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Noninvasive Assessment of Arterial Stiffness and Risk of Coronary Artery Disease

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Abstract

The early prediction of Coronary artery disease (CAD) is a major goal of healthcare through out the world. Aortic stiffness reflecting impaired elasticity of the aorta is shown to be an independent predictor of coronary artery disease which can be measured noninvasively. The aim of the study was to establish the noninvasive markers of Aortic stiffness as the predictor of CAD. In this prospective, observational study, total 100 patients were examined who were clinically suspected of having CAD and were scheduled to undergo CAG. Then the markers of aortic stiffness like Aortic strain, aortic distensibility and aortic propagation velocity were measured by transthoracic echocardiography. Other markers of aortic stiffness like Male sex, aging, systolic blood pressure and pulse pressure were significantly higher in the CAD group. Here it is showed that CAD can be significantly determined by aortic propagation velocity (AVP) cut off value d"41cm/sec. 82% patients were found CAD by AVP who had truly CAD on the basis of CAG and 96% patients were found no CAD by AVP who had no CAD by CAG. Thus an AVP value < 41 cm/sec predicted CAD with 82% sensitivity, 96% specificity (positive predictive value 95.35%, negative predictive value 84.21% and accuracy were 89%). In conclusion, bedside risk stratification of CAD is feasible by echcardiographic determination of Aortic propagation velocity(AVP).

Introduction:

Coronary artery disease is thought to be associated with a generalized atherosclerotic process that begins in the large arteries.[1] The Rotterdam study, which included over 3,000 elderly subjects, showed that arterial stiffness was strongly related to atherosclerosis at various sites in the vascular tree. [2] Aging results in vascular stiffening and an increase in the velocity of the pressure wave as it travel down the aorta.[3]

As such, investigation of arterial stiffness, especially of the large arteries, has gathered pace in recent years with the development of readily available noninvasive assessment techniques.

Aortic stiffness reflecting impaired elasticity of the aorta may predict coronary artery disease beyond classic risk factors. Aortic stiffness is an independent predictor of primary coronary events in hypertensive patients.[4] Hence, In this study, we will assess whether echocardiographic marker, color M-mode-derived propagation velocity along the origin of the descending thoracic aorta (AVP), aortic strain & aortic distensibility contribute to the diagnosis of coronary artery disease (CAD).

The aim of this study is to establish the validity of noninvasive assessment of aortic stiffness measured by echocardiography and significant coronary artery disease on coronary angiogram.

Methods & Materials:

This prospective cross sectional observational study was carried out in the depertment of Cardiology, University Cardiac Center, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh from July 2009 to January 2010.

- Inclusion criteria:
  1. Age between 35 to 75 years.
  2. Patients with suspected CAD and were scheduled to undergo coronary angiography.
  3. Left ventricular ejection fraction > 40%.

- Exclusion criteria:
  1. Acute Myocardial Infarction
  2. Severe Valvular heart disease.
  3. History of coronary angioplasty or coronary artery bypasses grafting.
  4. Left ventricular ejection fraction < 40%.
  5. Arrhythmia like atrial fibrillation, frequent VEC's.
  6. Aneurysm of the Aorta.
  7. Cardiomyopathy.
  8. Patients with end-stage renal disease.
  9. Inadequate echocardiographic image quality.
  10. They do not give the consent.

Considering the inclusion and exclusion criteria, a total 100 patients of suspected CAD who were admitted for coronary angiogram in this department were included in this study. Initial evaluation of the patients was done by history, clinical examination and releavant examination. Demographic data like age, sex etc were recorded. Risk factors profile for CAD including hypertension, diabetis mellitus, dyslipidaemia were noted. The study population was divided into two groups (50 patients in each group) according to the Coronary angiogram report.

1) Goup A/ Case (50) : Those who had the significant coronary artery disease on coronary angiogram.

2) Group B/ Control (50) : Those who had normal or insignificant coronary artery disease on coronary angiogram.

Coronary Angiography:

Coronary angiography was performed by the Judkin's technique. The percentage of luminal diameter stenosis was evaluated and CAD was defined as the presence of at least 50% narrowing in diameter for each of the three main coronary vessels.

Echocardiographic measurements:

Complete 2D & M mode echocardiography was performed in all patients by two experienced echo cardiographers who were blind to the clinical data. Echocardiographic marker of aortic stiffness such as aortic strain, aortic distensibility and aortic propagation velocity (AVP) were measured. Ascending aorta diameters were measured from the parasternal long axis view on the M-mode tracing at a level of 1 cm above the Sino tubular junction. Aortic diameter change with cardiac cycle was measured and the pulse pressure was determined by brachial sphygmomanometry.

- Aortic strain (AS) %[5]:

$$\frac{\text{(Aortic systolic diameter–Diastolic diameter) X 100}}{\text{Diastolic diameter}}$$

- Aortic distensibility (AD) (mm Hg-1):[5]

$$\frac{\text{(2 X Aortic Strain)}}{\text{(Systolic Blood pressure – Diastolic blood pressure)}}$$

- Aortic propagation velocity (AVP):

From the suprasternal window, in supine position, the descending aorta was visualized just distal to the subclavian artery and color M-mode Doppler recordings was obtained with the cursor parallel to the main flow of direction. The shape of a flame is displayed. Aortic flow propagation velocity (AVP) was calculated by dividing the distance between the points corresponding to the beginning and end of the propagation slope by the duration between the corresponding time points. AVP thus corresponds to the velocity at which the flow is propagated down the artery. It was shown that AVP cut off value d— 41 cm/sec predicted coronary artery disease significantly. [6]

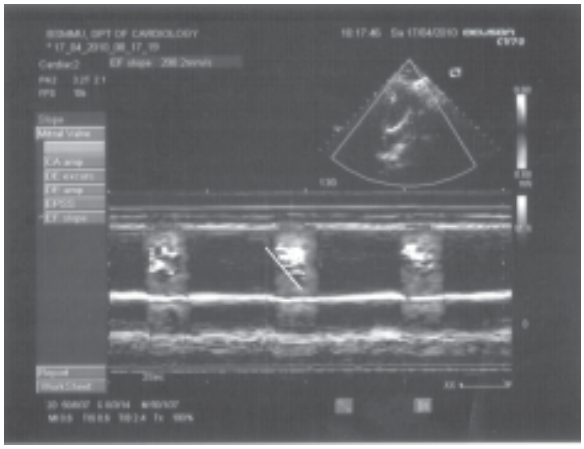

Figure : Color M-Mode Doppler Echo shows AVP 20.0 cm/sec.

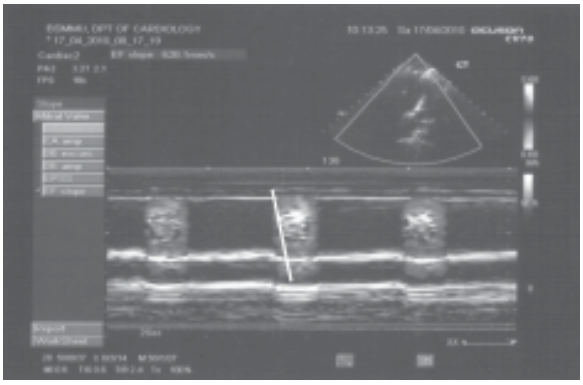

Figure : Color M-Mode Doppler Echo shows AVP 62.8 cm/sec.

Results:

The age of the study population ranges from 35-75 years, The mean (±SD) age of the group-A was 56.52 ± 6.70 and group-B was 51.32 ± 6.83 (P<0.001). 84% patients of group-A were 50yrs of age. Table-I presents the basic characteristics of the study subjects. BMI is relatively higher in group-A (24.66±2.21) than group-B (23.87±0.96). Among the risk factors of the CAD between two groups hypertension was observed in 66% patient in group-A & 26% in group-B (p<0.001), systolic BP was 130.10 ± 17.10 in group-A and in group-B was 124.20 ± 11.92 (p=0.048) and diastolic BP was in group-A (77.00 ± 8.21) and in group-B (80.90±6.83) (p=0.011). As a result the pulse pressure were found in group-A (53.10 ± 13.05) and in group-B (43.30 ± 9.13) (p<0.001).Thus these all were observed significantly different between two groups.

The other risk factors like diabetes mellitus, smoking and dyslipidaemia were almost identically distributed between the two groups (P>0.05).

Table-I

Basic characteristics of the study subjects

Parameters	Group A (n=50)		Group B (n=50)		P value
	No.	(%)	No.	(%)	
Sex					
Male	40	(80.0)	40	(80.0)	
					1.000^{ns}
Female	10	(20.0)	10	(20.0)	
Age (years)					
<50	8	(16.0)	22	(44.0)	
					0.002**
>50	42	(84.0)	28	(56.0)	
Mean±SD	56.52±6.70		51.32±6.83		<0.001***
Range	42.0 74.0		38.0 68.0		
Body mass index (kg/m^2)					
Mean±SD	24.66±2.21		23.87±0.95		0.022*
Range	16.50 30.50		20.95 26.10		
Hypertension	33	(66.0)	13	(26.0)	<0.001***
Systolic blood pressure (mmHg)					
Mean±SD	130.10±17.10		124.20±11.92		0.048*
Range	90.00 160.00		110.00 160.00		
Diastolic blood pressure (mmHg)					
Mean±SD	77.00±8.21		80.90±6.83		0.011*
Range	60.00 100.00		70.00 100.00		
Pulse pressure (mmHg)					
Mean±SD	53.10±13.05		43.30±9.13		<0.001***
Range	20.00 80.00		30.00 70.00		
Diabetes mellitus	17	(34.0)	20	(40.0)	0.534^{ns}
Smoking habit	19	(38.0)	15	(30.0)	0.398^{ns}
Dyslipidaemia	15	(30.0)	9	(18.0)	0.160^{ns}

Group A : CAD cases
Group B : Control
Statistical analyses done by Chi square test/Unpaired Student's 't' test
ns = Not significant
* = Significant at P<0.05.01
*** = Significant at P<0.0011

Table-II presents the echocardiographic findings of aortic stiffness. The mean Aortic strain was 4.25±2.32 in group-A and 10.59±3.99 in group-B (p<0.001), the mean Aortic Distensibility was 0.18±0.13 in group-A and 0.52±0.52 in group-B (p<0.001) and the mean Aortic propagation velocity (AVP) was 35.18±7.01 in group-A and 68.29±12.60 in group-B (p<.001). Thus it shows all of the echocardiographic findings were significantly different between two groups.

Table-III shows that CAD can be significantly determined by AVP cut off value d"41cm/sec. It shows that out of 50 patients of group-A, 41(82%) patients had AVP cut off value d"41 cm/sec and 9(18%) patients had AVP >41 cm/sec. In group-B only 2(4%) patients had AVP cut off value d"41cm/sec and 48(96%) patients had AVP >41 cm/sec (p<0.001).

Table-IV presents the efficacy of AVP in diagnosing CAD. It shows that 41(82%) patients of group-A were found CAD and 9 (18%) patients were found no CAD by aortic propagation velocity (AVP). In group-B, 2 (4%) patients were found CAD and 48 (96%) patients were found no CAD by AVP. So, an AVP value of d"41cm/sec predicts CAD with 82% sensitivity, 96% specificity (positive predictive value 95.35%, negative predictive value 84.21% and accuracy were 89%).

Table-II

Echocardiographic findings of the study subjects

Parameters	Group A (n=50)	Group B (n=50)	P value
Aortic strain (%)			
Mean±SD	4.25±2.32	10.59±3.99	<0.001***
Range	0.09 10.40	2.12 25.00	
Aortic distensibility (mmHg ^{1})			
Mean±SD	0.18±0.13	0.52±0.52	<0.001***
Range	0.03 0.75	0.10 1.25	
Aortic velocity propagation (cm/s)			
Mean±SD	35.18±7.01	68.29±12.60	<0.001***
Range	21.80 49.50	37.10 92.50	

Statistical analyses done by unpaired Student's 't' test
*** = Significant at P<0.001

Table-III

Determination of presence of CAD by APV cut off value

CAD	Group A (n=50)		Group B (n=50)		P value
	No.	(%)	No.	(%)	
Present (APV ?41 cm/s)	41	(82.0)	2	(4.0)	<0.001***
Absent (APV >41 cm/s)	9	(18.0)	48	(96.0)	

Statistical analyses done by Chi square test
*** = Significant at P<0.001

Table-IV

Efficacy of Aortic velocity propagation in diagnosing CAD

Coronary angiogram finding (n=100)	Echocardiographic finding					
	CAD present		CAD absent			
	No.	(%)	No.	(%)	No.	(%)
CAD present	50	(50.0)	41	(82.0)	9	(18.0)
CAD absent	50	(50.0)	2	(4.0)	48	(96.0)
Total	100		43	(41.0)	57	(59.0)

Sensitivity : 82%
Specificity : 96%
Positive predictive value : 95.35%
Negative predictive value : 84.21%
Accuracy : 89%

Discussion:

It is evident from the present study that the coronary artery disease can be predicted by aortic stiffness measured by echocardiography. This study also shows the different clinical parameters of aortic stiffness like age, hypertension; especially systolic hypertension and high pulse pressure are significantly correlated with coronary artery disease. These findings are consistent with the results of previous studies, which also concluded that aortic stiffness is an independent predictor of cardiovascular and especially coronary artery disease. [7]

Arterial stiffness has been shown to be associated with CAD and cardiovascular risk factors such as smoking, hypertension,[8] hypercholesterolemia[9], impaired glucose tolerance. [10] Although in the present study PP and SBP predicted CAD, in univariate analysis, they lost their predictive value after adjustment for AVP.

The other risk factors like diabetes mellitus, dmoking, dyslipidaemia were almost identical between two groups. Günes et al, found also almost similar distribution of these risk factors between two groups.[6]

The echocardiographic markers of aortic stiffness such as aortic strain, aortic distensibility, and aortic propagation velocity (AVP) were observed significantly lower in coronary artery disease group.

Stefanadis et al, showed that pulse pressure was increased; aortic strain and distensibility were decreased in stiffer aorta in IHD patients. The two stiffness parameters, aortic strain and distensibility, were shown to be powerful and independent predictors of recurrent acute coronary events in patients with CAD.[5]

The similar study done by Günes et al. found the AVP was lower in coronary artery disease. The present study shows that CAD can be significantly determined by AVP cut off value d—41cm/sec which was determined previously by Günes et al. [6]

The present study shows that an AVP value of d— 41cm/sec predicts CAD with 82% sensitivity, 96% specificity (positive predictive value 95.35%, negative predictive value 84.21% and accuracy were 89%) which is very much similar to the study done by Günes et al. [6]

Thus we have show that AVP predicted coronary atherosclerosis more powerfully than other methods of ultrasonographic aortic stiffness measurements. Furthermore, AVP was the most significant and powerful predictor of CAD among the clinical and echocardiographic variables.

Limitations of the study

The reliability and reproducibility of the acquisition and reading of the methods constitute the major limitation of the study. The other limitations are the small size of the study population, the single centre study and the limited echo image quality may be an obstacle to the measurement of AVP.

Conclusion

We can conclude that bedside risk stratification for CAD is feasible by noninvasive assessment of arterial stiffness. This novel approach may be particularly useful in identifying individual patients who will benefit from further diagnostic strategies for CAD. Nevertheless, the main contribution of this study is AVP (aortic propagation velocity), a practical method for risk assessment of CAD.

The low cost, portable, noninvasive, radiation free nature of this ultrasound approach make AVP, an attractive parameter in the ongoing search for the ideal marker of coronary artery disease.

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