and diastolic dysfunction [14].

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References