Transthoracic Color Doppler Flow Imaging As A Non Invasive Tool In The Assessment of Left Internal Mammary Artery Graft Patency In Patients With Post Coronary Artery Bypass Graft Surgery Anginal Symptoms

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ABSTRACT

Background: *The use of left internal mammary artery (LIMA) to bypass the left anterior descending artery (LAD) is the gold standard of coronary artery revascularization. In patients who suffer from post CABG anginal symptoms, cardiac catheterization is till now considered the gold standard for the assessment of graft patency. Evaluation of LIMA patency by a noninvasive method may be an alternative reliable tool in these patients.* ***Objective:*** *To 1- determine the applicability of transthoracic color Duplex scan of LIMA graft for detection of stenosis and assess its patency non-invasively, 2- to study the Duplex characteristics of left internal mammary artery graft to left anterior descending artery.* ***Methodology:*** *The present study included 26 patients who performed coronary angiography due to post CABG anginal symptoms. On the basis of coronary angiography patients were classified into two groups:* ***Group I*** *which included 11 patients with normal or insignificant diseased LIMA graft and/or distal vascular bed, and group II which included 15 patients with diseased LIMA graft and/or distal vascular bed. All patients were subjected to clinical evaluation, laboratory investigations, ECG, echocardiographic assessment, coronary angiography and Duplex sonography of the LIMA grafts within one week of the coronary angiography. Receiver Operator Characteristics (ROC) curves were used to detect cut-off points for Resistivity index and Peak Systolic to End Diastolic velocity ratio.* ***Results****: The two groups were comparable regarding the clinical presentation, risk factors, electrocardiographic findings and echocardiographic assessment of global contractility. We were able to identify LIMA graft blood flow in all the patients through parasternal approach. Patients in group II had a statistically significant higher resistivity index and higher peak systolic to end diastolic velocity ratio than group1 (P<0.001,P<0.05 respectively.).A statistically significant different pattern of flow consisting of a predominant systolic with minimal or absent diastolic flow was identified in group II,(P<0.001). The ROC curve showed a cut off point for the resistivity index (0 .7609) and for the systolic to diastolic ratio of (4.16262).* ***Conclusion:*** *We could identify a LIMA graft pattern of flow that is characteristic to diseased LIMA or diseased distal vascular bed consisting of a predominant systolic with minimal or absent diastolic flow .The resistivity index and peak systolic to end diastolic velocity ratio had an important role in prediction of LIMA graft patency such that if resistivity index is more than 0.76 and/or peak systolic to end diastolic velocity ratio more than 4.16 , one may expect the picture of diseased LIMA graft and or diseased distal vascular bed. Transthoracic color duplex scan of LIMA graft is an applicable non-invasive and easily reproducible tool for prediction of LIMA graft stenosis in patients with post CABG anginal symptoms*

Keywords*: Left internal mammary artery (LIMA), Color Duplex , Coronary Artery Bypass Graft "CABG".*

INTRODUCTION

Coronary artery bypass surgery (CABG) is an important cardiovascular surgical therapy for ischemic heart disease, there are nearly 1.000.000 CABG operations performed per year all over the world. [1,2]

CABG operation improves survival rates for patients with significant left main stenosis, three-vessel disease with abnormal left ventricular function, patients with two or three-vessel disease with >75 % stenosis in the proximal LAD and even single critical proximal LAD stenosis with impaired left ventricular function specially in diabetics.[3]

Grafts used in CABG operations are:

- *Venous grafts:* Saphenous vein grafts.
- *Arterial grafts;* Left internal mammary artery (LIMA), right internal mammary artery (RIMA), radial artery and other rarely used arterial conduits including the right gastroepiploic artery, the inferior epigastric artery and the sub scapular and ulnar arteries.[(1)]

The use of LIMA to bypass the left anterior descending artery (LAD) is the gold standard of coronary artery revascularization. The better size match with the coronary artery, the single anastomosis and the biochemical and physical qualities of this conduit for the most important coronary artery in the human circulation, the LAD, are clear advantages over the saphenous vein graft.[(4)]

Coronary bypass surgery is highly effective in the relief of angina and results in improved quality of life. Approximately 80 percent of patients are free of angina at 5 years and 63 percent at 10 years, but by 15 years only about 15 percent are free of an ischemic event.[(2)]

An estimated 571,000 coronary vessel bypass operations were performed in the United States in 1999. Angina recurred within 1 year in 24% of these patients and within 6 years in more than 40%. A total of 25% of grafts are found to be occluded within 5 years after surgery. Symptoms recurred because of the progression of disease in the coronary arteries and de novo disease in the grafts used [(5)]

The significant predictors of post-operative angina are preoperative angina, use of vein grafts only, previous myocardial infarction, incomplete revascularization, female gender, smoking and younger age. The presence of angina in the first postoperative year was associated with more frequent myocardial infarction.[(5)]

The evaluation of chest pain in patients with recurrent anginal symptoms after coronary artery bypass surgery may represent a problem because symptoms are often atypical and the result of provocative tests may be dubious or non diagnostic.[(6)]

Atherosclerosis may involve the IMA, but is rare, and the late development of atherosclerotic lesions in an IMA graft that is known to be patent is extremely rare[(3)]. Patency rates of LIMA to LAD artery grafts are more than 90% even 10 to 20 years after the operation[(7)]

Although angiography has until now been considered as the "golden standard" for the assessment of bypass grafts patency, the diffuseness of the atherosclerotic process - which in many patients decreases the luminal diameter of the entire vessel - may lead to an underestimation of the severity of a more focal lesion. More over, the calcified, tortuous, and diffusely diseased coronary arteries and degenerated bypass grafts hinders precise delineation of the lesions. There is a group of patients at increased risk for complications after coronary angiography such as: those above 70 years, congestive heart failure and renal failure. Accordingly, other imaging tools for evaluation of graft patency would be useful. Assessment of LIMA graft patency currently requires an invasive investigation "conventional angiography". A non invasive method of assessment would be useful in patients with recurrence of anginal symptoms after coronary artery bypass graft surgery'[(4)]

Duplex sonography of IMA grafts has increasingly gained importance over the last few years as a non-invasive method for post-operative assessment of function because this vessel is increasingly used for revascularization of LAD.

All LIMA grafts to LAD can be identified using the color Doppler (with a sensitivity of 100 % and specificity of 85 %), as it is possible to localize the origin of the LIMA (close to the chest wall), then to measure the flow (which changes after the anastomosis from triphasic pattern to. forward flow during systole and diastole). Velocity measurements are calculated and interpreted allowing identification of normally functioning grafts or those with different degrees of stenoses[(4)]

Aim of the work:

The aim of this study is

1. To assess the patency of the left internal mammary artery graft non-invasively by transcutaneous duplex ultrasound.
2. To study the Duplex characteristics of left internal mammary artery graft to left anterior descending artery.

MATERIAL & METHODS

The current prospective study includes 26 patients who had performed left internal

mammary artery grafting to the left anterior descending artery and then underwent coronary angiography because of recurrence of anginal symptoms, Patients were classified into two groups according to their angiographic findings:

- **Group I: 11** patients with normal or insignificant diseased LIMA graft and /or distal vascular bed.
- **Group II: 15** patients with diseased LIMA graft and/or distal vascular bed.

Group II was then sub-classified into:

II-a: Comprising **7** diseased LIMA graft patients

II-b: Comprising **8** diseased distal vascular bed patients

Exclusion criteria included patients at increased risk for complications related to coronary angiography (e.g: old "age > 70 yrs", congestive heart failure NYHA functional class III or IV, renal failure), technically difficult window for duplex examination (e.g morbid obesity, chronic obstructive pulmonary disease ...etc) and inadequate visualization or the LIMA by angiography (e.g difficult procedure, aberrant origin of the graft ...etc).

Each patient was subjected to the following:

1. **Detailed history taking and physical examination** emphasizing cardiovascular risk factors (smoking, hypertension, diabetes mellitus, hyperlipidaemia, family history of ischemic heart disease), *indications* for post-CABG coronary angiography (stable or unstable angina, myocardial infarction, positive stress test….etc) and CABG data including date, type and numbers of grafts
2. **Twelve leads surface electrocardiogram**.
3. **Echocardiographic assessment.**
4. **Coronary angiography:** Catheterization of the LIMA was performed using a specially designed LIMA catheter, lesions >70% stenosis by QCA analysis were considered haemodynamically significant. All patients signed a written consent for their approval to perform the coronary angiography and share in the study.
5. **Duplex sonography of the LIMA grafts** within one week of coronary angiography using Hewlett-Packard Philips 5000, equipped with 5 and 7 MHZ phased pulsed array and linear transducers. Peak systolic velocity, end diastolic velocity, peak systolic to end diastolic ratio and resistivity index were measured

Statistical Analysis

Data were collected, tabulated and fed to a commercially available computer system Statistical Package for the Social Sciences (SPSS version 11.01 for Windows). The two groups were compared using the chi-square test for categorical variables and independent samples t-test for continuous variables with equal variance. Receiver Operator Characteristics (ROC) curves were used to detect cut-off points for Resistivity index and Peak Systolic to End Diastolic velocity ratio. Data was expressed as percent for discrete variables and as mean value ±SD for continuous variables. Statistical significance was accepted for all p values < 0.05.

RESULTS

Twenty six patients (mean age: 57±9 years) undergoing coronary angiography because of recurrent anginal symptoms were prospectively included into this study. All patients had coronary artery bypass graft surgery using left internal mammary artery graft to the left anterior descending artery .They were classified into two groups according to their angiographic findings:

- **Group** I: included 11 patients with an angiographically normal LIMA graft and normal distal vascular bed (LAD distal to the site of anastomosis).
- **Group** II: included 15 patients with an angiographically diseased LIMA graft and *l or* distal vascular bed.

Baseline characteristics of all patients are given in table 1. The two groups didn't show any statistically significant difference regarding the clinical presentation, risk factors, electrocardiographic findings and echocardiographic assessment of global contractility (table 2)

Table (1): Baseline Characteristics of both groups

	Group I (n=11)	*Group II (n=15)*	*P value*
Age (mean, yrs)	55.5 ± 4.95	56.93 ± 7.1	**NS**
Male gender	8 pts (72.73%)	13 pts (86.67%)	**NS**
Smoking	7 pts (63.64%)	9 pts (60%)	**NS**
Hypertension	6 pts (54.55%)	10 pts (66.67%)	**NS**
Diabetes mellitus	6 pts (54.55%)	9 pts (60%)	**NS**
Dyslipidemia	5 pts (45.45%)	9 pts (60%)	**NS**
Family history	4 pts (36.36%)	7pts (46.67)	**NS**

Table (2): Clinical presentation, electrocardiographic and echocardiographic findings in both Gps

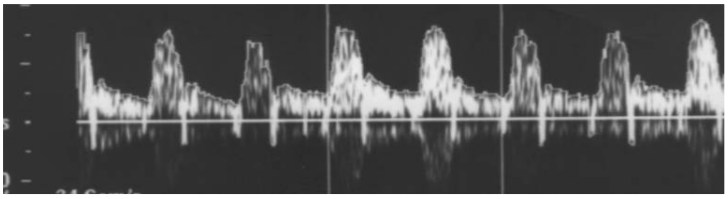
Mode of presentation	*Group I (n=11)*	*Group II (n=15)*	*P value*
Stable angina	6 pts (54.55%)	8 pts (53.33%)	**NS**
ACS	5 pts (45.45%)	7 pts (46.67%)	**NS**
ECG			
Ant. ST changes	5 pts (45.45%)	6 pts (40%)	**NS**
Ant.Q wave	6 pts (54.55%)	9 pts (60%)	**NS**
Echocardiographic left ventricular systolic function			
*Normal	3 pts (27.27%)	3 pts (20%)	**NS**
**Mild impairment	2 pts (18.18%)	4 pts (26.66%)	**NS**
***Moderate impairment.	5 pts (45.45%)	7 pts (46.6%)	**NS**
****Severe impairment.	1 pt (9.09%)	1 pt (6.6%)	**NS**

** EF > 60% ** EF = >45-60% *** EF = 30 – 45% **** EF < 30%*

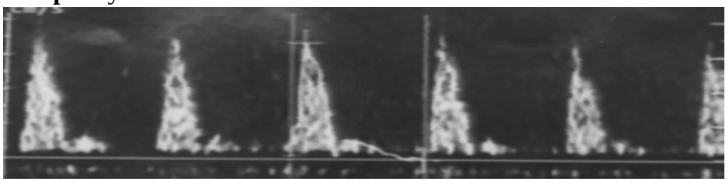
We were able to identify two patterns of LIMA Doppler flow through the parasternal approach. Table 3 and Fig 1 demonstrated the LIMA graft blood flow in all patients through parasternal approach and showed that there was a significant difference in Doppler flow pattern between the two groups (p<.0.001). All patients in group I had systolic and high diastolic flow while all patients in group II had systolic flow with minimal or absent diastolic flow.

Table (3): Doppler flow pattern in both groups

	Group I (n=11)	*Group II (n=15)*	*P value*
Systolic & high diastolic	100%	0%	0.000
Systolic & minimal or absent diastolic	0%	100%	0.000



Group I: systolic and diastolic flow



Group II: systolic and minimal diastolic flow

Fig (1): Doppler flow pattern in both groups

There was no statistically significant difference in peak systolic velocity between both groups. Patients in group I had a statistically significant increase in mean end diastolic velocity when compared to group II (p=0.001). Patients in group II had a statistically significant increase in the resistivity index and mean peak systolic to end diastolic velocity than group1 (p<0.001, p<0.05 respectively), as shown in table 4, Fig 2,3,4.

Table (4): Peak systolic (PSV) and end diastolic (EDV) velocities, resistivity index (RI) and peak systolic to end diastolic ratio (S/D) calculated in both groups

	Group I	***Group II***	***P value***
Peak systolic velocity (cm/sec)	49.97±22.53	44.47±28.18	**NS**
End diastolic velocity (cm/sec)	14.5±4.87	6.33±5.35	**0.001**
Resistivity index	0.69±0.07	0.88±0.09	**0.000**
Peak systolic to end diastolic ratio	3.39±0.75	5.76±3.31	**0.029**

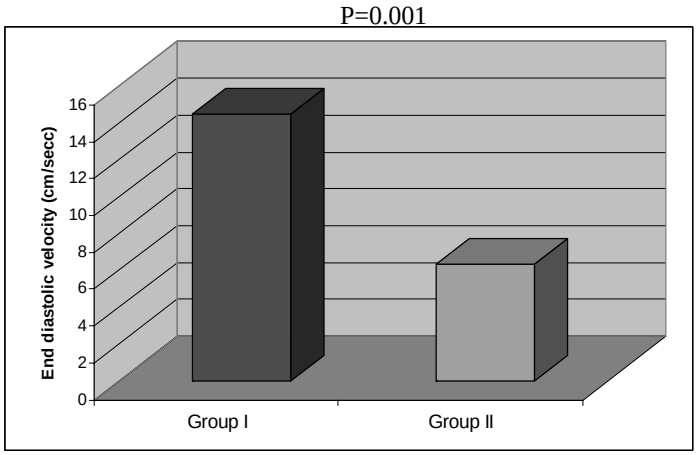


Fig. 2: End Diastolic Velocity in both groups

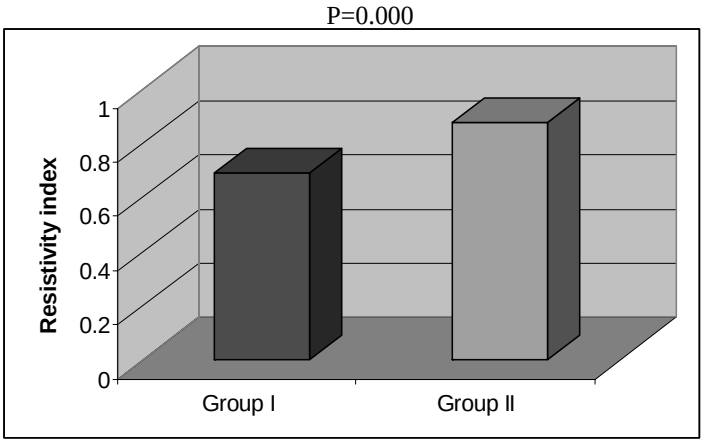


Fig. 3: Resistivity Index in both groups

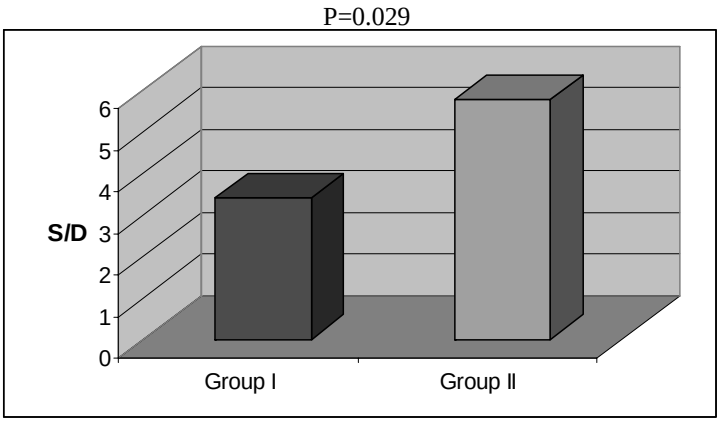


Fig. 4: Peak systolic to end diastolic velocity ratio (S/D) in both groups

Group II (patients with an angiographically diseased LIMA graft or distal vascular bed) was then sub-classified into: **II-a:** Diseased LIMA graft; which included **7** patients .and subgroup **II-b** which included the diseased distal vascular bed patients and included 8 patients. None of the study patients were found to have combined disease in LIMA and distal vascular bed.

We found that neither the pattern of flow nor the velocity indices were able to differentiate between significant diseases of LIMA graft versus significantly diseased distal vascular bed ($p>0.05$ for all), table 5.

Table (5): Peak systolic (PSV) and end diastolic (EDV) velocities, resistivity index (RI) and peak systolic to end diastolic ratio (S/D) calculated in subgroups a & b of group II

	Group II:a	***Group II:b***	***P value***
Peak systolic velocity(cm/sec)	40.81±20.94	51.23±35.08	NS
End diastolic velocity(cm/sec)	6.69±4.95	7.43±7.43	NS
Resistivity index	0.84±0.11	0.87±0.09	NS
Peak systolic to end diastolic ratio	5.93±3.66	5.51±3.33	NS

Receiver operator characteristics (ROC) plots were used to determine the optimum cut off point of resistivity index and peak systolic to end diastolic velocity for the prediction of LIMA graft patency (Fig. 5,6).

The ROC curve showed a cut off point of (0.76) for the resistivity index; above this value we can predict significant stenosis of LIMA graft or distal vascular bed. Lower values predict absence of significant stenosis of LIMA graft or distal vascular bed. Systolic to diastolic ratio showed a cut off point of (4.16). Above this value we can predict significant stenosis of LIMA graft or distal vascular bed. Lower values predict absence of significant stenosis of LIMA graft or distal vascular bed. If the resistivity index is more than 0.76 and the peak *systolic* to end diastolic velocity ratio is more than 4.16, one may predict the picture of diseased LIMA graft and or diseased *distal* vascular bed more confidently.

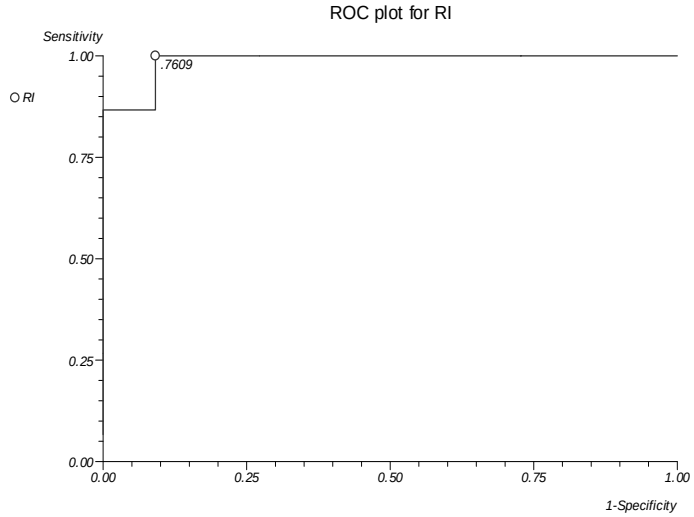


Figure (5): Receiver operator characteristics (ROC) plot showing the optimum cut off level of RI in predicting LIMA graft patency. The shown cut off = 0.7609 cm/sec

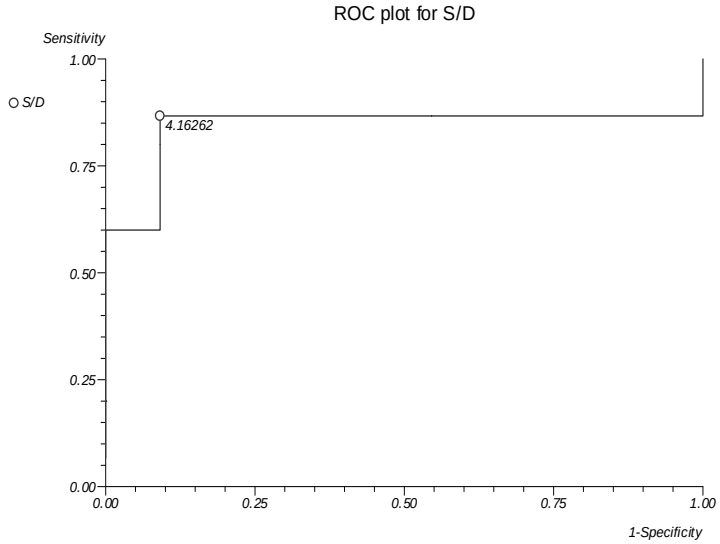


Figure (6): Receiver operator characteristics (ROC) plot showing the optimum cut off level of S/D ratio in predicting LIMA graft patency. The shown cut off = 4.16262

DISCUSSION

The use of left internal mammary artery (LIMA) to the left anterior descending artery (LAD) is the gold standard of coronary artery revascularization. Duplex ultrasound is a noninvasive, rapid, and easily reproducible tool for assessment of LIMA graft patency. In this work, we aimed to assess the utility of Duplex scan to evaluate the patency of left internal mammary artery graft non-invasively and to study the pulsed Doppler characteristics of LIMA graft to left anterior descending artery.

We used the parasternal approach to identify and assess LIMA graft and get the flow pattern, as the supraclavicular approach was found to be difficult and time consuming.

We were able to identify a LIMA graft

pattern of flow that is characteristic to the normal LIMA graft and a normal distal vascular bed through the parasternal approach; this pattern consists of predominant systolic and high diastolic flow (group I). In patients with diseased LIMA or diseased distal vascular bed we could identify a different pattern of flow that consists of a predominant systolic with minimal or absent diastolic flow (group II).

In concordance with our results, James J. Crowley et al.[4] mentioned that in normal coronary arteries, most blood flow occurs during diastole because myocardial compression during systole increases distal vascular resistance. The blood flow patterns and velocities (detected through supraclavicular approach) in patients with normal LIMA grafts or moderate stenoses (<70%) were similar to those in the normal LAD patients (dominant flow during diastole or diastolic predominance), suggesting that LIMA grafts allow smooth flow into the recipient artery without the development of turbulence. Blood flow in ungrafted internal mammary arteries occurs mainly during systole similar to flow in peripheral arteries .An occluded LIMA graft acts as a blind-ended tube similar to an ungrafted LIMA, resulting in loss of the diastolic component of coronary flow

R. Driever et al.[9] also found that the flow profile of LIMA graft changes postoperatively after anastomosis of the LIMA with the LAD from a dominant systolic flow pattern to a mainly diastolically determined velocity profile (detected through supraclavicular approach).

Luigi De Simone, Pio Caso et al.[10] found that ,in all cases, the analyzed artery shows a biphasic pattern of blood flow corresponding to the systolic and diastolic waves. Mammary graft flow shows a gradual transition in its pattern from a predominant systolic velocity proximally (at the origin from the subclavian artery) to a predominant diastolic velocity distally.

We found that the resistivity index (which wasn't used in all available previous studies) and peak systolic to end diastolic velocity ratio had an important role in prediction of LIMA graft patency. They were significantly lower in group I (healthy vessels) than in group II (diseased vessels). Optimum cut-off values were determined (0.76 and 4. 16 respectively). If the resistivity index is more than 0.76 and/or peak systolic to end diastolic velocity ratio more than 4.16, one may expect the picture of diseased LIMA graft and or diseased distal vascular bed

End-diastolic velocity was significantly higher in group I (healthy vessels) than group II (diseased vessels) but an optimum cut off point would be of no significance because an end diastolic velocity as a single value may be affected by other factors like low cardiac output and hypotension, so it must be correlated to other value (e.g: systolic velocity) in order to be reliable in comparison between both groups.

This was also detected by R. Driever et al.[11], who found that in patients with good revascularization results, a mean ratio of systolic to diastolic velocity of 1.38 was detected and in the case of bad revascularization results with stenosed or closed bypass vessels the ratio was 3.85. They concluded that proximal LIMA occlusion leads to a complete loss of Doppler signal, while in distal obstruction, the diastolic flow is reduced.

Conclusion:

Transthoracic color duplex scan of LIMA graft is possible and applicable. It's a simple, rapid, cost effective, non-invasive and an easily reproducible tool for prediction of LIMA graft stenosis in patients who underwent coronary artery bypass graft operation and presenting with anginal pains. Patients who had well functioning LIMA graft and distal vascular bed with no significant stenoses had a distinctive pattern of Doppler flow; higher end diastolic velocity, lower resistivity index and lower peak systolic to end diastolic velocity ratio. Patients who had a diseased LIMA graft and/or distal vascular bed had a different pattern of Doppler flow; lower end diastolic velocity, higher resistivity index and higher peak systolic to end diastolic velocity ratio. The resistivity index and peak systolic to end diastolic velocity ratio have a reliable predictive value in the detection of diseased LIMA graft and/or distal vascular bed.

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