

Effect of the Presence of Coronary Collaterals on Biventricular Functions in Patients with Multivessel Coronary Artery Disease, Tissue Doppler Study

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Abstract: Coronary collaterals or "natural bypasses" are anastomotic connections without an intervening capillary bed between portions of the same coronary artery and between different coronary arteries. Collateral circulation potentially offers an important alternative source of blood supply when the original vessel fails to provide sufficient blood. So it provides protection to myocardium in CAD, and it limits the ischemic area after total coronary occlusion. So presence of well-developed collaterals helps in preserving both systolic and diastolic LV functions. Several methods have been developed over the years to assess both qualitatively and quantitatively different parameters of LV function. Echocardiography has been the most popular since it is a non-invasive technique that can provide information on the structure of the heart as well as on its function. In addition it can help assessing the etiology of the heart condition and improve the understanding of the underlying pathophysiology; one of the first clinical applications of tissue velocity imaging (TVI) has been as a method of assessing left ventricular systolic function. Assessment of this parameter remains the commonest indication for echocardiography, as other standard methods are often limited by technical difficulties, inaccuracy and poor reproducibility. Pulsed Doppler tissue imaging (DTI) is a sensitive, reproducible, accurate, non invasive echocardiographic technique that become a very useful clinical tool for the diagnostic, follow-up, and evaluation of the prognosis of cardiac diseases. and quantify on-line systolic and diastolic ischemia-induced myocardial dysfunction. It appears to be a promising method to quantify regional wall motion abnormalities in the setting of ischemic heart disease **Aim of the work:** The purpose of this study is to evaluate the effect of presence of coronary collaterals on biventricular functions in patients with multivessel coronary artery disease using conventional echocardiography and tissue Doppler study. **Subjects and methods:** the study included 50 patients, 39 (78 %) males and 11 (22 %) females, with age from 40 to 67 years old with mean age 55.92. **Inclusion criteria:** Patients with multivessel coronary artery disease. **Exclusion criteria** 1. Patients with rheumatic heart disease. 2. Patients with end stage renal disease. 3. Patients with end stage liver disease. 4. Hemodynamically unstable patients. 5. Patients with acute coronary syndrome. 6. Patients with single and two vessel disease. 6. patients with decompensated heart failure. The following was done for all patients. a. Full history taking, b. Complete clinical examination, c. Resting surface 12 leads electrocardiography (ECG), d. Coronary angiography, and e. Transthoracic echocardiography. **Results:** All patients in the study had coronary collaterals. According to the number of coronary collateral pathways patients divided to: Patients with ≥ 5 pathways are 35 patients (70 %). Patients with < 5 pathways are 15 patients (30 %). **Echocardiography results:** LV systolic function by 2D: Normal (EF ≥ 55) in 13 (26 %) patients. Mild impaired (EF 45: < 55 %) in 13 (26 %) patients. Moderate impaired (EF 30: < 45 %) in 18 (36 %) patients. Severe impaired (EF < 30) in 6 (12 %) patients. LV systolic function by TDI: Normal (average S wave > 8.25 cm/s) in 19 (38 %) patients. Impaired (average S wave < 8.25 cm/s) in 31 (62 %) patients. LV diastolic function by pulsed Doppler over mitral flow: Normal or pseudonormal (E/A ratio 1- 2) in 5 (10 %) patients. Impaired relaxation (E/A ratio < 1) in 41 (82 %) patients. Restrictive pattern (E/A > 2) in 4 (8 %) patients. LV diastolic function by TDI: Average E_m wave normal (> 12 cm/s) in 7 (14 %) patients. Average A_m wave normal (> 5.05 cm/s) in 9 (18 %) patients. LV diastolic function impaired (E_m/A_m ratio < 1) in 44 (88 %) patients. LV systolic function by 2D: Normal (fractional area change 32 – 60 %) in 40 (80 %) patients. Mild impaired (fractional area change 25 – 31 %) in 10 (20 %) patients. No patients had moderate or severe impairment. RV systolic function by TDI: Normal (Lat T S wave > 11.5 cm/s) in 15 (30 %) patients. Impaired (Lat T S wave < 11.5 cm/s) in 35 (70 %) patients. RV diastolic function by pulsed Doppler over tricuspid flow: Normal (E/A ratio > 1) in 11 (22 %) patients. Impaired relaxation (E/A ratio < 1) in 39 (78 %) patients. RV diastolic function by TDI: Normal (Lat T E/A ratio > 1) in 7 (14 %) patients. Impaired relaxation (Lat T E/A ratio < 1) in 43 (86 %) patients **Conclusion:** Coronary collaterals can preserve resting global LV and RV systolic and diastolic functions which is not detected with conventional echo and detected with TDI. These findings are important especially to patients not eligible for PCI or CABG.

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Key words: coronary collaterals, CAD= coronary artery disease, echocardiography, tissue Doppler imaging, and left ventricular function

1. Introduction:

Coronary artery disease (CAD), is the leading cause of death in industrialized countries. Established options for revascularization include angioplasty and surgical bypass, both of which are not suitable in 20 – 30 % of patients in whom the extent of coronary atherosclerosis is especially severe. An alternative treatment strategy for revascularization is therefore warranted both to control symptoms as well as to alter the course of advanced CAD. An ideal candidate to fill in this gap is therapeutic promotion of coronary collateral growth—that is, the induction of natural bypasses (1). Coronary collaterals or "natural bypasses" are anastomotic connections without an intervening capillary bed between portions of the same coronary artery and between different coronary arteries (2). Collateral circulation potentially offers an important alternative source of blood supply when the original vessel fails to provide sufficient blood (3). Coronary collaterals protect the myocardium in patients with CAD. They limit myocardial ischemia during coronary occlusion. Well-developed coronary collaterals may minimize the infarct area and predict the presence of viable myocardium in patients with a history of myocardial infarction (4). Both systolic and diastolic left ventricular functions are directly related to the amount of collateral flow (5). Several methods have been developed over the years to assess both qualitatively and quantitatively different parameters of LV function. Echocardiography has been the most popular since it is a non-invasive technique that can provide information on the structure of the heart as well as on its function. In addition it can help assessing the etiology of the heart condition and improve the understanding of the underlying pathophysiology, and at the same time it can be repeated as many times as needed with no discomfort for the patient (6).

One of the first clinical applications of tissue velocity imaging (TVI) has been as a method of assessing left ventricular systolic function. Assessment of this parameter remains the commonest indication for echocardiography, as other standard methods are often limited by technical difficulties, inaccuracy and poor reproducibility (7). Pulsed Doppler tissue imaging (DTI) is a sensitive, reproducible, accurate, non invasive echographic technique that becomes a very useful clinical tool for the diagnostic, follow-up, and evaluation of the prognosis of cardiac diseases. DTI is an accurate, sensitive, non invasive tool to quantify on-line systolic and diastolic ischemia-induced myocardial dysfunction. It appears to be a promising method to

quantify regional wall motion abnormalities in the setting of ischemic heart disease (8). Patients and methods: the study was conducted through the period from October 2010 to October 2012 and included 50 patients, 39 (78 %) males and 11 (22 %) females, with age from 40 to 67 years old with mean age 55.92. They were selected from patients admitted to Al-Zahraa University Hospital and Railway hospital to do coronary angiography.

Inclusion criteria: Patients with multivessels coronary artery disease.

Exclusion criteria: 1. Patients with rheumatic heart disease. 2. Patients with end stage renal disease. 3. Patients with end stage liver disease. 4. Hemodynamically unstable patients. 5. Patients with acute coronary syndrome. 6. Patients with single and two vessel diseases. 6. patients with decompensated heart failure.

The following was done for all patients:

a. Full history taking. b. Complete clinical examination. c. Resting surface 12 leads electrocardiography (ECG): in the supine position by Cardiomax Fukuda Denshi model FX 7102. d. **Coronary angiography.** Left and right coronary angiography in multiple planes was done to diagnose coronary lesions and assess severity of these lesions. The type of lesions classified according to the ACC/AHA classification. Coronary collaterals specified by their anatomical site and number of their pathways. Patients then grouped according to the presence or absence of coronary collaterals, number of collateral pathways and by collateral connection grading method: Collaterals classified according to collateral connection (CC) grading to: 1- CC grade 0: no continuous connection 2- CC1: threadlike continuous connection 3-CC2: side branch-like connection (9).

e. **Transthoracic echocardiography & tissue Doppler imaging:** Transthoracic & tissue Doppler imaging performed with Vived 7 Dimensions echocardiogram using 3-7 MHz transducer with the patients breathing quietly and lying in the left lateral position according to American Society of Echocardiography's 2005. **The following data obtained:** LV systolic function by M mode: and 2D Simpson's method. These measurements used to estimate EF by the following formula $EF\% = \frac{LVED\ Volume - LVES\ Volume}{LVED\ Volume}$ (10). Right ventricular (RV) systolic function by area ratio method (apical four chamber view) Regional ventricular function: according to American Society of Echocardiography's 2005, Segmental wall motion abnormalities assessed in the following views

(parasternal long axis view, parasternal short axis view, apical two chamber view and apical four chamber view) Fig. 1.

Each segment analyzed individually and scored on the basis of its motion and systolic thickening. The function of each segment confirmed in multiple views. **Segment scores are as follows:** 1- Normal or hyperkinesis, 2-Hypokinesis, 3-Akinesis (negligible thickening), 4-Dyskinesis (paradoxical systolic motion), 5- Aneurysmal (diastolic deformation).

Wall-motion score index can be derived as a sum of all scores divided by the number of segments visualized (11).

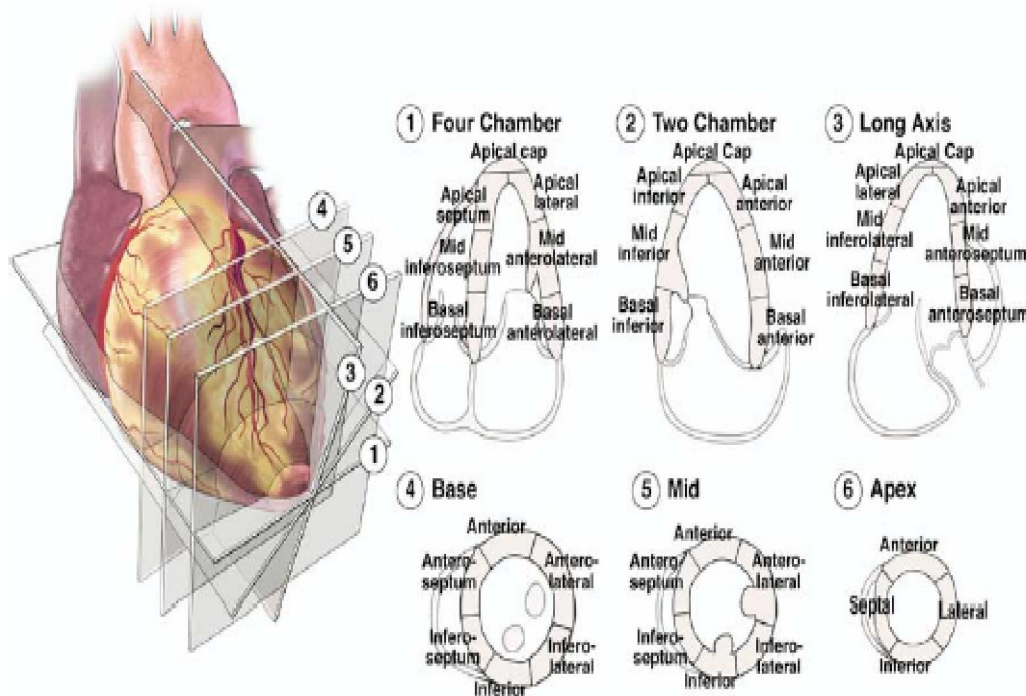


Fig. (1) show Segmental analysis of LV walls based on schematic views. A 17-segment model, including the apical cap, has been suggested by the American Heart Association Writing Group on Myocardial Segmentation and Registration for Cardiac Imaging (from Journal of the American Society of Echocardiography (10).

Patients were grouped according to the following grading of LV, RV systolic and diastolic functions:

LV EF by M mode and 2D: Normal $\geq 55\%$, Mild impaired 45 to $< 55\%$, Moderate impaired 30 to $< 45\%$, severe impaired $< 30\%$ (12).

LV systolic function by TDI: Normal: average S wave > 8.25 cm/s or Impaired: average S wave < 8.25 cm/s (13).

LV diastolic function by pulsed Doppler over mitral_flow: Normal or pseudonormal E/A ratio 1- 2, impaired relaxation E/A ratio < 1 , and Restrictive pattern E/A > 2 .

Pulsed wave Doppler flow across mitral and tricuspid valves (apical four chamber view) to measure E and A waves velocities to assess diastolic function of the LV and RV respectively.

Mitral annular velocity (lateral, septal, anterior and inferior) by pulsed tissue Doppler and average S, E_m and A_m waves measured also tricuspid annular velocity (septal and lateral) S, E and A waves measured to assess global left and right ventricular functions.

LV diastolic function by TDI: E_m wave normal > 12 cm/s, A_m wave normal > 5.05 cm/s, LV diastolic function impaired E_m/A_m ratio < 1 .

RV systolic function by 2D (difference in fractional area change): Normal: fractional area change 32 to 60 %, Mild impaired: fractional area change 25 to 31 %, Moderate: impaired fractional area change 18 to 24 %, and Severe impaired: fractional area change $< 18\%$ (12).

RV systolic function by TDI: Normal: Lat T S wave > 11.5 cm/s.

RV diastolic function by pulsed Doppler over tricuspid flow: Normal: E/A ratio >1, Impaired relaxation: E/A ratio < 1.

RV diastolic function by TDI: Normal: Lat T E/A ratio > 1 and Impaired relaxation: Lat T E /A ratio < 1.

Statistical analysis:

The clinical and investigating data were collected and transferred to statistical program "SPSS" for windows V6.12 to obtain: -_Minimum, Maximum, and Mean (X) Standard deviation \pm SD Number and percentage (from quantitative data) **Analytic statistics** "T" test to compare more than two groups **Conclusion matrix** P-value = level of significance $P > 0.05$ = not significant, $P < 0.05$ = significant, and $P < 0.001$ = highly significant.

3. Results

All patients in the study had coronary collaterals: Three patients (6 %) had two collateral pathways. 4 patients (8 %) had 3 collateral pathways. 8 patients (16 %) had 4 collateral pathways. 9 patients (18 %) had 5 collateral pathways. 7 patients (14 %) had 6 collateral pathways. 5 patients (10 %) had 7 collateral pathways. 4 patients (8 %) had 8 collateral pathways. 6 patients (12 %) had 9 collateral pathways. One patients (2 %) had 10 collateral pathways. Two patients (4 %) had 11 collateral pathways. One patients (2 %) had 16 collateral pathways.

According to the number of coronary collateral pathways patients divided to: Patients with ≥ 5 pathways are 35 patients (70 %). And Patients with < 5 pathways are 15 patients (30 %).

Table (1) show anatomical distribution of coronary collaterals

Anatomical site of coronary collaterals	Number of cases according to collaterals found		
	CC0	CC1	CC2
1 – Collaterals to RCA			
• Septal	36	7	7
• Apical	35	9	6
• LCX to distal RCA	45	3	2
• Atrial circumflex artery to distal RCA	46	4	0
• Right marginal artery to PDA			
• OM to PDA	37	12	1
• Sinus node artery to RCA	48	1	1
• Kugel's artery	48	1	1
• Conus artery to right marginal artery	6 to LCX, 1 TO RCA 50	0	0
• Intracoronary collaterals	30	16	4
2 – Collaterals to LAD			
• Septal	7	22	21
• Apical	7	24	19
• OM to diagonals	32	16	2
• Diagonals to post stenoses of LAD	25	20	5
• Vieussen's circle	50	0	0
• Intracoronary collaterals	24	19	7
• Right marginal artery to LAD	44	0	6
• Ramus to LAD	49	0	1
3 – Collaterals to LCX			
• Distal RCA to LCX	40	2	8
• Left atrial circumflex artery to LCX	42	6	2
• Diagonals to LCX	31	16	3
• Intracoronary collaterals	24	22	4
• Ramus to LCX	48	1	1

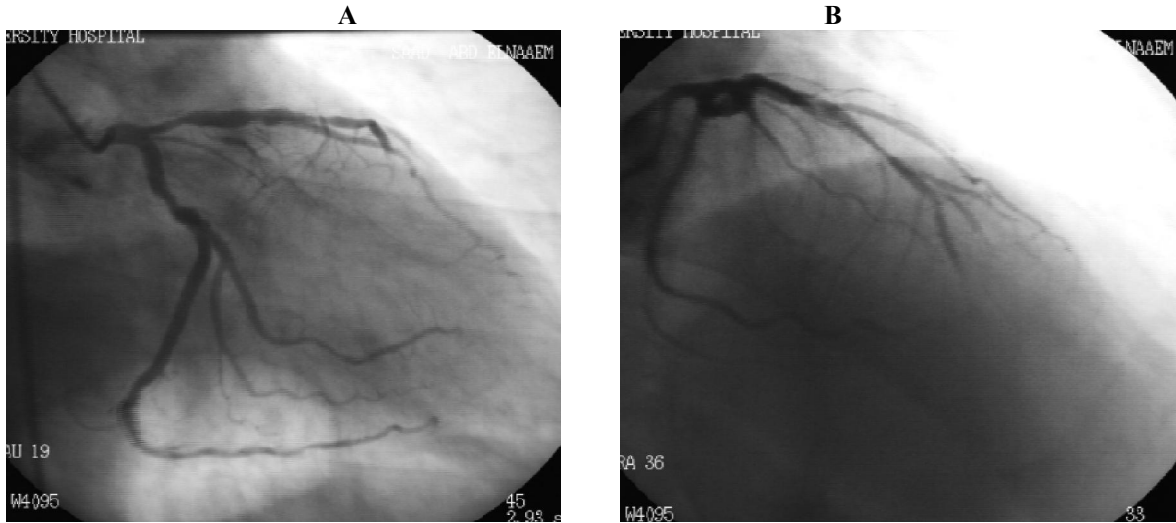
The following are examples of angiographic findings

Fig. 2 (A) Case no.1 RAO 21 CAU. 19 view showing Osteal LAD 95 % lesion then totally occluded LAD and 70 % lesion at mid LCX. (B) Case no. 2 RAO 45 CRA 36 view showing total occlusion of mid LAD

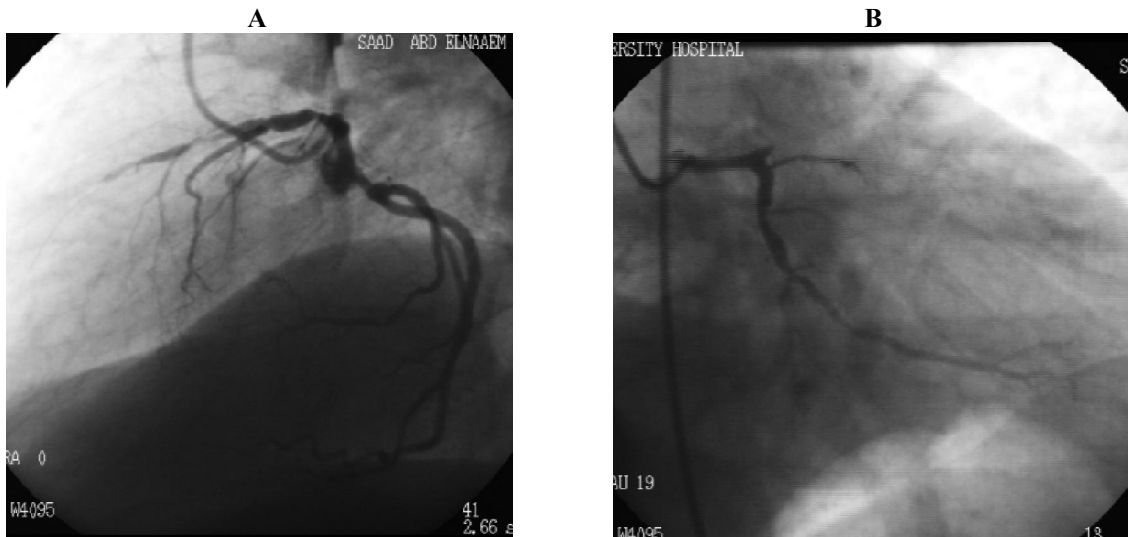


Fig. 3 (A) Case no. 3 LAO 90 view showing Osteal LAD (B) Case no. 4 RAO 50 CAU 19 view showing total LAD occlusion proximal and multiple lesions in LCX then totally occluded

Echocardiography results

LV systolic function by M mode: Normal ($EF \geq 55$) in 25 (50 %) patients. Mild impaired ($EF 45: < 55$ %) in 5 (10 %) patients. Moderate impaired ($EF 30: < 45$ %) in 14 (28 %) patients. Severe impaired ($EF < 30$) in 6 (12 %) patients. **LV systolic function by 2D:** Normal ($EF \geq 55$) in 13 (26 %) patients. Mild impaired ($EF 45: < 55$ %) in 13 (26 %) patients. Moderate impaired ($EF 30: < 45$ %) in 18 (36 %) patients. Severe impaired ($EF < 30$) in 6 (12 %) patients. **LV systolic function by TDI:** Normal (average S wave > 8.25 cm/s) in 19 (38 %) patients.

Impaired (average S wave < 8.25 cm/s) in 31 (62 %) patients. **LV diastolic function by pulsed Doppler over mitral flow:** Normal or pseudonormal (E/A ratio 1- 2) in 5 (10 %) patients. Impaired relaxation (E/A ratio < 1) in 41 (82 %) patients. Restrictive pattern ($E/A > 2$) in 4 (8 %) patients. **LV diastolic function by TDI:** Average E_m wave normal (> 12 cm/s) in 7 (14 %) patients. Average A_m wave normal (> 5.05 cm/s) in 9 (18 %) patients. Left ventricular diastolic function impaired (E_m/A_m ratio < 1) in 44 (88 %) patients. **RV systolic function by 2D:** Normal (fractional area change 32 – 60 %) in 40 (80 %)

patients. Mild impaired (fractional area change 25 – 31 %) in 10 (20 %) patients. No patients had moderate or severe impairment. **RV systolic function by TDI:** Normal (Lat T S wave > 11.5 cm/s) in 15 (30 %) patients. Impaired (Lat T S wave < 11.5 cm/s) in 35 (70 %) patients. **RV diastolic function by pulsed Doppler over tricuspid flow:** Normal (E/A ratio >1) in 11 (22 %) patients. Impaired relaxation (E/A ratio < 1) in 39 (78 %) patients.

RV diastolic function by TDI: Normal (Lat T E/A ratio > 1) in 7 (14 %) patients. Impaired relaxation (Lat T E/A ratio < 1) in 43 (86 %) patients.

Patients grouped according to:

1. The presence or absence of coronary collaterals:

All patients in the study had coronary collaterals. **2.**

Number of collaterals and collateral connection method: Patients divided into two groups:

Group I (patients with ≥ 5 collateral pathways) 35 (70 %) patients.

Group II (patients with < 5 collateral pathways) 15 (30 %) patients.

Group I (patients with ≥ 5 collateral pathways) 35 (70 %) patients: In this group ventricular functions were: **LV systolic function by M mode:** Normal (EF ≥ 55 %) in 18 (51.2 %) patients. Mild impaired (EF 45: < 55 %) in 2 (5.8 %) patients. Moderate impaired (EF 30: < 45 %) in 11 (31.4 %) patients. Severe impaired (EF < 30 %) in 4 (11.6 %) patients. **LV**

systolic function by 2D: Normal (EF ≥ 55 %) in 9 (25.7 %) patients. Mild impaired (EF 45: < 55 %) in 9 (25.7 %) patients. Moderate impaired (EF 30: < 45 %) in 12 (34.3 %) patients. Severe impaired (EF < 30 %) in 5 (41.3 %) patients. **LV systolic function by TDI:** Normal (average S wave > 8.25 cm/s) in 16 (45.7 %) patients. Impaired (average S wave < 8.25 cm/s) in 19 (54.3 %) patients. **LV diastolic function by pulsed Doppler over mitral flow:** Normal or pseudonormal (E/A ratio 1- 2) in 3 (8.5 %) patients. Impaired relaxation (E/A ratio < 1) in 30 (85.5 %) patients. Restrictive pattern (E/A > 2) in 2 (6 %) patients. **LV diastolic function by TDI:** LV diastolic function normal (E_m/A_m ratio > 1) in 6 (17 %) patients. LV diastolic function impaired (E_m/A_m ratio < 1) in 29 (83 %) patients. **RV systolic function by 2D (difference in fractional area change):** Normal (fractional area change 32 - 60) in 28 (80 %) patients. Mild impaired (fractional area change 25 - 31) in 7 (20 %) patients. **RV systolic function by TDI:** Normal (Lat T S wave > 11.5 cm/s) in 10 (28.5 %) patients. Impaired (Lat T S wave < 11.5 cm/s) in 25 (71.5 %) patients. **RV diastolic function by pulsed Doppler over tricuspid flow:** Normal (E/A ratio >1) in 8 (23 %) patients. Impaired relaxation (E/A ratio < 1) in 27 (77 %) patients. **RV diastolic function by TDI:** Normal (Lat T E/A ratio > 1) in 6 (17 %) patients. Impaired relaxation (Lat T E/A ratio < 1) in 29 (83 %) patients.

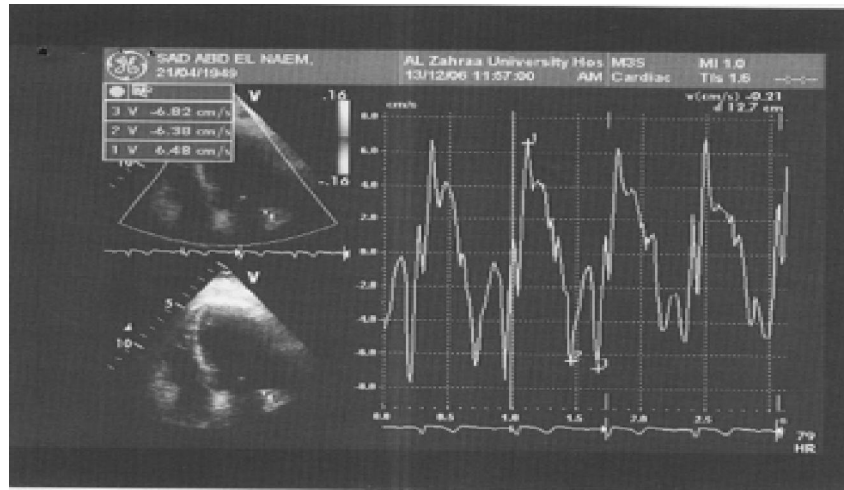


Fig. 4 Case no. 1 Echocardiography, Apical 4 chamber view, TDI, MAV at lateral point, S wave 6.4 cm./sec., E – 6.3 wave cm./sec. and A wave – 6.8 cm./sec.

Group II (patients with < 5 collateral pathways) 15 (30 %) patients: In this group ventricular functions were: **LV systolic function by M mode:** Normal (EF ≥ 55 %) in 7 (46.6 %) patients. Mild impaired (EF 45: < 55 %) in 3 (20 %) patients. Moderate impaired (EF 30: < 45 %) in 3 (20 %) patients. Severe impaired (EF < 30 %) in 2 (13.4 %) patients. **LV systolic function by 2D:** Normal (EF ≥ 55 %) in 4 (26.8 %) patients.

Mild impaired (EF 45:< 55 %) in 4 (26.8 %) patients. Moderate impaired (EF 30: < 45 %) in 6 (40 %) patients. Severe impaired (EF < 30 %) in 1 (6.4 %) patients. **LV systolic function by TDI:** Normal (average S wave > 8.25 cm/s) in 3 (20 %) patients. Impaired (average S wave < 8.25 cm/s) in 12 (80 %) patients. **LV diastolic function by pulsed Doppler over mitral flow:** Impaired relaxation (E/A ratio < 1)

in all patients of this group. **LV diastolic function by TDI:** LV diastolic function impaired (E_m/A_m ratio < 1) in all patients of this group. **RV systolic function by 2D:** Normal (fractional area change 32 – 60 %) in 12 (80 %) patients. Mild impaired (fractional area change 25 – 31 %) in 3 (20 %) patients. **RV systolic function by TDI:** Normal (Lat T S wave > 11.5 cm/s) in 5

(33.3 %) patients. Impaired (Lat T S wave < 11.5 cm/s) in 10 (66.7 %) patients. **RV diastolic function by pulsed Doppler over tricuspid flow:** Normal (E/A ratio >1) in 3 (20 %) patients. Impaired relaxation (E/A ratio < 1) in 12 (80 %) patients. **RV diastolic function by TDI:** Impaired relaxation (Lat T E /A ratio < 1) in all patients of this group.

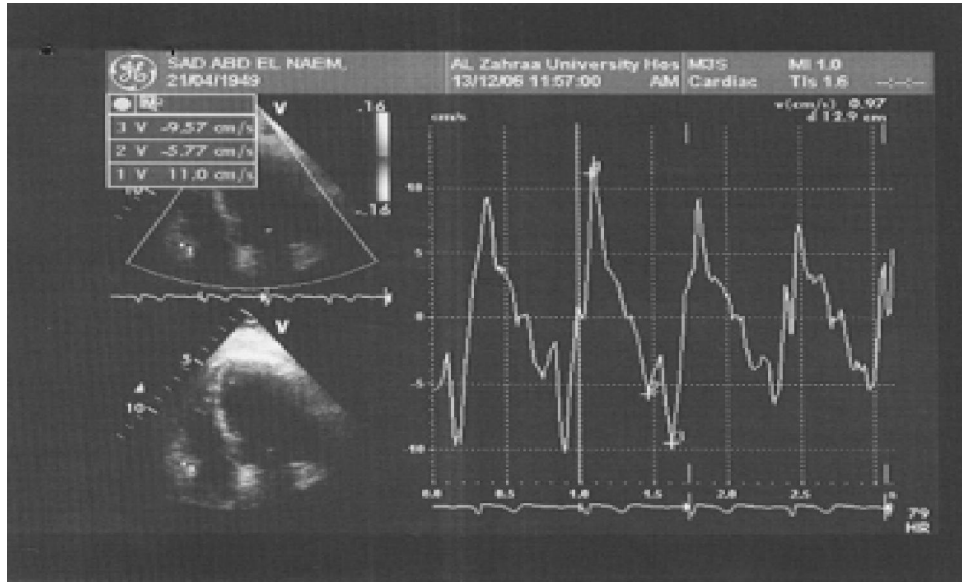


Fig. 5 Case no. 3 Echocardiography, Apical 4 chamber view, TDI, TAV at free point S wave 11 cm./sec., E – 5.77 wave cm./sec. and A wave – 9.57 cm./sec.

LV EF by M mode

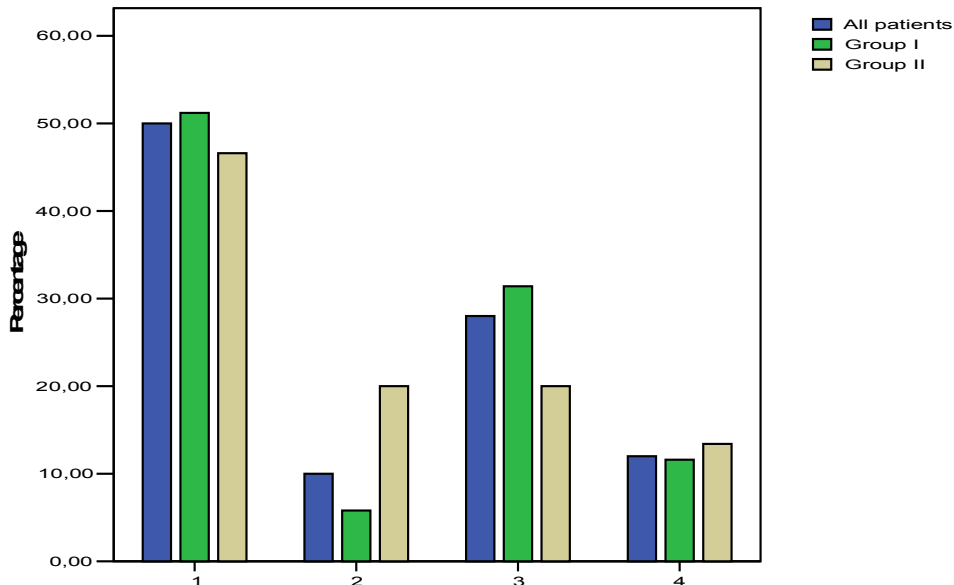


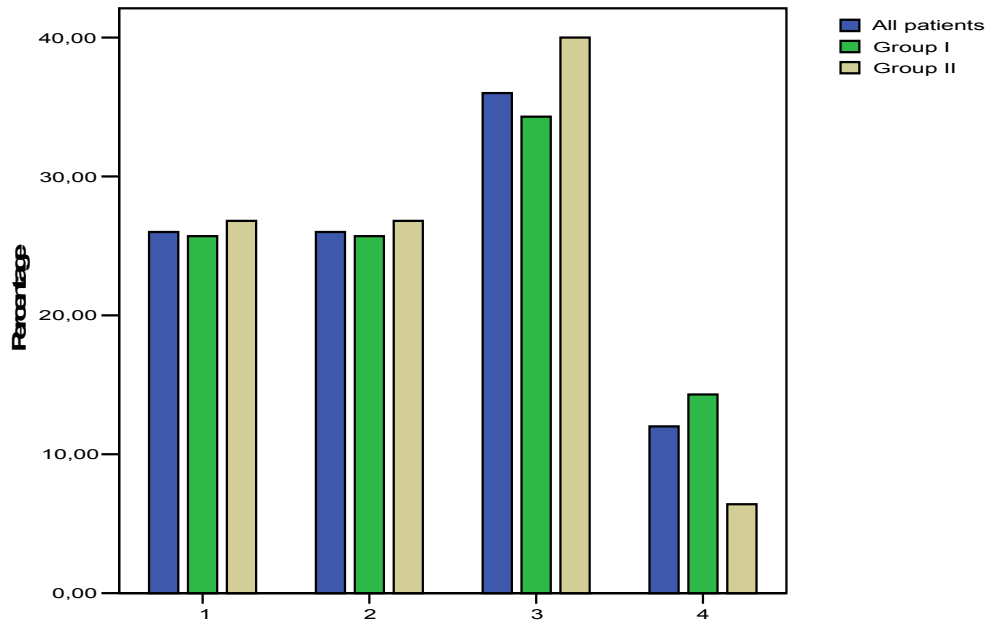
Fig. 6 LV functions by M mode 1- Normal, 2- Mild impaired, 3- Moderate impaired, 4- Sever impaired

Table 2. LV EF by M-mode P value =0.08 non-significant

	All patients (50)	Group I (35)	Group II (15)
Normal	(25) 50 %	(18) 51.2 %	(7) 46.6 %
Mild impaired	(5) 10 %	(2) 5.8 %	(3) 20 %
Moderate impaired	(14) 28 %	(11) 31.4 %	(3) 20 %
Severe impaired	(6) 12 %	(4) 11.6 %	(2) 13.4 %

LV EF by 2D**Table: 3LV EF by 2D P value 0.07 non- significant**

	All patients (50)	Group I (35)	Group II (15)
Normal	(13) 26 %	(9) 25.7 %	(4) 26.8 %
Mild impaired	(13) 26 %	(9) 25.7 %	(4) 26.8 %
Moderate impaired	(18) 36 %	(12) 34.3 %	(6) 40 %
Sever impaired	(6) 12 %	(5) 14.3 %	(1) 6.4 %

**Fig. 7 LV function by 2D 1- Normal 2- Mild impaired 3- Moderate impaired 4- Sever impaired****LV systolic function by TDI****Table 4. LV systolic functions by TDI P value =0.03 significant**

	All patients (50)	Group I (35)	Group II (15)
Normal	(19) 38 %	(16) 45.7 %	(3) 20 %
Impaired	(31) 62 %	(19) 54.3 %	(12) 80 %

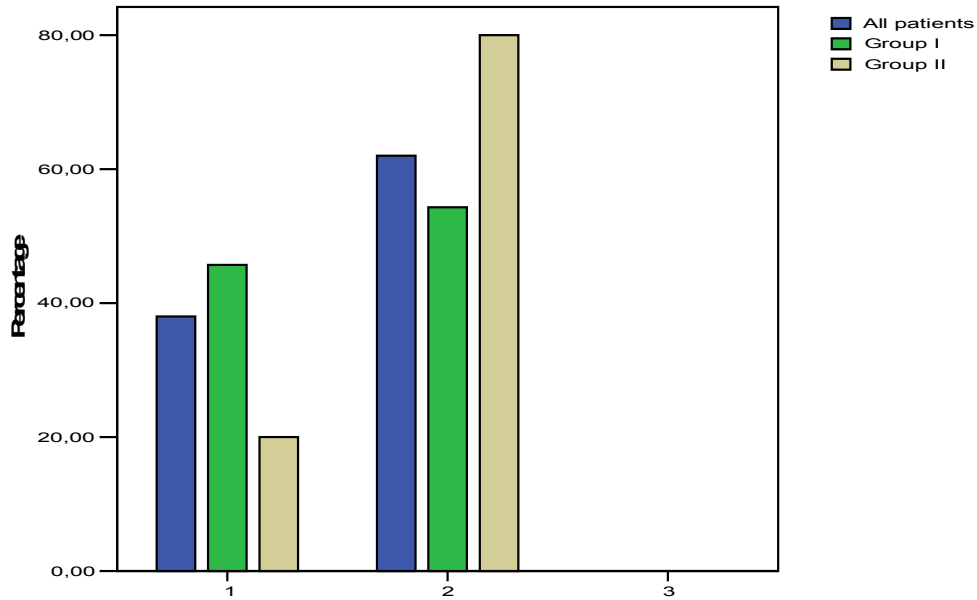


Fig. 8 LV systolic function by TDI 1- Normal 2- Impaired

LV diastolic function by PWD over mitral valve

Table (5) LV diastolic function by PWD over mitral valve

	All patients (50)	Group I (35)	Group II (15)
Normal	(3) 10 %	(3) 8.5 %	0
Impaired relaxation	(45) 82 %	(30) 85.5 %	(15) 100 %
Restrictive pattern	(2) 8 %	(2) 6 %	0

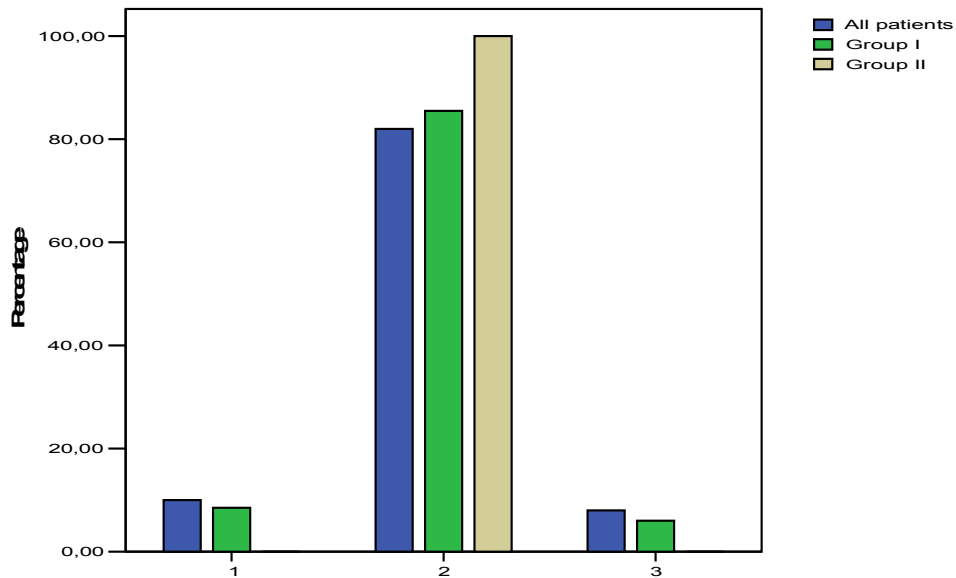
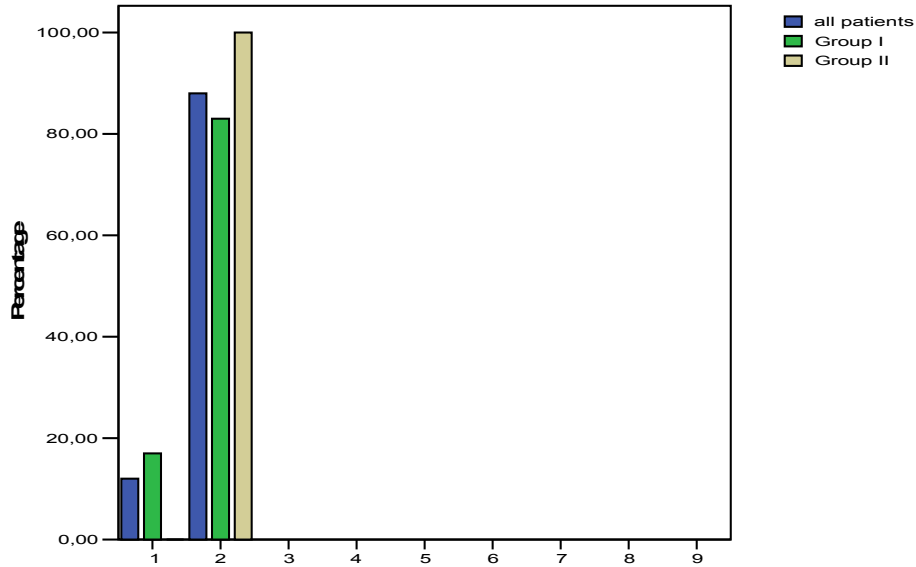


Fig. 9 LV diastolic function by PWD over mitral valve 1- Normal 2- Impaired relaxation 3- Restrictive pattern

LV diastolic function by TDI

Table (6) LV diastolic function by TDI

	All patients (50)	Group I (35)	Group II (15)
Normal	(6)12 %	(6)17%	0 %
Impaired	(44) 88 %	(29)83 %	(15) 100 %

**Fig. 10 LV diastolic function by TDI** 1- Normal 2- Impaired**RV systolic function by 2D****Table (7) RV systolic function by 2D**

	All patients (50)	Group I (35)	Group II (15)
Normal	80 %	80 %	80 %
Mild Impaired	20 %	20 %	20 %

P value= 0.08 non-significant

RV systolic function by TDI**Table 8. RV systolic function by TDI**

	All patients (50)	Group I (35)	Group II (15)
Normal	30 %	28.5 %	33.3 %
Impaired	70 %	71.5 %	66.7 %

P value 0.98 non-significant

RV diastolic function by PWD over tricuspid valve**Table: 9 RV diastolic function by PWD over tricuspid valve**

	All patients (50)	Group I (35)	Group II (15)
Normal	22 %	23 %	20 %
Impaired	78 %	77 %	80 %

RV diastolic function by TDI

Table 10. RV diastolic function by TDI

	All patients (50)	Group I (35)	Group II (15)
Normal	14 %	17 %	0 %
Impaired	86 %	83 %	100 %

LV systolic function by M mode and 2 D was nearly the same in both groups, but with TDI Left ventricular systolic function was better in patients of group I than patients in group II. LV diastolic function by PWD over mitral valve and by TDI was better in patients of group I than patients in group II. RV systolic function by 2D and TDI was nearly the same in both groups. RV diastolic function by PWD over tricuspid valve was nearly the same in both groups. RV diastolic function by TDI was better in patients of group I than patients in group II.

4. Discussion:

Despite decades of study, the functional role of the coronary collateral circulation remains controversial. Although myocardium supplied by well-developed collaterals may maintain normal resting perfusion, patients may still have myocardial ischemia, as manifested by anginal symptoms, ischemic (ECG) changes, or abnormal myocardial perfusion studies (14).

The purpose of this study is to evaluate the effect of presence of coronary collaterals on biventricular functions in patients with multivessel CAD using conventional echo and tissue Doppler study.

In this study, 50 arteriograms of patients with multivessels CAD selected and reviewed for coronary collaterals then global LV and RV systolic and diastolic functions examined by echo and tissue Doppler study. All patients in the study had coronary collaterals with varying number of collateral pathways and with varying grades of collaterals graded according to collateral connection grading (9). According to number of collateral pathways patients grouped into two groups, group I with ≥ 5 collateral pathways are 35 patients (70 %) and group II patients with < 5 collateral pathways are 15 patients (30 %), and by comparing global ventricular functions in both groups the following results obtained:

LV systolic function by M mode and 2 D was nearly the same in both groups, but with TDI LV systolic function was better in patients of group I than patients in group II. LV diastolic function by PWD over mitral valve and by TDI was better in patients of group I than patients in group II. RV systolic function by 2D and TDI was nearly the same in both groups. RV diastolic function by PWD over tricuspid valve was nearly the same in both groups. RV diastolic function by TDI was better in patients of group I than patients in group II.

These results corresponding to **David 1974** who indicated that effective collateral circulation helps preserve myocardial function in patients with CAD (15) In David's study coronary arteriograms and left ventriculograms were analyzed in 200 consecutive patients having significant CAD without valvular disease. All had at least 75% stenosis of at least one major vessel.

The various collateral pathways were noted and tabulated. The effect of these collaterals upon myocardial contractility was studied in 166 instances in which major coronary arteries were completely occluded and therefore entirely dependent upon collateral circulation to provide "runoff" flow in their distal segments. The size and degree of opacification of the distal segments, as seen angiographically, was taken as an indication of the adequacy of collateral circulation. It was considered adequate if the average caliber of the distal segment measured greater than 1.0 mm in diameter after correction for angiographic magnification. Where inflow to the distal segment was absent or so reduced that its average caliber was only 1.0 mm or less, collateral circulation was considered inadequate. By this criterion, collateral circulation was adequate in 86 instances and inadequate in the other 80.

The performance of the various regions of the LV was evaluated by studying contractility of the chamber as seen at ventriculography. It was considered mildly impaired if hypokinesia was present, and severely impaired if akinesia or dyskinesia occurred. Regional contractility of the affected myocardial segments in the groups with adequate and inadequate collateral circulation was then compared.

The vast majority of the 166 arteries under consideration in this section of the study were left anterior descending (LAD) and right coronary (RC) arteries. These arteries generally supply the anterior and diaphragmatic aspects of the LV, which are the areas best demonstrated by ventriculography in the RAO projection.

The LCX generally supplies only the posterolateral aspect of the ventricle, an area not well visualized in this projection. Therefore, a number of LCX lesions were excluded from consideration. These were included only when the LCX was dominant and supplied a large portion of the diaphragmatic aspect of the ventricle.

Figure (11) shows the incidence of normal contractility, mildly impaired contractility

(hypokinesia) and severely impaired contractility (akinesia - dyskinesia) in regions of the LV supplied by totally obstructed coronary arteries. The set of bars on the left reflects the regional contractility patterns of the entire group of 166.

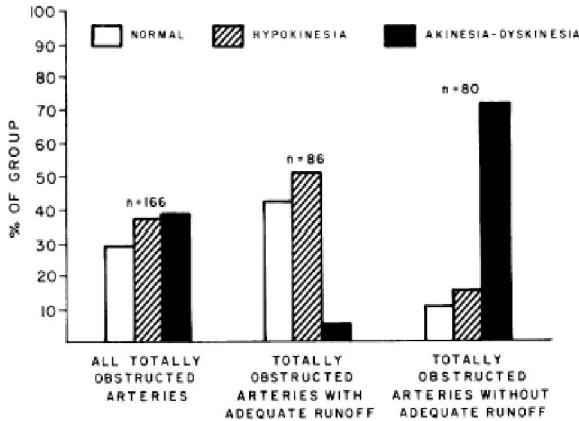


Fig. (11) (David 1974. from *Circulation* 1974; 50:831-837).

The other two sets reflect the same data with the original 166 divided according to whether collateral circulation and distal runoff were adequate or inadequate. Where collateralization and runoff were adequate, regional contractility was normal or mildly impaired in most instances. Where collateralization and runoff were inadequate, regional contractility was severely impaired in most instances. These results shows that adequate collaterals preserved regional ventricular function in the area supplied by the affected territory.

There are the following differences in David's study:

- Patients selected with total occlusion in one or major coronary arteries and in our study selected patients with multivessel coronary artery disease.
- Collaterals assessed by coronary angiography, anatomical site and also in our study collaterals assessed by coronary angiography, anatomical site.
- Coronary collaterals was considered adequate if the average caliber of the distal segment of TCO artery measured greater than 1.0 mm in diameter but in our study patients grouped according to number of collateral pathways.
- David studied regional functions of left ventricle by studying contractility of the myocardium as seen at ventriculography but in our study both right and left ventricular global systolic and diastolic functions assessed with echocardiography and with TDI.

Our study showed that coronary collaterals preserve ventricular functions at rest and this corresponds to **Eng et al, 1982**. Eng et al. selected thirty-one patients who had at least one totally occluded coronary vessel that did not result in myocardial infarction for his study. All patients underwent cardiac catheterization, left ventriculography was performed and the regional pattern of ventricular contraction was analyzed, then all patients had exercise thallium-201 MPI. Eng et al. showed the ability of coronary collaterals to provide adequate perfusion and preserve function at rest by demonstrating totally occluded coronary vessels without historical, electrocardiographic, or ventriculographic evidence of myocardial infarction. These non-infarcted, entirely collateral-dependent myocardial regions (NIECDMRs)- encountered in 28-50% of all total occlusions but collaterals couldn't preserve ventricular functions with exercise (16).

Our study differs with Eng et al. in the following:

- Eng et al. selected patients who had at least one totally occluded coronary artery but our study selected patients with multivessel coronary artery disease.
- Eng et al. studied regional functions of left ventricle by studying contractility of the myocardium as seen at ventriculography but in our study both right and left ventricular global systolic and diastolic functions assessed with echocardiography and with TDI.
- Eng et al. studied regional ventricular function with thallium-201 MPI and found that collaterals couldn't preserve ventricular functions with exercise but in our study ventricular function studied at rest only.

Goldberg et al, 1984 also support this idea. They showed that angiographically demonstrable coronary collateral vessels preserve myocardial function at rest, but disagreement exists regarding the importance of collaterals in preventing exercise-induced ischemic dysfunction. They used radionuclide cineangiography during exercise to assess the left ventricular (LV) functional effects of collateral vessels in 125 patients with at least 1 major coronary artery that had greater than or equal to 90% diameter stenosis but without prior myocardial infarction. Regional LV function, graded on a 4-point scale, worsened during exercise by at least 1 grade in 14 of 43 regions (33%) with good collaterals, and in 70 of 98 without good collaterals (p less than 0.001) (17).

Our results also corresponds with Seiler et al, 2002 who studied 50 patients with coronary artery disease and without myocardial infarction, regional systolic and diastolic LV function was determined using tissue Doppler ultrasound (TD) before and at the

end of a 60 second occlusion of a stenotic lesion undergoing percutaneous transluminal coronary angioplasty (PTCA) through a pressure guide wire. The study population was subdivided into a group with collaterals insufficient (n = 33) and one with collaterals sufficient (n = 17) to prevent ECG ST shifts suggestive of myocardial ischaemia during PTCA. Pulsed TD was performed from an apical window in the myocardial region supplied by the vessel being treated by PTCA. Pressure derived collateral flow index (CFI) was determined by simultaneous measurement of mean aortic (Pao) and distal intracoronary occlusive pressures (Poccl). Seiler et al found that at 60 seconds of occlusion, several parameters of systolic and diastolic TD derived LV long axis function were significantly different between the groups. Also, there was a significant correlation between regional systolic excursion velocity, early diastolic excursion velocity, regional isovolumetric relaxation time, and CFI and they concluded that during brief coronary artery occlusions, regional systolic and diastolic LV function is directly related to the amount of collateral flow to this territory (5).

Seiler et al studied regional systolic and diastolic left ventricular functions but our study on global systolic and diastolic ventricular functions, also Seiler et al assessed CFI which not available in our study due to economic factors and they studied left ventricular functions during brief coronary occlusion.

Our results also corresponds with **Aboul-Enein et al., 2004**. They studied the functional role of various angiographic grades for coronary collaterals in patients with single-vessel chronic total occlusion (CTO) and no prior myocardial infarction (MI). Their study included 56 patients with single-vessel CTO and no prior MI who underwent stress myocardial perfusion SPECT and coronary angiography. All patients had angiographic evidence of coronary collaterals. Patients were divided according to the Rentrop classification: Group I had grade 1 or 2 (25 patients) and group II had grade 3 collaterals (31 patients). Aboul-Enein et al found that Group I had a higher frequency of resting regional wall motion abnormalities on left ventriculography (52.6% vs. 19.2% [P value 0.019. In the setting of single vessel CTO and no prior MI, coronary collaterals appear to protect against resting perfusion defects. Excellent angiographic collaterals may prevent resting regional wall motion abnormalities but do not appear to protect against stress-induced perfusion defects (14).

Our study differs with Aboul-Enein et al. in the following:

- Aboul-Enein et al. selected patients who had at least one totally occluded coronary artery but our

study selected patients with multivessel coronary artery disease.

- Aboul-Enein et al studied resting regional functions of LV by studying contractility of the myocardium as seen at ventriculography but in our study both right and LV global systolic and diastolic functions assessed with Echo and with TDI.

- Aboul-Enein et al studied regional ventricular function with stress myocardial perfusion SPECT and found that collaterals couldn't preserve ventricular functions with exercise but in our study ventricular function studied at rest only.

Our results also corresponds with **Jeroen et al, 2005**, Jeroen et al examined the prognostic significance of coronary collaterals in patients with coronary artery disease. In their study, baseline coronary angiograms were reviewed for 244 patients who underwent PTCA, the presence and extent of coronary collaterals on each baseline coronary angiogram were defined and visually assessed using Rentrop's classification (grade 0, no filling of collateral vessels; grade 1, filling of collateral vessels without any epicardial filling of the recipient artery; grade 2, partial epicardial filling by collateral vessels of the recipient artery; and grade 3, complete epicardial filling by collateral vessels of the recipient artery). The coronary collateral presence was defined as the presence of minimal or well developed collaterals (Rentrop grade 1, 2, or 3) (18).

They considered the presence of coronary collaterals as a measure of a patient to form collaterals in vascular areas other than the heart, such as the brain and peripheral circulation. Therefore, they defined the cardiovascular outcome as a composite of cardiovascular death, nonfatal MI, nonfatal stroke, any cardiovascular intervention, or any amputation of lower extremities. The outcome of interest was defined as the first cardiovascular event occurring during follow-up, median follow up for 2.6 years (range 0.2 to 4.6).

Their results indicate that, overall, in patients with ischemic cardiac disease, the presence of coronary collaterals may represent a prognostic indicator of adverse cardiovascular outcome, especially if present to only a limited extent (Rentrop grade 1), rather than a favorable sign. However, in patients with relatively low cardiac risk, the presence of well-developed coronary collaterals may protect against subsequent cardiovascular or cardiac events. It is likely that in these relatively low-risk patients, the presence of well-developed collaterals marks sufficient collateral blood flow to adequately counterbalance the adverse effects of CAD. However, particularly in relatively high-risk patients, the presence of poor coronary collaterals (Rentrop grade 1) may indicate such limited collateral function that it

does not compensate for the disease severity, thus putting the patient at an even greater risk. In relatively high-risk patients, the presence of well-developed collaterals may also mark better myocardial perfusion, but the more adverse affects of IHD tend to prevail. So the fate of a patient will ultimately be determined by the balance between the disease severity and the presence and extent of the coronary collaterals.

Our study differ from Jeroen et al. as we studied effect of coronary collaterals on ventricular functions but Jeroen et al studied the prognostic effect of coronary collaterals.

Most of the previous studies used ventriculography to study ventricular function but echo which used in our study has been the most popular since it is a non-invasive technique that can provide information on the structure of the heart as well as on its function. In addition it can help assessing the etiology of the heart condition and improve the understanding of the underlying pathophysiology, and at the same time it can be repeated as many times as needed with no discomfort for the patient (19).

Our study and these previous studies showed that well developed coronary collaterals can preserve resting ventricular functions but couldn't prevent exercise induced dysfunction.

Summary: Coronary collaterals or "natural bypasses" are anastomotic connections without an intervening capillary bed between portions of the same coronary artery and between different coronary arteries, these connections potentially offers an important alternative source of blood supply when the original vessel fails to provide sufficient blood.

Coronary collaterals protect the myocardium in patients with CAD. They limit myocardial ischemia during coronary occlusion. Well-developed coronary collaterals may minimize the infarct area and predict the presence of viable myocardium in patients with a history of myocardial infarction.

Coronary collaterals present since birth but they are very small with a lumen diameter of 20 to 350 μm and lengths ranging from 1 or 2 cm to 4 or 5 cm.

There are many factors affecting the growth and development of coronary collaterals, of these factors: environmental factors and genetic factors.

Assessment of coronary collaterals

1. Angiographic methods 1- Anatomical location. 2- Rentrop method. 3- Collateral connections grading. 4- Washout collaterometry.

2. Intracoronary pressure or Doppler sensor measurements: The purpose of this study is to evaluate the effect of presence of coronary collaterals on biventricular functions in patients with multivessel coronary artery disease using conventional echocardiography and tissue Doppler study.

50 patients with multivessel coronary artery disease, collaterals assessed angiographically by their anatomic location, and by collateral connections grading (CC grade 0: no continuous connection, CC1: threadlike continuous connection, CC2: side branch-like connection).

Ventricular functions (left and right ventricular functions, global systolic and diastolic functions) assessed by:

Echocardiography using the following modalities of echo:

1- M mode echo 2-2D echo 3- Colour Doppler echo 4-CW and PW Doppler.

Tissue Doppler imaging: Mitral annular velocity (lateral, septal, anterior and inferior) measured by pulsed wave tissue Doppler and average S , E_m and A_m waves assessed, also tricuspid annular velocity (septal and lateral) S , E and A waves measured to asses global left and right ventricular functions.

Patients grouped into two groups and ventricular functions compared in both groups each other and to all patients:

Group I patients with ≥ 5 collateral pathways.

Group II patients with < 5 collateral pathways.

Conclusion:

Coronary collaterals can preserve resting global left and right ventricular systolic and diastolic functions which is not detected with conventional echocardiography and detected with TDI. These findings are important especially to patients not eligible for PCI or CABG.

References

1. Seiler C. The human coronary collateral circulation. *Heart* 2003;89:1352–1357.
2. Popma JJ and Bittl J. Coronary angiography and intravascular ultrasonography. In: Braunwald E, Zipes DP, Libby P, eds. *Heart Disease: A Textbook of Cardiovascular Medicine*. Philadelphia: W.B. Saunders Company; 2001: 387–418.
3. Sasayama S and Fujita M. Recent insights into coronary collateral circulation. *Circulation*. 1992; 85: 1197–1204.
4. Fukai M, Ii M, Nakakoji T, et al. Angiographically demonstrated coronary collaterals predict residual viable myocardium in patients with chronic myocardial infarction: a regional metabolic study. *J Cardiol*. 2000; 35: 103–111.
5. Seiler C, Pohl T, Lipp E, Hutter D, Meier B. Regional left ventricular function during transient coronary occlusion: relation with coronary collateral flow. *Heart* 2002;88:35–42.

6. St John SM, Pfeffer MA, Plappert T, et al. Quantitative two-dimensional echocardiographic measurements are major predictors of adverse cardiovascular events after acute myocardial infarction. The protective effects of captopril. *Circulation* 1994; 89: 68-75.
7. Simpson IA. Echocardiographic assessment of long axis function: a simple solution to a complex problem? *Heart* 1997;78:211-12.
8. Derumeaux G, Michel O, Joseph L, Xavier A, Yves M, Alain C and Brice L, Doppler Tissue Imaging Quantitates Regional Wall Motion During Myocardial Ischemia and Reperfusion. *Circulation*. 1998;97:1970-1977.
9. Gerald S, Markus F, Stephan H, Friedhelm K, Ralf S, Barbara M, Richartz and Hans R. Angiographic Assessment of Collateral Connections in Comparison With Invasively Determined Collateral Function in Chronic Coronary Occlusions. *Circulation*. 2003;107.
10. Lang RM, Vignon P, Weinert L, Bednarz J, Korcarz C, Sandelski J, Koch R, Prater D and Mor-Avi V. Echocardiographic quantification of regional left ventricular wall motion with color kinesis. *Circulation*. 1996;93: 1877-1885.
11. Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, Laskey WK, et al. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart: a statement for healthcare professionals from the cardiac imaging committee of the council on clinical cardiology of the American Heart Association. *Circulation* 2002;105:539-42.
12. Roberto et al., ASE committee recommendations. *J Am Soc Echocardiogr* 2005;18:1440-1463.
13. Galiuto L, Ignone G and DeMaria AN. Contraction and relaxation velocities of the normal left ventricle using pulsedwave tissue doppler echocardiography. *Am J Cardiol* 1998; 81:609-14.
14. Aboul-Enein F, Saibal K, Sean W, Maria S, Aiden A, Raj, John D, Neal E and Daniel S. Influence of Angiographic Collateral Circulation on Myocardial Perfusion in Patients with Chronic Total Occlusion of a Single Coronary Artery and No Prior Myocardial Infarction. *J Nucl Med* 2004; 45:950-955.
15. David C. Pathways and Functional Significance of the Coronary Collateral Circulation. *Circulation* 1974;50:831-837.
16. Eng C, Randolph E, Steven F, Doris A, Augusto D, Jay M, Michael V and Richard G. Coronary Collateral Function During Exercise. *Circulation* 1982; 66, 2.
17. Goldberg HL, Goldstein J, Borer JS, Moses JW and Collins MB. Functional importance of coronary collateral vessels. *Am J Cardiol*. 1984, 1;53:694-9.
18. Jeroen K, Peter P.T., Marianne C., Diederick E, and Yolanda DG. Prognostic Significance of Coronary Collaterals in Patients With Coronary Heart Disease Having Percutaneous Transluminal Coronary Angioplasty. *Am J Cardiol* 2005;96:390 -394.
19. St John SM, Pfeffer MA, Plappert T, et al. Quantitative two-dimensional echocardiographic measurements are major predictors of adverse cardiovascular events after acute myocardial infarction. The protective effects of captopril. *Circulation* 1994; 89: 68-75.

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