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Comparing Intraoperative Flow Measurement in Both off-Pump Coronary Artery Bypass and on-Pump Coronary Artery Bypass Graft Patients

MOHAMMED SHAFIK, M.D.*; SALEH R. HUSSEIN, M.D.*; MOHAMMED EL-SAYED, M.D.*; AL-SAYED M. SALEM, M.D.** and KAREEM ZAYED, M.Sc.**

*The Department of Cardiothoracic Surgery, National Heart Institute** and Al-Azhar University*, Al-Hussein Hospital, Cairo, Egypt*

Abstract

Background: Patent bypass grafts are fundamental to successful coronary artery bypass grafting. We studied the use of transit-time flow measurement to determine its ability to detect technical errors in grafts, to measure the mean flow norms, and to compare flow in both on-pump and off-pump CABG procedures.

Aim of Study: To compare conduit flow in a standardized type of CABG and OPCAB using the Left Internal Mammary Artery (LIMA) and vein grafts.

Patients and Methods: This study was conducted on 60 patients requiring coronary artery bypass surgery classified into 2 equal groups:

- *Group A:* (Conventional CABG), who were approached through on pump CABG.
- *Group B:* (OPCAB), whom approached without cardiopulmonary bypass machine.

Results: There was no statistical difference between the two groups in baseline pre-operative characteristics regarding their age, sex, NYHA class and EF%.

In Group (A), the MGF was (39.51 ±5.26) and PI values were (2.33±0.64). While in Group (B), the MGF was (32.71± 6.47) and PI measurements were (2.71 ±1.22). The MGF for the occluded grafts in Group A was (14.33±3.21) ml min and (12.75±2.87) in Group B (p=.522). The corresponding PI values were (8.03±1.0) for Group A and (8.85±1.67) for Group B (p=0.489).

Conclusions: TTFM technique is a highly valuable equipment. Mean flow is lower in the OPCAB group with higher pulsatility index than the conventional CABG group, which raises suspicion about the long term patency of OPCAB grafts.

Key Words: *Coronary artery bypass grafting – Transit-time flow measurement – Graft patency.*

Correspondence to: Dr. Mohammed Shafik, The Department of Cardiothoracic Surgery, Al-Azhar University, Al-Hussein Hospital, Cairo, Egypt

Introduction

CORONARY Artery Bypass Grafting (CABG) has contributed to treatment of patients with ischemic heart disease to increase their survival and reduce ischemic complications [1]. Early graft occlusion after conventional CABG or OPCAB may have deleterious consequences as it is associated with a high risk of post-operative myocardial infarction, postoperative hemodynamic instability, and even sudden death [2].

Thus, anastomotic quality of CABG is directly associated with both perioperative and long-term clinical results [3].

It has recently been demonstrated that off-pump surgery is associated with a lower graft patency at short term follow-up when compared with on-pump CABG, suggesting that there is a risk of less anastomotic accuracy, secondary to a more technically demanding procedure and to the learning curve of surgeons performing myocardial revascularization without cardiopulmonary bypass [4].

Therefore, it is critical for surgeons to evaluate the quality of the anastomoses of CABG in the operating room [5].

Transit-time flow measurement is considered to be more convenient, less invasive, more reproducible, and less time consuming [6].

In the 1990s, transit time (also called time of flight) ultrasonic technology was introduced and became widespread. In 1994, Canver [7] and Matre [8] and their colleagues reported the clinical application of TTF measurement during CABG. It has the advantage of being independent of hematocrit level, and angle of insonation. As Matre and colleagues reported. It is considered as a quality control tool for intraoperative graft evaluation in Coronary Artery Bypass Graft (CABG) surgery. In this study we will assess grafts by measuring: Mean graft flow and pulsatility index.

Patients and Methods

The study was conducted on 60 patients, classified into two equal groups. Group A include 30 patients who underwent conventional CABG with no concomitant procedures while Group B had 30 patients who underwent OPCAB at the National Heart Institute, Cairo, Egypt between August 2014 and August 2016. All patients have signed fully informed consents.

Statistical analysis:

Data were collected, verified and edited on a personal computer then analyzed by SPSS, EPICalc software program to get the final result. Arithmetic mean, standard deviation and hypothesis” t” for quantitative values. The chi-square test (χ^2) for qualitative values expressed. A proportion analysis was performed by using life table methodology.

Pre-operative data:

The two groups were matched with no statically significant difference regarding age and sex.

Table (1): Age and sex in both groups.

Parameter / Group	Group A No.=30	Group B No.=30	Chi-square test χ^2	Chi-square test p-value
Age:				
Mean ± SD	53.57±7.51	57.2±6.53	2.000	0.050
Range	39-71	46-73		
Sex:				
Females	11 (36.7%)	9 (30.0%)	0.300	0.584
Males	19 (63.3%)	21 (70.0%)		

Pre-operatively, various high-risk factors were present in both groups.

Table (2): Pre-operative risk factors.

Risk factor / Group	Group A (conventional)	Group B (OPCABG)	Chi-square test χ^2	Chi-square test p-value
FH	12 (40.0%)	18 (60.0%)	2.400	0.121
DM	14 (46.7%)	15 (50.0%)	0.067	0.796
HTN	26 (86.7%)	26 (86.7%)	0.000	1.000
Smoking	14 (46.7%)	16 (53.3%)	0.267	0.606
Dyslipidemia	20 (66.7%)	22 (73.3%)	0.317	0.573
Obesity	13 (43.3%)	16 (53.3%)	0.601	0.438
Unstable angina	4 (13.3%)	5 (16.7%)	0.131	0.718
Recent MI	3 (10.0%)	7 (23.3%)	1.920	0.166

Echocardiographic examination revealed that the mean LVEF % for Group A patients was 58.47± 6.15% (range 45-69%); versus 59.47±8.76% for Group B patients (range 42-75%) (p=0.611).

Table (3): Echo findings.

Echo / Group	Conventional Group (A)	OPCAB Group (B)	Chi-square test χ^2	Chi-square test p-value
LVEF %	58.47±6.15	59.47±8.76	0.512	0.611

The angiographic findings were recorded and analyzed in a table.

Table (4): Angiographic data.

Coronary involvement / Group	Group A (conventional) No (30)	Group B (OPCABG) No (30)	Chi-square test χ^2	Chi-square test p-value
Lt coronary disease	30 (100.0%)	30 (100.0%)	0.000	1.000
Rt coronary disease	15 (50.0%)	15 (50.0%)	0.000	1.000
One vessel disease	4 (13.33%)	6 (20.0%)	0.480	0.488
Two vessel disease	14 (46.67%)	15 (50.0%)	0.067	0.795
Three vessel disease	12 (40.0%)	9 (30.0%)	0.659	0.416

Surgical technique and flow measurement:

All operations were performed through a median sternotomy during cardiopulmonary bypass in Group A and without in OPCAB group. The distal anastomoses were sutured with continuous 7/0 or 8/0 polypropylene sutures, and the proximal anastomoses in the ascending aorta with continuous 6/0. The TTFM values of all grafts were recorded intra-operatively in a standardized fashion thus: 5 min after the patient was weaned from cardiopulmonary bypass and the hemodynamic condition was assessed as being stable, in Group A and after finishing the proximal anastomosis in Group B. The TTFM flow measurement values and respective flow curves were obtained by using the VeriQ system TTFM device (MediStim Inc., Oslo, Norway). To guarantee that a proper size of the TTFM probe was used, the probe was fitted precisely around the mid-portion of the Left Internal Mammary Artery (LIMA) graft and proximally around the greater saphenous vein. To achieve the best possible ultrasonic coupling, skeletonization of a small segment of the pedicled LIMA graft was generally necessary. Aqueous gel was used to improve probe contact. The following variables were recorded and evaluated: (1) Mean graft flow volume (MGF; ml min) (2) Pulsatility index (PI: (maximum flow volume – minimum flow volume) / mean flow volume).

Results

The mean flow of the functioning grafts was 39.51±5.26mls/minute in Group A patients, and 32.71±6.47mls/minute for Group B patients (p= 0.003). The mean pulsatility index for Group A patients was 2.33±0.64, and 2.71±1.22 for Group B patients (p=0.008). The mean arterial pressure (mms Hg) was 89±3mmsHg for Group A patients, and 86±6 for Group B patients (p 0.017).

Table (5): TTFM data.

Group / Measurment	Group A (conventional)	Group B (OPCABG)	*t*-test	*p*-value
• Mean graft flow (ml/minute)	39.51±5.26	32.71±6.47	4.965	0.003
• Mean pulsatility index	2.33±0.64	2.71±1.22	–3.030	0.008
• Mean arterial pressure (mms Hg)	89±3	86±6	2.449	0.017

Details of intraoperative flow measured through the revised (not well -functioning) grafts:

Intraoperatively, and after TTFM 3/74 (4.05%) of the grafts in Group A were considered "not well-functioning" and needed surgical revision; compared 4/66 (6.06%) of grafts in Group B (p=0.586).

In the conventional Group A, two SVGs: One to the diagonal (intimal flap) and one to the RCA (malpositioned stitch) were not well-functioning; versus one LIMA-LAD (graft stenosis). While in Group B there were 3 SVGs grafts: Two to RCA (malpositioned stitch) and one to diagonal branch (intimal flap) and one LIMA-LAD (graft stenosis).

The mean flow in the non-functioning grafts before correction was 14.33±3.21mls/minute in Group A patients, and 12.75±2.87mls/minute for Group B patients (p=0.522). The mean pulsatility index for Group A patients was 8.03±1.0, and 8.85±1.67 for Group B patients (p=0.489). The mean arterial pressure (mms Hg) was 69±3mmsHg for Group A patients, and 65±6 for Group B patients (p=0.345).

Table (6): Measurements of non functioning grafts.

Group / Measurment	Group A (conventional)	Group B (OPCABG)	χ^2	*p*-value
• Grafts revised intraoperatively	3/74 (4.05%)	4/66 (6.06%)	0.296	0.586
• Mean graft flow (ml/minute)	14.33±3.21	12.75±2.87	0.687	0.522
• Mean pulsatility index	8.03±1.0	8.85±1.67	0.746	0.489
• Mean arterial pressure (mms Hg)	69±3	65±6	1.043	0.345

After using TTFM to assess the grafts, ill-functioning grafts were revised and showed the following measurements after correction of the causes.

Table (7): Data of revised grafts after correction.

Graft	Cause of obstruction	Type of operation	MF BC	PI BC	MF AC	PI AC
LIMA-LAD	Graft stenosis	Conventional	13	7	26	1.5
S VG-DIAG	IF	Conventional	12	8.1	33	1.8
SVG-RCA	MS	Conventional	18	9	49	2.1
LIMA-LAD	Graft stenosis	OPCAB	12	9.2	29	2.4
S VG-DIAG	IF	OPCAB	15	7.1	32	1.9
SVG-RCA	MS	OPCAB	9	11	40	2.3
SVG-RCA	MS	OPCAB	15	8.1	39	2.5

IF : Occluding intimal flap.
MS : Malpositioned stitch (stenosing or attached to posterior vessel wall).
BF : Before correction. AC : After correction.

Discussion

Recently the transit time ultrasound principle has been introduced into cardiac surgery to measure blood volume flow. Soon, transit time flowmetry received wide acceptance for use in intraoperative graft assessment because it is noninvasive, technically simple, reproducible, fast, and inexpensive **[9]**. Its use was extended also in patients operate on with cardiopulmonary bypass to verify presence of any unavoidable errors (intimal flap, purse string effect, heel or toe tapering, or acute thrombosis) which could sometimes occur in spite of conditions of the perfect visibility and stability such as during cardioplegic arrest **[10]**.

We critically-analyzed the TTFM findings in our 60 patients operated upon with and without CPB attempting to define the readability of the transit time curve in the absence of perturbation of its contour, which might have led us to deduce a wrong analysis. The flow was measured by the transit time method with the apparatus manufactured by MediStim VQ2111 VeriQ flowmeter (MediStim ASA, Oslo, Norway). The purpose of the study was to evaluate the impact of transit-time flow and resistance measurement on graft function and patency in those patients with coronary artery bypass grafting.

Overall, we had 53 patients in whom TTFM measurement revealed patent and adequately-functioning grafts while this was not the case in another 7 cases (4 OPCABG versus 3 ONCABG). It is worth-mentioning to state that the number of cases in which graft flow failure occurred was, due to various factors, higher in the OPCABG group of the series displayed (with high statistical significance in our series) despite the presence of no intraoperative or early post-operative mortality in [9,11-14].

The lowest acceptable flow values in CABG grafts (especially LIMAs) is not clearly-defined. Consequently, graft revision has been advised if graft flow is less than 20mls/minute [15].

It was reported by many authors that the Pulsatility Index (PI) values are good indicators of the quality of the anastomosis [9,11-13,16,17]. The normal range for PI has empirically been considered, by most of the previous authors, to be 1-5. In agreement with their findings, we found high PI values to be truly suggestive of anastomotic imperfections in 7 cases in whom stenosed grafts were revised. Even though an absolute PI values has not been defined, [18], however, empirically selected the limit of 5 based on their clinical experience with TTFM. Proposed a value, derived from their clinical experience, of 5 as the limit of PI value above which an anastomosis should be revised. It is noteworthy to say that the cut-off value of 5 for an optimal graft is also suggested by the manufacturer [14]. The high PI values (in our 7 cases) could justify well surgical revision of those coronary grafts. The same results were reached and reported by different surgeons like: [1,10,12,16,19].

After considering the previously mentioned statements together with the results of our work, we came to the conclusion that prompt graft revision may be very well be necessary whenever, abnormalities in flow curves and values are found.

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مقارنة قياس سريان الدم داخل غرفة العمليات بإستخدام وبدون ماكينة القلب الصناعى

إن عملية توصيل وترقيع الشرايين التاجية حل مهم لزيادة معدل النجاة وتقليل مضاعفات الجلطة القلبية. وإنه من الأساسى لضمان نجاح زرع الشرايين أن تكون المزروعات الجديدة تعمل بكفاءة. ولقد قمنا بدراسة إستخدام جهاز قياس تدفق الدم خلال الوقت لتحديد الأخطاء فى هذه المزروعات، لقياس المحددات الطبيعية ومقارنة إستخدام ماكينة القلب الصناعى من عدمها. ولقد تضمنت هذه الدراسة ستين مريضا سيخضعون لجراحة زرع الشرايين وتم تقسيمهم لمجموعتين متساويتين:

مجموعة (أ) بإستخدام ماكينة القلب الصناعى ومجموعة (ب) بدون إستخدام ماكينة القلب الصناعى.

لم توجد إختلافات تذكر بين المجموعتين السالفتين بخصوص السن، الجنس، مدى صعوبة التنفس أو كفاءة عضلة القلب.

وتبين الدراسة أن جهاز قياس سريان الدم ذو أهمية عالية. كما إتضح أن متوسط سريان الدم كان أقل فى حالات زرع الشرايين التاجية بدون ماكينة القلب الصناعى عنها فى مجموعة إستخدام ماكينة القلب الصناعى فى حين كانت المقاومة أعلى، مما يزرع الشك حول الكفاءة المستقبلية لهذه المزروعات.