ORIGINAL PAPER

Non Invasive Detection of Coronary Sinus Flow Changes Over Time After CABG

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ABSTRACT

Background: Coronary New blood in the vascular bed after Coronary Artery Bypass Grafting (CABG) may represent a turning point between ischemia and normal tissue nutrition. Its quantification can help to better understand coronary artery hemodynamics after revascularization. Objective: Quantification of coronary sinus blood flow changes over time after Coronary Artery Bypass Grafting (CABG) using Transthoracic Echocardiography (TTE). Methods: Prospective basic research, with repeated measurements on hospital sample of 61 patients whom CABG was conducted. We performed TTE recordings to measure CS flow before and two times after CABG (1 and 6 postoperative day). We measure CS diameter, Velocity Time Integral (VTI) and systemic hemodynamic data. Data needed for LV mass calculation were recorded once. During statistical analysis we define: α = 0,01, β = 0,01 (power = 1- β β= 0,99), Sample size = 60, Effect size= 0,68. We used ANOVA for Repeated Measures as main statistical test in SPSS. Results: Preoperatively we found low overall CS flow of 181 ±72 ml/min (0,68 ±0,30 ml/gram-LV/min). After surgery there was constant increase of CS flow from 276 ±79 ml/min (1,13 ±0,35 ml/gram-LV/min) first postoperative day, to 355 (±99) ml/min (1,30 ±0,46 ml/gram-LV/min) sixth postoperative day. Discussion: Amount of new blood was statistically significant after CABG with P<0,001. Same result was found after classifying patients per number of graft received, with the highest amount of new blood after four bypasses. Amount of new blood was not different if patient gets two or three bypasses. Conclusion: There was significantly new amount of blood in coronary bed after CABG, with constant increase over first 6 days.

Key words: Coronary Sinus, Transthoracic Ultrasound, Flow, Coronary Artery Bypass Grafting.

1. BACKGROUND

Ischemic Heart Disease represent disease of coronary arteries and capillary bed that narrow vessel lumen leading to reduced blood flow bellow heart needs. Flow reduction during rest is rare except in severely stenotic coronary arteries, hibernated myocardial segments and after acute myocardial infarction. More often there is flow reduction during maximal dilatation.

Complication in macrocirculation during disease progression can be stopped or decelerated with adequate revascularization. Microcirculatory disturbances can be decreased conservatively or using new devices like C-sinus device.(1,2)

Contemporary recommendations for surgical revascularization are based on several studies: ARTS I, MASS II, ERACI-II, AWESOME, SOS, BARI 2D, COURAGE and SYNTAX study. According to those recommendations CABG is treatment of choice for severe coronary artery disease: isolated or combined Left Main stenosis (with single, double or triple vessel disease) and triple vessel disease(3).

Ischemic Heart Disease represent part of cardiovascular disease which are connected to 30% of death worldwide. Especially in low or moderate developed countries where is concentrated 80% of cardiovascular disease(4). As millions of people are in danger to have CVD, 25% will had heart attack in asymptomatic stage of disease. All put to-

gether suggest that it will be important to develop more accurate method of screening of coronary artery disease and for quality control after revascularization procedures. Contribution to mentioned quality control can be done by quantifying coronary flow changes after CABG using noninvasive method.

Currently there are no TTE based diagnostic criteria for Ischemic Heart Disease. There are publications which describe TTE as screening method for Coronary Artery Disease in isolated populations(5,6,7).

Quantifications of CS blood flow changes after CABG can be performed using Echocardiography (8,9,10). We can identify all three coronary arteries and their segments but because of accuracy and reliability it is easy to measure flow on venous side of coronary circulation – CS blood flow(11).

CS flow after CABG increase 20% per gram of myocardium per one graft(12). Anny sudden decrease during follow up period can suggest new native or bypass flow problem.

1.1 Flow

Normal coronary artery flow is 5% of cardiac output, around 250ml/min(13). Resting flow through normal coronary arteries, according to invasive measurements, is 0.5–1.5 ml/gr/min (0.8-1.2 ml/gr/min). At same time maximal coronary artery flow is 3-4 ml/gr/min.

Resting flow through severely stenotic coronary arteries (=>80%), hibernated myocardial segments or infarcted area is <0,5 ml/min/gr. At same time maximal coronary artery flow is <1 ml/min/gr.

Resting flow in intermediate stenosis (60-80%) is same as in healthy coronary arteries but slightly near lower value, with differences in published literature (14). Maximal flow through intermediate stenosis strongly correlates with degree of stenosis. Flow started to decrease with stenosis of 40% and become same as resting flow in stenosis =>80%. Patients with microcirculatory disturbances, even without angiographically evident stenosis also have decreased flow during rest or effort(15). It is mainly because vasodilatatory defect of endothelial cells.

After CABG resting net flow increases from 0,65 ml/min/gr to 0,78 ml/min/gr and maximal flow increase from 0,85 ml/min/gr to 1,0 ml/min/gr.

CS flow is lower than sum of coronary arteries flow. It is because there are: alternative drainage route (Thebasian veins and tributaries not connected to CS) and because CS drains ¬mainly left coronary artery territory(16). Severe coronary artery stenosis can decrease the CS blood flow. Revascularization of severely stenotic vessel can increases coronary artery and consequently CS flow.

1.2 Technique of ultrasound Coronary Sinus (CS) flow measurement

TTE is performed in lateral decubitus position. With B mode, 4 chamber view is used to find CS after dorsal probe angulation. CS can then be found in atrioventricular grove and traced to distal segment. Then probe is rotated until minimal angle of insonation is recorded (about 30 degree). In this position we have to record VTI with Doppler angle of 60% and in B/M mode diameter of CS under same systemic hemodynamic parameters(19). After few cardiac cycles VTI is traced and average value memorized together with CD diameter and systemic hemodynamic data, Figure 1. For recordings in Short Axis View patient is in same position. Distal CS segment is recorded behind mitral valve with minimal probe angulation. Using this view Doppler angle can be even more decreased. (Figure 1)

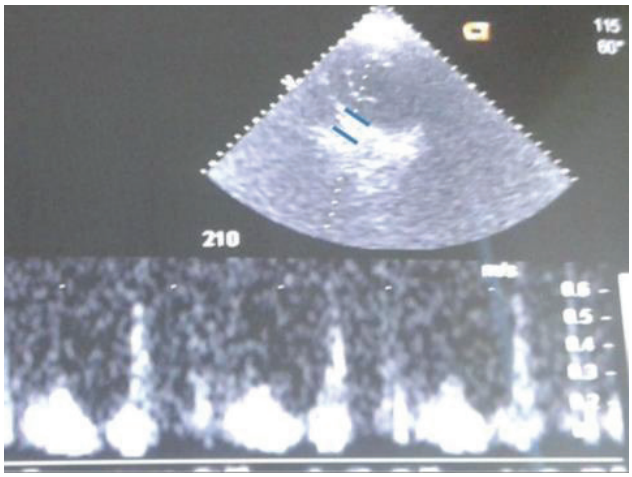

Figure 1. CS in B mode with Doppler flow traces below.

We used following formula for flow calculations: Q = (VTI × CSA) × HR. Where's Q is flow, (VTI × CSA) is stroke volume, HR is heart rate, CSA = cross section area of CS (πr^2, r = radius if vessel is round), VTI is average velocities calculated automatically after tracing heart cycle velocities. We adopted above formula as CSA = CSA x 0,39. Reason for this is ellipsoid shape of cross section area of CS with ratio 2:1. As we had recorded longer cross section diameter in four chamber view calculation of cross section area was πab ("a" was half of longer CS diameter, "b" was half of shorter CS diameter that mean "b" was 1/4 of measured diameter);

For LV mass calculations we need averaging flow rate over gram of myocardium. LV mass was calculated using ASE; Devereux formula: LVgr=0,8(1,04(LVDD+PWTD+IVSTD)3-(LVIDD)3))+0,6. Here LVDD is LV diameter in diastole, IVSTD is diastolic diameter of septum, PWTD is diastolic diameter of posterior wall near apex of papillary muscle.

2. OBJECTIVE

Quantification of CS flow changes after CABG during first week after operation using Transthoracic Echocardiography (TTE).

3. MATERIAL AND METHODS

Prospective basic research, with repeated measurements on 61 patients, whom CABG was conducted. We performed three repeated measurements (one population, one treatment) wich decrease bias.

Patients are hospital sample whom CABG treatment was needed base on Heart Time. Sample include patients with LM stenosis (isolated, combine with single, double or triple vessel disease) or triple vessel disease. Affected vessel had at least one vessel with severe coronary artery stenosis of =>80%. Ejection fraction of LV=>30%. Valvular disease patient were not included in this study. Patient were excluded from study if had bad outcome (prolong stay in ICU, exitus letalis, perioperative AMI, transfer to other hospital) or recorded data not reliable,

Study was performed in compliance to Declaration of eth-

Preoperative characteristics of 61 patients	
Variable	Percent, Mean or Median
Male	52 patients (85%)
Age	60 years (±6,5)
Arterial Hypertension	60 patients (98%)
Dyslipidemia	38 patients (62%)
Diabetes Mmellitus	24 patients (39%)
COPD	8 patients (13%)
Nicotine use	25 patients (41%)
Myocardial Infarction	36 patients (±59%)
BMI	Median Q2 (BMI 25-30), Q1(BMI 18,5-25), Q3(BMI 25-30)
LV mass	271 grams (±60)
Legend: LV-Left Ventricule, RV-Right Ventricule, LV mass-LV mass, BMI-Body Mass Index	

Table 1. Preoperative patient characteristics

ical principles during medical research (Helsinki, 2008) and respecting best medical practice (20).

We performed TTE recordings to measure CS flow before and two times after CABG (1 and 6 postoperative day). We measure CS diameter, Velocity Time Integral (VTI) and systemic hemodynamic data. Data needed for LV mass calculation were recorded once.

Power analysis was performed using standard statistical software. For key variable we have define: $\alpha = 0{,}01$ arbitrary, $\beta = 0{,}01$ arbitrary (power = $1 - \beta = 0{,}99$), Sample size = 60, Effect size= 0,68.

We use dedicated statistical software for main statistical test (ANOVA for Repeated Measures).

4. RESULTS AND DISCUSSION

Several studies show usefulness of CS flow measurements using TTE as screening methods of coronary artery disease in specific populations (21). Even more there are published data about immediate flow changes after CABG recorded using TTE and TEE (13, 14).

Immediate coronary flow increase after triple CABG is up to 50% of native coronary flow. Increase is much higher if there are no micro vascular disturbances. Over time flow increase because graft and capillary bed vasodilatation.

Preoperative patient characteristics are on Table 1. Risk factors for micro vascular disturbances and existence of Peripheral Arterial Disease did not influence results because we used repeated measurements.

Because all patients had at least on severely diseased coronary artery (stenosis >80%, Table 2) and because we used repeated measurements it was not necessary to use vasodilatators for flow recordings during rest.

Our results show preoperatively very low CS flow (mean 181 ±72 ml/min), (Table 3 and Figure 2). Some studies show higher preoperative CS flow (mean 274 ±95ml/min). In this particular study authors did not mentioned number of significant or severely stenotic Coronary Arteries (60% or 80%). In published data we found that normal CS flow is higher (mean 327 ±125 ml/min). During follow up according to our results there was constant increase in CS flow from first postoperative day (mean 276 ±79 ml/min) to last measurement on 6 postoperative day (mean 355 ±99 ml/min), Table 3 and Figure 2. Other published data show higher immediate postoperative/post PCI CS flow (mean 451 ±102 ml/min) (21, 22). Our understanding of this flow discrepancy is in flow calculation. We take into account ellipsoid shape of terminal CS (2:1) during calculation, so our flow data were less for 0,39 times. Also using angle of 60 degrease during Doppler VTI calculation bring us with error of 10%. CS flow discrepancy could be because recording position wary in terminal CS segment from patient to patient. But this was probably nullified by repeated measurements. According to literature net flow through three grafts after CABG is about 110-130 ml/min. As net native coronary artery flow is about 250 ml/min during rest, volume of new blood in coronary artery bed after CABG is 50% of net native flow during rest (13, 23).

Our results show statistically significant difference in CS flow during time. Using ANOVA tests for repeated measurements with Sphericity Assumed we found statistically significant difference during recording periods FVTI (Syst+Diast) $(2;180) = 80{,}5$, $p<0{,}001$ with Effect size (Effect Size; Cohen, 1988) of 0,68. We can see significant difference in CS flow during three time point: (preoperative, at 1 and at 6 postoperative day). Effect size was calculated directly from Partial $\eta 2$. It shows strong effect of time on measured CS flow values. Also, ANOVA Pairwise Comparation in all measured time combination show statistically significant difference with $p<0{,}001$.

For even more individualization of our results we performed CS flow calculation over LV mass. Table 3 and Figure 3). We had found preoperatively low CS flow per gram of LV (mean 0,68 ±0,30 ml/gram/min). Those results correspond

Percent of patients with Coronary Artery Stenoses of 60% i od 80%				
		Stenosis =>80% One vessel	Stenosis =>80% Two vessel	Stenosis =>80% Three vessel
Stenosis =>60% one vessel	4 patients (6,7%) from that =>	4 patients (100%)		
Stenosis =>60% two vessel	16 patients (26,7%) from that =>	6 patients (37%)	10 patients (63%)	
Stenosis =>60% three vessel	40 patients (66,7%) from that =>	4 patients (10%)	14 patients (35%)	22 patients (55%)
Stenosis =>60% anywhere	60 patients (100%) from that =>	15 patients (25%)	24 patients (40%)	21 patients (35%)

Table 2. Distribution of significant and severe Coronary Artery stenoses

Doppler and hemodynamic characteristics of flow through CS			
	Preoperative	1 postoperative day	6 postoperative day
Flow (VTI syst+diast) ml/min	181 ml/min (±72)	276 ml/min (±79)	355 ml/min (±99)
Flow (VTI syst+diast) ml/gram LV	0,68 ml/gram (±0,30)	1,13 ml/gram (±0,35)	1,30 ml/gram (±0,46)
CS VTI (syst+diast)	12,0 cm (±3,4)	11,9 cm (±3,9)	12,2 cm (±3,3)
CS VTI (max)	35 cm (±7,7)	41 cm (±14,5)	34 cm (±5,9)
CS diameter	7,5 mm (±1,1)	8,2 mm (±1,4)	9,3 mm (±1,3)
Heart rate	68 (±8,9)	87 (±11)	87 (±11)
Legend: CS-Coronary Sinus LV-left ventricle, RV-right ventricle,			

Table 3. Flow during repeated measurements

to invasive measurements. Here we also found CS flow increase over time per gram of LV: first postoperative day CS flow was mean 1,13 ±0,35 ml/gram/min and 6 postoperative day it was mean 1,30 ±0,46 ml/gram/min. Al data above support correct indication for CABG because obviously coronary vessel bed was empty and constantly filled with new blood in following 6 day.

Our results show statistically significant difference in CS flow per gram during time. Using ANOVA tests for repeated measurements we found statistically significant difference during recording periods: with Greenhouse-Geisser correction FLV mass (Syst+Diast) (1,6; 84,9)= 40,0, p<0,001 with Effect size (Effect Size; Cohen, 1988) from 0,80. We can see significant difference in CS flow during three time point: (preoperative, at first postoperative and at 6 postoperative day). Effect size was calculated directly from Partial η2. It shows strong effect of time on measured CS flow values. Also ANOVA Pairwise Comparation in all measured time combination show statistically significant difference with p<0,001.

Other variable recorded were: CS diameter was preoperatively mean 7,5±1,1 mm), first postoperative day mean 8,2 ±1,4 mm and 6 postoperative day 9,3 ±1,3mm, Table 3). As flow is proportional to forth square of diameter, those changes can have huge impact on flow calculations. In our calculation error was decreased three times by fact that we record elliptic segment of CS. Heart rate also has direct positive impact in flow calculations. In our results heart rate increase from mean 68 (±8,9) preoperatively to 87 (±11) firs and same at sixth postoperative day. As heart rate was constant postoperatively, impact on error in flow calculation was decreased, Table 3.

Increase of VTI first postoperative day was borderline and later evident probably because vascular bed dilatation Table 3. We found preoperatively overall mean VTI 12 (±3,4) cm, and maximal mean 35 (±7,7) cm, first postoperative day overall mean was VTI 11,9 (±3,9) cm, and maximal mean 41 cm (±14,5) cm, and finally at sixth postoperative day overall mean VTI 12,2 (±3,3) cm, and maximal mean 34 (±5,9) cm.

Our findings also show that it is possible to detect effect of graft number on CS flow. There was statistically different amount of new blood per graft with LV mass recalculations (Table 3 and Figure 4).

Our results show statistically significant effect using ANOVA for repeated measurements (Between Subject Effect) on CS flow by variable graft number F (3, 56)=6,0, p=0,001 with Effect size (effect size: Cohen, 1988) from 0,56. It means that we found independent effect of variable graft number on CS flow. Effect size was calculated directly from Partial η2. It shows average effect of variable graft number on variable CS flow.

Calculated variables interaction for graft number and CS flow show statistically non-significant difference by ANOVA test for repeated measures, within subject effect interaction, (Time of measured CS flow * Graft number) F (5,102)=1,7, p=0,422 with effect size (Effect Size, Cohen, 1988) from 0,23. It mean we did not found variables (graft number and CS flow) interaction. Effect size was calculated directly from Partial η2, it show weak effect of interaction. Also ANOVA Pairwise Comparation in all measured time combination show statistically insignificant difference with p>0,01 except in combination one and four grafts where we found p=0,001, Table 4.

From our data we are not able to make any conclusion based on one graft flow calculations because of small sample. Otherwise, there is evident of maximal amount of new blood in coronary bed after four bypasses and that same amount of new blood was whatever patient gets three or two grafts. So, increase in coronary bed flow was constant during first 6 days postoperatively.

5. CONCLUSION

There was significantly new amount of blood in coronary bed after CABG, overall and after classifying per gram of LV and per graft number. And there is constant overall increase in amount of new blood postoperatively first 6 days.

Main variables that influence CS flow are: VTI, diameter of CS and heart rate.

Clinical benefit of CS flow measurements still should to be proved. Proving will be possible if further studies define cut-offs value for CAD screening and for early graft failure.

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