Time Flow Measurements (TTFM) Differ Between Grafts Do Transit Performed On and Off-Pump CABG ? A Comparitive Study

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Mustafa Güden[1], Belhhan Akpınar[1], Ertan Sagbas[1], Ilhan Sanisoglu[1], Osman Bayındır[2]

Kadir Has University, Florence Nightingale Hospital, Istanbul, Turkey

[1]Department of Cardiovascular Surgery
[2]Department of Anesthesiology

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ABSTRACT

Background: The aim of this study was to compare intraoperative coronary graft flows performed on and off-pump and to evaluate the effects of hemodilution on coronary graft flows in off-pump CABG patients by using TTFM.

Materials and Methods: During a one year period, 150 patients undergoing a CABG only procedure were enrolled in a prospective randomized manner. Group 1 consisted of 50 patients undergoing CABG using standard CPB techniques. Group 2 consisted of 50 cases who were planned to undergo revascularization using off-pump techniques. Group 3 consisted of 50 patients undergoing CABG using off-pump techniques under controlled hemodilution. (Htc % levels were kept between a range of 25-28%.) TTFM were performed using the CTS (Cardiothoracic Systems) – USA flometer . Mean Flows (Qmed), Pulsatile _ndex (PI) and flow patterns were evaluated. Twenty-five patients in each group were randomly assigned for control angiography 6 days postoperatively. Reoperations, combined cases and emergency operations were not included. Patients requiring high doses of vasoactive drugs were also excluded for the benefit of a controlled vascular resistance.

Results: The mean number of anastomoses were higher in Group 1 when compared to Group 2 and 3. ($p<0.05$) Mean Arterial Pressure (MAP), heart rate (HR) were similar between groups during measurements. Hematocrit values in Group 2 were higher than Group 1 and Group 3 ($p<0.05$).

Mean flows (Qmed) for LAD and RCA territories were significantly lower in Group 2 patients ($p<0.05$) For the circumflex artery territory despite lower flows again in Group 2, this did not reach significant levels. The pulsatile index were similar in all three groups for all three coronary territories. Postoperative coronary angiography revealed similar graft patencies among three groups (p=ns).

All values are shown as mean + SD unless expessed otherwise. The Kruskal-Wallis H test was used for analysing differences between three groups. Dunn's Multiple Comparison test was used for sub-group analysis $p<0.05$ was considered significant.

Conclusions: Off-pump CABG patients with hemodilution had significantly higher graft flows compared to off-pump CABG patients without hemodilution. It can be hypothesed that hemodilution may help to improve graft patency during the early postoperative period in off-pump CABG patients.

INTRODUCTION

Ensuring quality of the anastomosis during coronary artery surgery has been an important concern among cardiac surgeons,especially with the increasing popularity of off-pump coronary artery bypass revascularization (CABG). Transit time flow measurement (TTFM) is a non- invasive method based on advanced doppler technology that can measure intraoperative coronary bypass graft flows [Laustsen 1996]. Although the efficacy of TTFM has been shown by many groups, studies comparing graft flows performed on and off-pump have been limited so far. Factors like vessel diameter, distal vessel bed, spasm and viscosity are known to effect coronary graft flows, however the influence of these factors during off-pump CABG has not been throughly established. The aim of this study was:

1. To compare intaoperative coronary graft flows performed using on and off-pump CABG methods

2. To evaluate the effects of hemodilution on coronary graft flows during off-pump CABG surgery.

MATERIALS AND METHODS

During a one-year period, 150 patients undergoing a CABG only procedure were enrolled in a prospective randomized manner. Reoperations, combined cases, patients requiring high doses of vasoactive drugs and emergency cases were excluded.

Fifty patients were planned to undergo CABG using CPB (Group1). These patients were operated under moderate hypothermia and standard CPB techniques. Tepid blood cardioplegia was administered in a simultaneous fashion both antegrade and retrograde for myocardial protection. Distal and proximal anastomosis were completed under a single cross-clamp period.

Group 2 consisted of 50 patients planned to be revascularized using off-pump techniques. Four patients in this group had to be converted to CPB; two for hemodynamic instability, one for unsuitable coronary anatomy and one for mitral regurgitation needing correction. Octopus 3 Suction Stabilization (Medtronic Inc, Minn. USA) was used for coronary stabilization. The target vessel was occluded using silastic loops (Ethicon) proximally and suction stabilization was applied to stabilize the target vessel. Proximal anastomosis were performed during a single side clamp and before the distal anastomoses when necessary, especially during the right coronary artery anastomosis.

Group 3 consisted of 50 patients undergoing off-pump CABG under a hemodilution protocol. After induction of anesthesia, one unit of blood was withdrawn from the patients and collected in a bag to be retransfused after the operation if necessary. One to two units of colloid solutions were transfused during the procedure; to prevent hypovolemia and to keep the blood hematocrit levels between 25-28%. Three patients in this group had to be excluded from the study because they had to be converted to CPB. The rest of the patients underwent off-pump CABG using the same methods as described in patients in Group 2.

Measurements were performed 10 minutes after weaning from CPB in Group 1. In Group 2 and Group 3 measurements were done 10 minutes after all the anastomoses were completed. Three consecutive measurements were performed for each anastomoses and the mean value was taken into consideration as the final result. All measurements were performed without using proximal snares to avoid spasm or damage to the vessel.

Patients received up to 2 mcg/kg/min nitroglycerine and 0.03 mcg/kg/min adrenaline perfusion during measurements. Any patient who needed higher doses of vasoactive drugs were excluded for the aim of a controlled vascular resistance. Within these criteria, 45 patients in Group 1, 46 patients in Group 2 and 46 patients in Group 3 concluded the study.

A CTS (Cardiothoracic Systems, Idaho USA) TTFM device was used for flow measurements.

A 2 mm probe was used for ITA flow measurements, (Figure1) while measurements for venous grafts were performed using 3 and 4 mm probes. Systolic, diastolic and mean flows (Qmed) were measured for each anastomosis and the pulsatile index (PI) was calculated.

The pulsatile index (P I) = Systolic flow – diastolic flow
----------------------------------- has been accepted
Mean Flow

As a valuable indicator of the quality of the anastomosis by many authors. Values of PI between 1 and 5 have been accepted within the limits as suggested by Louagie et al and D'Ancona et al. [D'Ancona 1999, D'Ancona 2000].

Statistical Analysis

All values are expressed as mean + SD. Kruskal-Wallis H test was used for comparison of parameters between three groups. Dunn's Multiple Comparison Test was used for sub-group analysis. P<0.05 was considered significant (SPSS Version 10 (Chicago ILL).

RESULTS

Table 1 shows a detailed analyses of the results among the three groups. None of the patients in 3 groups suffered any neurological, renal or cardiac complications. One patient in group 1 underwent a reoperation for bleeding.

In summary, the mean number of anastomosis was higher in Group 1 in comparison to Groups 2 and 3 ($p<0.05$). There were no differences between mean arterial pressures (MAP) and heart rates (HR) during flow measurements. Hematocrit levels were higher in Group 2 patients ($p<0.05$).

When the mean flows (Qmed) were compared for LAD, CX and RCA territories;

1. Qmed values were similar between Groups 1 and 3 for all three coronary territories.
2. Qmed in Group 2 was lower than Qmed in Group 1 and 3 in LAD and RCA territories ($p<0.05$). Qmed values for the CX area in Group 2 were lower than Qmed values for Group 1 and Group 3 patients for the same territory without reaching statistical significance.
3. Despite the differences in Qmed values, the pulsatile indexes were similar between the three groups for all territories.

Graft Revisions

One anastamosis in Group 1, two in Group 2 and one in Group 3 were revised . In three instances, the inadequate flows were due to intimal flaps and localized dissections at the site of anastamoses and TTFM measurements improved after the coprrection of the anastamosis. In one case TTFM did not improve after the anastamosis was repeated, probably due to poor vessel and distal coronary bed quality. MR imaging one week after the operation suggested an occluded graft.

Angiographic results

Group 1: Overall graft patency was 97%. LIMA patency was 100 %.
Group 2: Overall graft patency was 95 %. LIMA patency was 100 %.
Group 3: Overall graft patency was 96 %. LIMA patency was 100 %.

DISCUSSION

An objective method for determining intraoperative graft flow patency is an essential part of minimally invasive direct coronary artery bypass, especially with concerns about graft patency and long term outcome. Intraoperative measurement of graft volume blood flow during cardiac surgery can be useful for quality control and to reveal technical errors. Among other technologies used for this purpose, TTFM offers stable and reproducible measurements representative of the real flow within the constructed graft with a high sensitivity and specificity [Laustsen 1996, D'Ancona 1999, D'Ancona 2000]. The agreement between the transit time volume blood flow values and the directly measured blood flows [Laustsen 1996] and the non-invasive nature of the method has made this our method of choice for measurement of volume blood flow in venous and arterial grafts. Despite these assets, the method is not without flaws. Mean flow per se is not a good indicator for the quality of the anastomosis [D'Ancona 2000]. One has to consider mean flow, the pulsatile index and the flow patterns all together while analysing the results. Vessel diameter,distal vessel bed ,high vascular resistance are some of the factors that can influence TTFM and have to be taken into account as well [D'Ancona 1999, D'Ancona 2000]. A low Qmed in a very small vessel anastomosis can be accepted if the flow pattern is mainly diastolic and the P_ is within the limits. Conversely, very low flow in a large vessel should not be acceptable. These suggest that some experience and clinical sense are needed to evaluate results during TTFM.

Our experience in more than 500 patients with the TTFM has suggested that coronary graft flows were constantly higher in on-pump CABG patients in comparison to off-pump CABG patients; which was the main reason leading us to undertake this study. One ınteresting finding was that despite the low flows in off-pump CABG patients, the pulsatile index (PI) and flow patterns; both indicators of the quality of the anastomoses were similar. Initially in the study,we had planned to evaluate graft flows in two group (on and off-pump) of patients. As the study advanced and the difference in graft flows became more apparent between on and off-pump patients we tried to find an explanation for this. Graft flows could be effected by factors such as vessel diameter, distal vessel bed, spasm and high vascular resistance. However patients were randomized and they all received similar doses of vasoactive drugs. It is known that patients with diabetes mellitus have smaller coronary arteries and more severe distal vessel disease. In this study, there were 11 patients with diabetes mellitus in Group 1, 9 in group 2 and 13 in Group 3. However, it should be emphasized that this is an ongoing study and with larger number of patients in each group, there differences should be even less. Coronary vessel diameters ranged between 1.25 mm to 2.5 mm's in all three groups and there was no indication that vessel sizes were different in the three groups. We know from the evidence both in the literature and from our published work that angiographic graft patencies are similar between on- and off-pump CABG patients [Akpinar 2000, Arom 2000]. In addition, early angiographic evaluation of 75 patients in this study also revealed similar graft patencies;suggesting similar quality anastomoses.

One factor that came to our attention was the high levels of blood hematocrit levels in off-pump patients during flow measurements. The mean Htc value was 36% for these patients (Group 2) during flow measurements versus Htc values of 28% for on-pump patients. (Group 1) After these findings we decided to add a third group to the study to evaluate the effects of hemodilution in off-pump patients (Group 3) and under similar hemodynamic parameters, we observed higher mean flows (Qmed) in off-pump CABG patients with hemodilution in comparison to their counterparts without hemodilution. ($p<0.05$)

Hemodilution has been one of the major improvements during the advance of CPB. Reduction in viscosity,increase in organ flow,reduction in mean arterial pressure and dilution of coagulation factors are some of the effects of hemodilution [Bojar 1992, Doss 1995]. Besides, safety of hematocrit values between 24-28% have been established in the literature [Bojar 1992] and we did not observe any adverse effects due to hemodilution in Group 3 patients. The rate of bleeding complications and transfusions were similar between Group 2 and Group 3 patients.

Mariani et al described a hypercoaguble state that is observed in off-pump CABG patients on the second and third postoperative days [Mariani 1999]. Silvay et al have elegantly shown this hypercoaguble state in off-pump patients during the early postoperative period using thromboelastograms (TEG); which was not observed in postoperative CPB patients [Silvay 2000]. During CPB there is a 30-50% decrease in platelet numbers due to consumption and hemodilution. Another important consequence of CPB is fibrinolysis which is absent in off-pump patients. Both Mariani and Silva suggested that lack of fibrinolysis after off-pump cases could be the main reason for the hypercoaguble state seen in these patients which could lead to early graft thrombosis or other end organ complications and advised the use of Plavix during this period [Gu 1998, Mariani 1999, Silvay 2000].

The mechanism of an ANHD (acute normovolemic hemodilution) - induced fall in systemic vascular tone has not been fully elucidated. However, local endothelium-based (nitrous oxide) mediated mechanisms have been implicated in the vasodilatory responses to hemodilutıon [Doss 1995]. Although a technically perfect anastomosis is the gold standard for graft patency, hemodilution may be another helpful tool to improve graft flow and perhaps patency during this critical hypercoaguble state that off-pump patients are going through. Mechanisms such as reduction in viscosity, dilution of coagulation factors and nitrous oxide upregulation that contribute to vasodilatation after ANHD may help in the design of novel therapeutic strategies [Doss 1995, Silvay 2000]. The authors realize that higher volume prospective randomized trials are needed to support these hypotheses. However, within the limitation of this study, they conclude that;

1. Flow rates were lower in off-pump CABG patients when compared to on-pump CABG patients. ($p<0.05$)

2. Off-pump patients with hemodilution had comparable flows with on-pump CABG patients.

3. Hemodilution did not cause any adverse effects in the early postoperative period.

4. It can be hypothesed that hemodilution may help to improve graft patency during the early postoperative period in off-pump patients. Higher volume trials are needed to further support this hypothesis.

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Table 1 Analysis of flow characters

	Group 1	Group 2	Group3	pvalue
M. N. A	3. 2±0. 4	2. 6±0. 2	2. 4±0. 6	p<0. 05(3-2<1)
M. A. P (mmHg)	70±10	75±12	65±10	p=ns
HR	78±5	82±4	87±12	p=ns
Htc	28±4	36±8	25±3	
Flow Values				p<0. 05(2-3)
LAD				
Q med (ml/min.)	28±11	20±7	30±12	p<0. 05
PI	2. 2±1. 8	2±1. 5	1. 9±0. 5	p=ns
OM				
Q med (ml/min.)	36±10	28±5	40±15	p=ns
PI	2±1. 8	2. 6±1. 4	2. 5±1	
RCA				p=ns
Q med (ml/min.)	49±14	30±10	50±12	
PI	1. 8±1	1. 8±1. 6	2±1. 3	p<0. 05
				p=ns

MNA:mean number of anastomosis
MAP:mean arterial pressure
HR:heart rate
Htc: hematocrit
LAD:left anterior descending coronary artery
OM:obtuse marginal branch of circumflex coronary artery
RCA:right coronary artery
PI:pulsatile index
Qmed:mean flow
P value: please refer to text