INTRAOPERATIVE FLOWMETRY FOR GRAFT ASSESSMENT IN CORONARY ARTERY BYPASS GRAFTING. OUR EXPERIENCE

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ABSTRACT

INTRODUCTION: Cardiovascular diseases and coronary artery disease (CAD) in particular are the leading causes of death all around the world. At present, coronary artery bypass grafting (CABG) is one of the most common cardiac operations worldwide.

MATERIAL AND METHODS: During a three-year period (between 2014 and 2016), a total of 761 CAD patients hospitalized in the Department of Cardiac Surgery, St. Marina University Hospital of Varna underwent CABG surgery. In 64 patients, several transit time flowmetry (TTFM) parameters were assessed. A total of 161 grafts, 125 arterial, 58 in off-pump (OPCAB) and 67 in on-pump CABG as well as 36 venous conduits, 18 in both OPCAB and CABG each were carried out.

RESULTS: In arterial grafts, mean flow was of 30.7 ± 23.8 mL/min and mean pulsatile index (PI) was of 2.8 ± 1.1 while in venous ones, the mean flow was of 30.9 ± 19.3 mL/min and the mean PI of 2.5 ± 0.9 . The corresponding figures in OPCAB and CABG were 28.8 ± 13.8 mL/min and 2.9 ± 1.04 as well as 36.3 ± 0.3 mL/min and 2.4 ± 0.1 , respectively. There were two lethal cases due to cardiogenic shock. TTFM assessment of conduit patency identified that only 3.7% of the anastomoses were at risk for postoperative failure.

CONCLUSION: TTFM is a simple, easy and rapid diagnostic method which allows for immediate and precise objective evaluation of the status of the graft anastomosis in CABG and OPCAB. *Scr Sci Med.* 2017;49(4):73-78

Keywords: coronary artery disease, coronary artery bypass grafting, intraoperative transit time flowmetry, conduit patency, risk assessment

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INTRODUCTION

Cardiovascular diseases are the leading cause of death all around the world. Among them, coronary artery disease (CAD) has been introduced as the first and most common cause of mortality in all age groups (1,2). According to the 2010 report by the American Heart Association, CAD accounts for one in every six deaths in the United States of America. In addition, 379,555 Americans have died as a result of CAD in 2010 (1). With an increase in the number

of CAD incidents, coronary artery bypass grafting (CABG) has become one of the most common operations worldwide, such that almost 500,000 CABG operations are performed in the USA every year (2). Use of bilateral internal mammary artery (BIMA) is associated with a greater risk for the development of surgical site infections though skeletonization of these two arteries significantly diminishes it (3,4).

Intraoperative graft-related problems belong to the important causes for death after CABG. Technical errors in bypass graft construction are responsible for myocardial infarction (MI), postoperative angina pectoris, and fatal outcome. Modern coronary artery bypass series report perioperative MI rates between 5 and 11%. In open-chest CABG, cardiac surgeon faces several intraoperative challenges: i) to locate the target coronary artery, ii) to select the optimal anastomotic site, and iii) to assess the quality of the graft and distal anastomosis (5).

Quality of anastomosis is an important determinant of graft patency. There is need of simple and reliable technique for precise intraoperative graft flow assessment. Its aims consist in the prompt diagnosis and immediate correction of a technical problem as well as in the prevention of a severe perioperative complication. Concerning the postoperative ischemia, distal anastomosis stenosis is the most frequently recognized technical problem followed by torsion, intimal flap, or haematoma. Early graft patency is a major determinant of morbidity and mortality following coronary artery bypass surgery. New transit time ultrasound based methods for graft-patency verification such as transit time flowmetry (TTFM) are adopted for CABG interventions as flow curves, pulsatility index (PI), and flow values should always be considered simultaneously before revising the coronary graft (6). Some main TTFM features are described and technical pitfalls and suggestions to achieve an adequate intraoperative flow measurement adopting this method are provided. When combined with high resolution epicardial ultrasonography, TTFM provides high diagnostic yield (7).

There exists a variety of simple techniques such as palpation, electrocardiographic and haemodynamic data. According to a limited sample of interviewed cardiac surgeons, palpation of the graft to taste graft patency after CABG is used by 68% of the

respondents. About 70% of these surgeons share that they have never used an intraoperative graft patency verification tool in their practice at all. The majority declares that a flowmeter is not routinely required, however, 86% of them state that it is important to have such a system available in their operating room (OR).

Nowadays, the following methods of intraoperative graft verification are applied: i) standard angiography representing a gold standard necessitating specific equipment in OR, a qualified staff and proper contrast agent available. It prolongs intraoperative time and remains not preferable in the patients with a radial artery (RA) already used as a conduit; ii) TTFM. This is a simple, noninvasive and fast diagnostic tool that is easy to perform and its usage does not depend on the relation between diameter and length of the graft.

The following flow parameters are currently monitored: i) wave form, i.e. blood flow mainly during diastole with minimal systolic peak, ii) pulsatile index (PI) expressed as absolute number that should be included between 1 and 5, and iii) mean flow with data depending on the quality of revascularized coronary artery. The thirds parameter is not considered a good indicator alone.

MATERIAL AND METHODS

The present study covered a total of 64 CAD patients hospitalized in the Department of Cardiac Surgery, St. Marina University Hospital of Varna and analyzed between 2014 and 2016. Their characteristic was summarized on Table 1.

We performed 125 arterial grafts (58 in OPCAB and 67 in CABG) and 36 venous ones (18 in both OPCAB and CABG each), i.e. a total of 161 grafts.

The following procedures were carried out: left internal mammary artery (LIMA) to left anterior descending artery (LAD) in 55 cases; LIMA to Dg - in 4; LIMA to Rcx - in one; right internal mammary artery (RIMA) to Rcx - in 36, RIMA to Dg - in 11, RIMA to right coronary artery (RCA) - in 12, RA and Rcx+RCA - in 6, saphenous vein grafts (S.V.G.) to Rcx and to RCA - in 15 each, S.V.G. to Dg - in 5 and S.V.G. to LAD - in one patient. The mean anastomosis number was 3.08 in CABG and 2.90 in OPCAB. A series of intraoperative TTFM parameters were assessed.

Table 1. Patients' characteristics

Parameters	CABG		OPCAB	
	n	%	n	%
Number of patients	34	53.12	30	46.88
Males	25	73.53	26	86.67
Females	9	26.47	4	13.33
Mean age (years)	58.40±8.20		63.50±10.70	
Arterial hypertension	30	88.23	30	100.00
Diabetes mellitus	9	26.47	7	23.33
Peripheral vascular disease	3	8.82	4	13.33
Cerebrovascular disease	1	2.94	4	13.33
History of stroke	4	11.76	10	3.33
Pulmonary disease	0	0	3	10.00
Non-stable angina	13	38.24	3	10.00
Acute coronary syndrome	2	5.88	4	13.33
Emergent operation	3	8.82	10	3.33
In-hospital mortality	2	5.88	0	0

RESULTS

The results from TTFM indicated a mean flow of 30.7 ± 23.8 mL/min and a mean PI of 2.8 ± 1.1 in arterial grafts as well as a mean flow of 30.9 ± 19.3 mL/min and a mean PI of 2.5 ± 0.9 in venous ones. The corresponding figures in OPCAB and CABG were 28.8 ± 13.8 mL/min and 2.9 ± 1.04 as well as 36.3 ± 0.3 mL/min and 2.4 ± 0.1 , respectively.

Graft-related problems as detected by means of TTFM were demonstrated on Table 2.

Table 2. Graft-related problems diagnosed by TTFM

Problem	Graft type	Surgical solution
Kinking	LIMA-LAD	Graft shortening
	location n	
Anastomotic problems	LIMA-LAD	Graft revision
	OM	
	RCA	
Competitive flow	RIMA - RCA	Graft removing

Two patients deceased because of cardiogenic shock during the hospital stay that amounted to a lethality rate of 3.12%. It should be mentioned that both of them presented with TTFM parameters in the acceptable limits at the end of the coronary intervention (OPCAB or CAPB).

TTFM patterns of an anastomotic problem with LIMA-LAD were illustrated on Fig. 1 while those of the graft after its surgical revision were demonstrated on Fig. 2.

Fig. 1. TTFM patterns of an anastomotic problem with LIMA-LAD

Fig. 2. TTFM patterns of the graft after its surgical revision

In the Department of Cardiac Surgery, St. Marina University Hospital of Varna, we use this graft flow verification tool since 2014 onwards. There is no data available about its usage elsewhere in Bulgaria yet. In line with the approved strategy for surgical CAD management in our Department of Cardiac Surgery, off-pump CABG (OPCAB) is applied in the patients aged over 75 years as well as in accompanying chronic arterial insufficiency of the extremities, cerebrovascular disease, or chronic kidney disease. During the three-year period, the following trends in CAD could be outlined: i) an increase use of arterial grafts in myocardial revascularization, ii) OPCAB application in total arterial revascularization, iii) evidence of better long-term results, and iv) optimal intraoperative evaluation of the blood flow through the arterial conduits. We make use of Medistim VeriQ with 3 and 4 mm probes for TTFM.

DISCUSSION

The VeriQ™ system is one of the currently available systems, which detects imperfections that may be corrected by graft revision (8).

Recently, intraoperative TTFM (9-12), intraoperative fluorescence imaging system using fluorescent indocyanine green excited with laser light (12) and high-frequency (6.5-15 MHz) epicardial ultrasound (13) are commonly used for real-time assessing the grafts in CABG.

There is a trend towards a broader TTFM application in clinical practice. OPCAB benefits in low risk patients remain debatable and unknown yet as very large randomized controlled trials are required to show a difference in stroke and mortality rates when compared to on-pump CABG (14). In our opinion, OPCAB demonstrates advantages, especially in patients with low fraction and numerous accompanying diseases. However, OPCAB has disadvantages over CABG, such as requirements for very experienced cardiac surgeons, equal mortality, MI, stroke, and equal or lower long-term graft patency (15).

Acute MI complicated by cardiogenic shock is associated with substantial mortality. The analysis of 5,496 patients who have undergone either non-elective CABG, or CABG with ventricular assist device implantation within seven days after MI between June 2011 and December 2013 demonstrates an overall operative mortality of 18.7% that has de-

creased from 19.3% in 2005 down to 18.1% in 2013 ($p<0.001$) (16). Between 1991 and 2013, 1,750 consecutive patients with triple-vessel disease or left main plus right coronary system disease undergo primary isolated *in-situ* bilateral internal mammary artery (BIMA) grafting with at least one IMA to the LAD divided into BIMA-RA group (255 patients) and BIMA-S.V.G. one (1,495 patients) (17). There is no difference in operative mortality rates between both groups (0.8% versus 0.4%; $p=0.6$).

The results from the analysis of 16 observational studies covering a total of 52,966 patients demonstrate similar perioperative mortality for CABG performed primarily by trainees versus consultants (18). There is no significant difference in the incidence of perioperative stroke, myocardial infarction, acute renal failure, reoperation for bleeding, or wound infection. With appropriate supervision, conventional CABG can be performed by trainee surgeons without an adverse impact on perioperative outcomes or midterm survival.

TTFM variables recorded early in failing grafts after CABG for chronic total occlusion present with a significantly lower mean flow and higher PI compared with patent grafts (19). A high PI predicts not only technically inadequate arterial grafts during CABG - even if all other intraoperative assessments indicate good grafts but also postoperative outcomes, particularly mortality (11).

TTFM 9-polynomial maximal graft flow acceleration in the early diastolic phase is a promising predictor of future graft failure for AC bypass grafts, particularly in abnormal TTFM grafts (10). By means of intraoperative TTFM, cutoff values for standard variables are defined and correlated with the ability to predict midterm and long-term graft patency for arterial and venous conduits (20).

The results from intraoperative TTFM measurements of 695 CABG patients show lower flows in CABG without cardiopulmonary bypass than of 201 OPCAB ones (21). Evaluation of these measurements is valuable in determining the coronary graft patency after CABG with and without cardiopulmonary bypass.

During a three-year period, in the cardiovascular center in Tuzla, Bosnia Herzegovina a total of 440 CABG or OPCAB procedures are performed

(22). Graft patency is routinely controlled by means of TTFM. Eighteen patients are converted from OP-CAB to ONCAB only. Revision is required for 1.8% of the grafts. All the grafts are patent at the time of wound closure.

CONCLUSION

Our initial experience convincingly indicates that TTFM is a simple, easy and rapid diagnostic method providing immediate and precise objective evaluation of the status of the graft anastomosis in CABG and OPCAB. TTFM assessment of conduit patency identifies that only 3.7% of the anastomoses are at risk for postoperative failure. TTFM procedures are safer for the surgeons, especially for trainee ones, and for the patients, ensuring that the operation has been technically well done.

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