Turkish Journal of Thoracic and Cardiovascular Surgery 2018;26(2):167-176
http://dx.doi.org/doi: 10.5606/tgkdc.dergisi.2018.15004

Original Article / *Özgün Makale*

EDITOR'S CHOICE

Intraoperative transit-time flow measurement in on-pump coronary artery bypass graft surgery: Single center experience

Pompa ile yapılan koroner arter baypas greft cerrahisinde ameliyat sırası transit time akım ölçümü: Tek merkez deneyimi

Uğur Kaya, Abdurrahim Çolak, Necip Becit, Münacettin Ceviz, Hikmet Koçak

Department of Cardiovascular Surgery, Medicine Faculty of Atatürk University, Erzurum, Turkey

ABSTRACT

Background: This study aims to evaluate the effects of graft dysfunction detected by intraoperative transit-time flow measurement on the outcomes of on-pump coronary artery bypass graft surgery.

Methods: A total of 1,240 patients (856 males, 384 females; mean age 57.4±12.1 years; range, 47 to 74 years), who underwent isolated on-pump coronary artery bypass graft surgery via median sternotomy performed by the same surgical team, were reviewed retrospectively. With the introduction of transit-time flow measurement into practice at our clinic in 2006, all patients regularly underwent transit-time flow measurement during surgery in order to evaluate the graft patency. Interpretation of the data obtained using the transit-time flow measurement in patients who underwent surgery has directed our decision as to whether to perform graft revision. Patients were evaluated for early- and late-period mortality/morbidity, perioperative and postoperative myocardial infarction, and intraaortic balloon requirement.

Results: A total of 3,596 grafts in the perioperative period was evaluated using transit-time flow measurement. Anastomosis/graft revision, new anastomosis/patch plasty to distal native artery or free left internal mammary artery graft was performed in 146 grafts of 143 patients in whom transit-time flow measurement showed insufficient patency. Four of six patients who developed peri/postoperative myocardial infarction were found to have perioperative hypotension, ST elevation, and wall motion abnormality on transesophageal echocardiography before closure of the sternum. The flow was corrected by extending the short length of the grafts with insufficient flow after transit-time flow measurement and it was recorded that transit-time flow measurements were at normal values at these four grafts. Two patients developed acute myocardial infarction in the postoperative period and stent was applied in one vessel of each patient; however, one of these patients died. Sixteen patients were inserted intraaortic balloon pump, four of which being in the preoperative period. Revision surgery was performed due to bleeding in 56 patients and sternal infection in 12 patients. Of all patients, 28 (2.3%) died in the early postoperative period.

Conclusion: We believe that transit-time flow measurement may be an important tool in evaluating graft function and contribute to eliminate the causes of graft failure during surgery.

Keywords: Coronary artery bypass grafting; transit-time flow measurement; graft patency.

ÖZ

Amaç: Bu çalışmada greft disfonksiyonunun ameliyat sırası transit time akım ölçümü ile saptanmasının pompa ile yapılan koroner arter baypas greft cerrahisi sonuçları üzerindeki etkileri değerlendirildi.

Çalışma planı: Aynı cerrahi ekip tarafından gerçekleştirilen median sternotomi yoluyla pompa ile yapılan izole koroner arter baypas greft cerrahisi uygulanan toplam 1240 hasta (856 erkek, 384 kadın; ort. yaş 57.4±12.1 yıl; dağılım, 47-74 yıl) retrospektif olarak incelendi. Transit time akım ölçümünün 2006 yılında kliniğimizde kullanılmaya başlanması ile birlikte, greft açıklığının değerlendirilmesi için ameliyat sırasında tüm hastalara transit time akım ölçümü düzenli olarak uygulandı. Cerrahi uygulanan hastalarda transit time akım ölçümü kullanılarak elde edilen verinin yorumlanması, greft revizyonu uygulayıp uygulamama kararımızı yönlendirdi. Hastalar erken ve geç dönem mortalite/morbidite, perioperatif veya ameliyat sonrası miyokard enfarktüsü ve intraaortik balon gereksinimi açısından değerlendirildi.

Bulgular: Perioperatif dönemde toplam 3596 greft transit time akım ölçümü kullanılarak değerlendirildi. Transit time akım ölçümünün yetersiz açıklık gösterdiği 143 hastanın 146 greftinde anastomoz/greft revizyonu, distal nativ artere yeni anastomoz/yama plasti veya serbest sol internal meme arteri grefti uygulandı. Perioperatif veya ameliyat sonrası miyokard enfarktüsü gelişen altı hastanın dördünde sternum kapatılmadan önce perioperatif hipotansiyon, ST elevasyonu ve transözofageal ekokardiyografide duvar hareket bozukluğu tespit edildi. Transit time akım ölçümü sonrası yetersiz akımlı greftlerin kısa olan boyları uzatılarak akım düzeltildi ve bu dört greftin transit time akım ölçümlerinin normal değerlerde olduğu kaydedildi. İki hastada ameliyat sonrası dönemde akut miyokard enfarktüsü gelişti ve her hastanın bir damarına stent uygulandı, ancak bu hastalardan biri kaybedildi. Dördüne ameliyat öncesi dönemde olmak üzere 16 hastaya intraaortik balon pompası yerleştirildi. Elli altı hastada kanama, 12 hastada sternal enfeksiyon nedeni ile revizyon cerrahisi uygulandı. Tüm hastaların 28'i (%2.3) ameliyat sonrası erken dönemde kaybedildi.

Sonuç: Transit time akım ölçümünün greft fonksiyonunun değerlendirilmesinde önemli bir araç olabileceğini ve ameliyat sırasında greft başarısızlığının nedenlerini gidermeye katkıda bulunabileceğini düşünüyoruz.

Anahtar sözcükler: Koroner arter bypass greftleme; transit-time akım ölçümü; greft açıklığı.

Received: June 21, 2017 *Accepted:* December 19, 2017

Correspondence: Uğur Kaya, MD. Atatürk Üniversitesi Tıp Fakültesi Kalp ve Damar Cerrahisi Anabilim Dalı, 25240 Yakutiye, Erzurum, Turkey.
Tel: +90 442 - 316 63 33 e-mail: dr.ugurum@hotmail.com

Cite this article as:

Kaya U, Çolak A, Becit N, Ceviz M, Koçak H. Intraoperative transit time flow measurement in on-pump coronary artery bypass surgery: Single center experience. Turk Gogus Kalp Dama 2018;26(2):167-176.

Coronary artery bypass grafting (CABG) contributes to issue such as survival, quality of life, and increase in expectations.[1] The quality of anastomosis is directly related to both early and long term clinical outcomes following CABG. Refractory angina is a complication which can lead to myocardial infarction, arrhythmia, and even mortality.[2-5] Although most surgeons believe this to be a rare condition, the perioperative incidence of graft failure is estimated to be between 5% and 11%.[6-8] Surgeons were widely used to assessing anastomotic adequacy, hemodynamic stability, and electrocardiographic changes by assessing graft pulsation. However, this is both an unreliable and an indirect method. As a result, it is of critical significance for surgeons to evaluate the quality of anastomosis in CABG with more reliable methods. Various methods have recently been introduced to improve the reliability of the quality of anastomosis.[2-9] Transit time flow measurement (TTFM) has been reported to be a convenient method for the easy and rapid intraoperative functional assessment of bypass grafts independent of vessel size and shape.

The purpose of this study is to assess the effect of intraoperative TTFM on the detection of graft dysfunction on pump-induced CABG results.

PATIENTS AND METHODS

In this study, a total of 3,596 grafts were examined retrospectively in 1,240 patients (856 males, 384 females; mean age 57.4±12.1 years; range, 47 to 74 years) who underwent median sternotomy and pump-isolated CABG between 2007 and 2017 at the Cardiovascular Surgery Clinic of Atatürk University Faculty of Medicine between January 2007 and March 2017. Patients who underwent coronary bypass together with other cardiac surgical operations and who underwent off-pump coronary bypass were excluded from the study. Interpretation of values obtained using TTFM in patients who were operated on, enabled us to decide on whether to revise a graft or not. Patients were evaluated with regards to intra-aortic balloon requirement, angina, perioperative and postoperative myocardial infarction, postoperative angioplasty, as well as to early and late mortality.

Surgical procedure

All patients were premedicated with 0.07-0.1 mg/kg midazolam. Anesthesia was performed with fentanyl and propofol, while vecuronium was used for muscle relaxation. Every patients was subjected to median sternotomy, and the left internal mammary artery (LIMA), saphenous vein graft (SVG) and/or radial artery grafts were used as graft material. The first dose of heparin was given to each patient at 3 mg/kg and the active coagulation time (ACT) was maintained above 450 seconds. All interventions were performed with mild hypothermic cardiopulmonary bypass and cross clamping. Cardiac arrest was first performed with antegrade crystalloid cardioplegia, followed by antegrade and left main coronary artery containing the potassium, and an additional continuous retrograde blood cardioplegia to patients with an equivalent. Hot blood cardioplegia was ultimately performed. Distal anastomoses were performed with the 7-0 or 8-0 polypropylene continuous suture technique. Proximal anastomoses were performed with 5-0 or 6-0 polypropylene continuous suture technique in the ascending aorta. After decannulation, heparin was neutralized with protamine. Fractional heparin (s.c.) was administered at the fourth postoperative hour and continued until the patient was mobilized. Treatment with low-dose aspirin (100 mg) was initiated one day after the operation and this treatment was later continued.

The protocol prepared by D'Ancona et al.[10-12] was used during TTFM. Inotropic agents were used to maintain a systolic pressure of 90-100 mmHg in patients with low blood pressure prior to the measurement. The TTFM device (MediStim VQ-1101, MediStim ASA, Oslo, Norway) was used for the evaluation of each graft after completion of anastomosis during the operation and before the sternum could be closed. Flow in both the proximal and distal segments of the graft were examined in patients with sequential bypass surgery. Measurements were made by examining whether or not the proximal native coronary artery was occluded, in order to assess the presence of any competition in the native vessels and to detect the presence of any potential defect localized distally to the anastomosis, and where native retrograde blood flow was present. Flow curves images and mean flow (mL/min), pulsatility index (PI) and the diastolic filling percentage (DF%) were recorded automatically by the device. A DF <50% and/or PI >5 was considered as an indication of poor flow. The mean flow was not used alone as a sign of weak flow and was evaluated together with the other two parameters. Interpretation of the values obtained made it possible for us to decide on whether or not a graft was to be revised. The graft length and characteristics were examined when insufficient TTFM findings were detected. It was also examined for bending, curling, air bubbles or spasm. Corrections were made if any of these conditions was detected. Arterial grafts were applied over the papaverine/nitroglycerine graft to resolve any possible spasm. In the absence of any problem with the graft,

an opening in the graft was made with a small incision about 1 cm proximal to the anastomosis. Patency of the distal anastomosis and native coronary artery were examined using antegrade graft blood flow and a 1.5 mm coronary probe (Figure 1). Any stenoses detected in the anastomotic region were revised. A new anastomosis was made with either the same graft or another graft, either in the distal anastomosis, or in native vascular problems such as dissection or plaque rupture. Revision of anastomosis was performed on a functioning heart or during ventricular fibrillation for the vessels on the anterior surface of the heart, and by cross clamping during diastolic arrest for vessels on the posterior aspect of the heart. All measurements were repeated before the sternum could be closed in order to determine a possible graft curling or pressure, even if satisfactory TTFM findings were obtained during the final measurement.

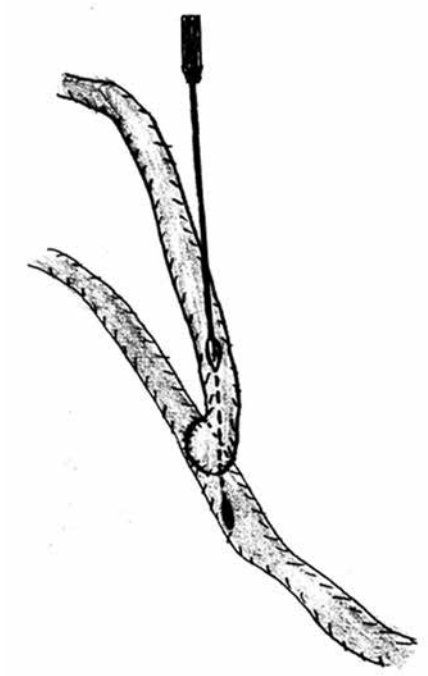


Figure 1. Examination of the anastomosis.

Statistical analysis

Statistical analysis of the data was performed using the IBM SPSS 20.0 for Windows package

Table 1. Demographic characteristics of patients and preoperative risk factors

Parameters	n	%	Mean±SD	Range
Age (year)			57.4±12.1	47-74
Gender				
Male	856	69		
Female	384	30.1		
Cigarette smoking	635	51.2		
Arterial hypertension	680	54.8		
Diabetes mellitus	433	34.9		
Hypercholesterolemia	576	46.5		
Previous myocardial infarction	773	62.3		
Peripheral artery disease	68	5.4		
Chronic obstructive pulmonary disease	124	10		
Coronary lesions				
Left main coronary artery	78	6.3		
3 vascular disease	738	59.5		
2 vascular disease	412	33.2		
1 vascular disease	90	7.2		
Left ventricular ejection fraction (%)			47.59±8.66	30-65
Emergency surgery	114	9.2		
EuroSCORE			4.16±1.79	

SD: Standard deviation.

Table 2. Intraoperative patient data (n=1,240)

	n	Mean±SD
Number of grafts		
1	12	
2	248	
3	620	
4	248	
5	112	
Number of grafts per patient		3.0±0.6
Total distal anastomosis	3720	
Left anterior descending artery	1260	
Diagonal	580	
Circumflex system	1010	
Right coronary arterial system	870	
Total proximal anastomosis	2132	
Number of grafts	3596	
Left internal mammary artery	1230*	
Radial artery	128	
Saphenous vein graft	2230	
Cephalic vein graft	8	
Sequential bypass	124	
Y graft	110	

SD: Standard deviation; * Was not used in 10 patients due to poor left internal mammary artery flow and quality.

program (IBM Corp., Armonk, NY, USA). Descriptive statistics for continuous variables were demonstrated as mean±standard deviation or median (minimum-maximum), while categorical variables were shown as cases numbers and percentages. The receiver operating characteristic (ROC) curve analysis was performed to determine the efficacy of PI, DF% and Q-mean variables when predicting early graft failure. The area under the curve for each variable, sensitivity, specificity, 95% safety interval, and p-value were also reported.

RESULTS

Demographic characteristics and intraoperative data of patient are shown in Tables 1 and 2, respectively. The EuroSCORE values of the patients were 4.16±1.79. The number of graft per patient was reported as 3.01±0.6. The most common target vessel was the left anterior descending coronary (LAD) artery. Transit time flow measurements were performed on 3,596 grafts (Figure 2). The mean intraoperative TTFM values performed before closure of the sternum in the patients are shown in Table 3. Anastomosis/graft revision, distal native anastomosis/patch plasty or free use of the left internal mammary artery (LIMA) was reported in 146 grafts of 143 patients with insufficient TTFM findings, and the procedure was terminated after obtaining TTFM values of a good flow (Figure 3). The causes of the weak flow and the technical data of the 146 grafts are shown in Table 4. Very long grafts were shortened or twisted grafts were repositioned with proper orientation. The length of short grafts was made longer by adding grafts. Transit time flow measurement findings were found to be inadequate in 21 patients with LIMA-LAD grafts. Anastomotic stenosis was revised and corrected in five patients. Stenosis/dissection was detected in the proximal segment of LIMA in 10 patients. The LIMAs were transected proximally and anastomosed end-to-side to the aorta as free graft. In three patients who were detected of having plaque rupture in LAD distal to anastomosis, a new anastomosis to the distal LAD was performed with radial artery graft, while an end-to-side anastomosis to the LIMA was performed proximal to graft. A patch plasty was performed on the distal LAD in three patients who had native coronary artery disease but with introduction of a 1 mm probe. Insufficient flow was detected in circumflex system in 26 grafts in 67 diagonal arteries, during TTFM measurements. Three grafts in the circumflex system were re-anastomosed due to stenosis in the distal anastomosis, while other problems such as kink, flexion or shortening in the other grafts were corrected. Thirty-two right coronary artery (RCA) grafts with insufficient TTFM findings demonstrated anastomotic stenosis in four, graft shortening in 24, kink or twist in four, severe second lesion distal to anastomosis in RCA or plaque rupture/dissection in four. Anastomotic stenosis was corrected by reanastomosis while problems in native vessels distal to anastomosis were corrected by performing a new anastomosis with saphenous vein grafts, and end-to-side proximal anastomosis to previous RCA grafts. Problems such as kink, twists or shortening of the grafts were eliminated. No electrocardiographic changes were recorded in patients with poor TTFM findings and with corrected anastomoses. Postoperative major complications, total morbidity and mortality rates are shown in Table 5. Hypotension, ST elevation and wall motion impairment in TEE were detected before perioperative sternal closure in four patients, while the graft was revised and flow corrected after TTFM measurement. On the other hand, postoperative acute myocardial infarction was detected and stent applied

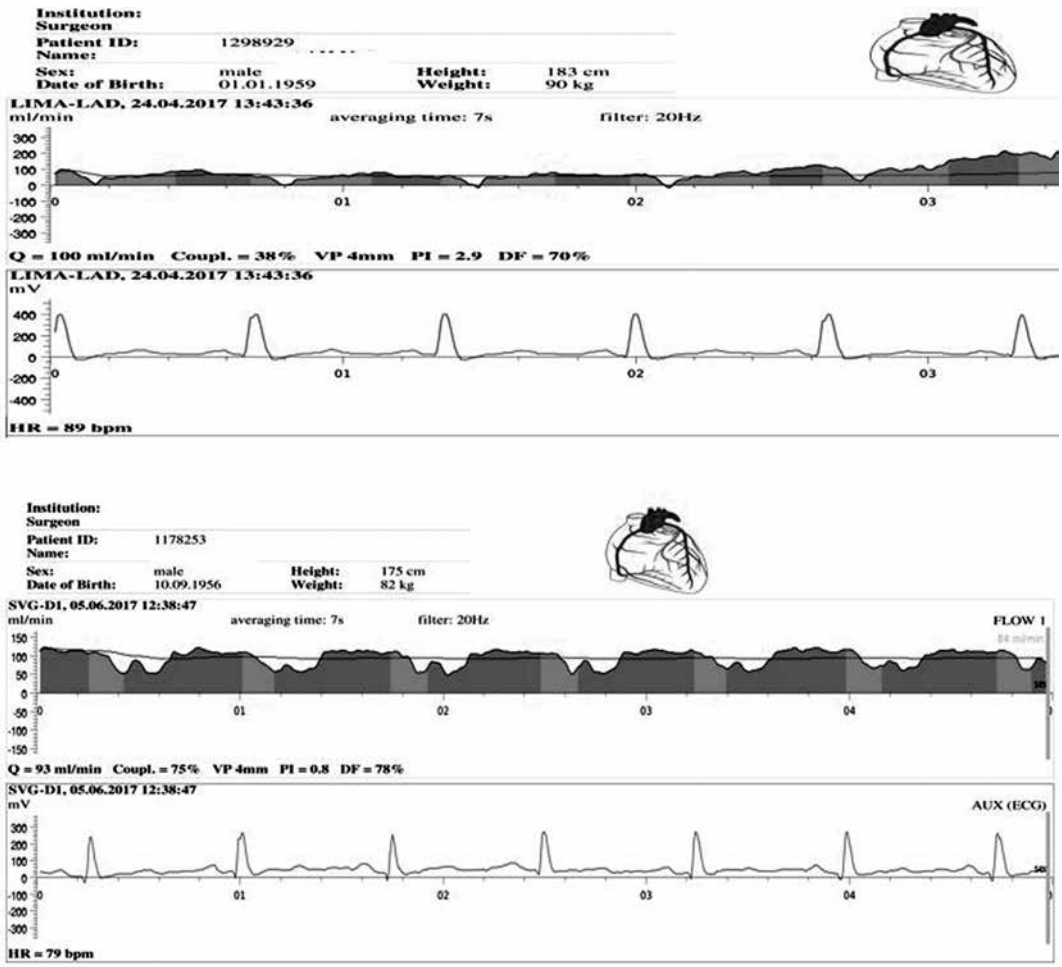


Figure 2. Satisfactory transit time flow measurement findings were obtained with left internal mammary artery-left anterior descending and saphenous vein-graft for diagonal artery bypass.

in two patients, one of whom was reported dead. Intra-aortic balloon pump (IABP) was implanted in 16 patients, four of them preoperatively. Patients were subjected to revision, 56 due to hemorrhage and 12 due to sternal infection. The duration of stay of patients at the intensive care unit was 2.63±0.8 days, while the period of hospitalization was 8.9±3 days. The diagnostic value of PI for early graft failure was reported to have a sensitivity of 93% and specificity of 79%, according to the result of the ROC analysis,

Table 3. Intraoperative transit time flow measurement findings before sternal closure

Grafts	Number of grafts	Mean flow (mL/min)		Mean PI		Mean DF%	
LIMA-LAD	1250	55.1±22.3	30-120	2.2±0.7	1-4.9	62.2±6.5	55-94
Rd-LAD	10	53.1±21.2	25-110	2.3±0.8	1-4.9	66.3±7.6	50-84
Ao-diagonal	580	41.3±13.4	26-110	2.2 ±0.7	1-4.8	63.6±6.4	50-91
Ao-Cx system	1010	46.0±11.7	25-100	2.3±0.8	1-4.3	56.3±6.7	50-75
Ao-RCA system	870	39.3±19.5	18-126	3.4±0.8	0.8-4.8	61.0±5.8	53-91

LIMA: Left internal mammary artery; LAD: Left anterior descending artery; Rd: Radial artery; Ao: Aorta; Cx: Circumflex; RCA: Aorta right coronary artery system.

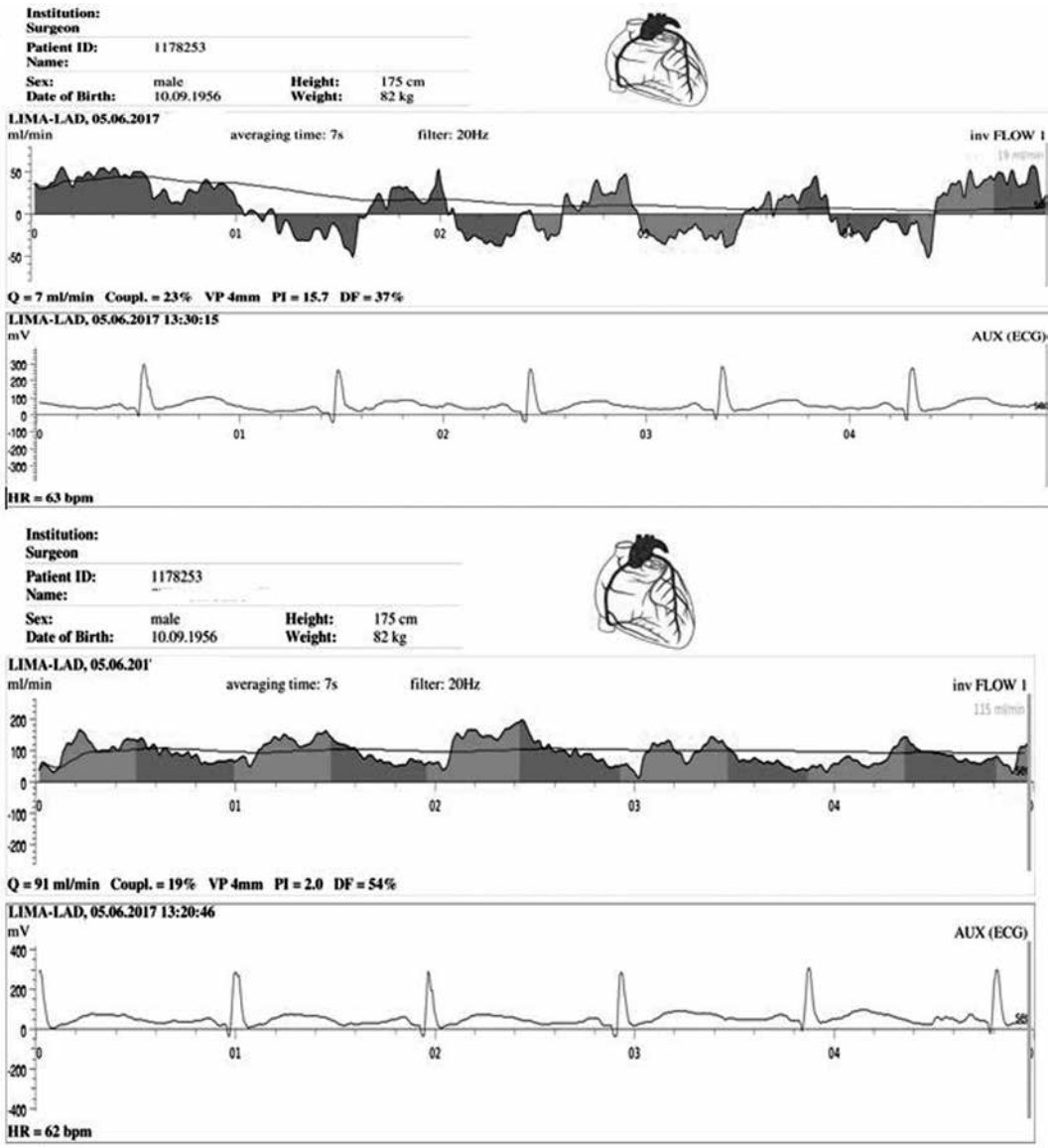


Figure 3. Unsuccessful transit time flow measurement findings of a patient with left internal mammary artery-left anterior descending graft caused by stenosis detected in the left internal mammary artery proximal segment **(a)**. The proximal left internal mammary artery was subjected to a transection and subsequent end-to-side aortic anastomosis **(b)**.

these results were found to be statistically significant (p=0.003). The diagnostic values of diastolic filling percentage and Q-mean variables were not found to be statistically significant (p>0.05) (Figure 4).

DISCUSSION

Coronary artery bypass grafting (CABG) has been in use now for approximately half a century, and has contributed to survival, increased quality of life and life expectancy.[1] Despite significant improvement in surgical technique, surgical operative treatment of ischemic heart disease remains palliative approach. Occlusion of saphenous vein grafts at a rate of 10-15% during the first month, with subsequent 5-10% re-occlusion by the 11th month is considered as a failure in the surgical technique. This can occur as a result of the kinking of the graft and due to the linear tension caused by insufficient graft length. However, it can often occur due to failure registered during the formation of anastomosis.[13,14]

Several techniques have been used in the past to perform intraoperative assessment of graft patency.

Table 4. Causes of graft revision, the number of grafts and target vessels being examined

Parameters	n	%
Total number of revised grafts	146 (3,596)	4.1
Total number of patients with revised grafts	143 (1,240)	11.5
Causes of revision		
Kink graft/graft length	52	35.6
Twisted graft	48	32.8
Graft shortening	17	11.6
Stenosis/dissection in the LIMA proximal segment	10	6.8
Poor native coronary vessels	7	4.8
Anastomotic stenosis	12	8.2
Target vessels		
Left anterior descending artery	21*/1,260	1.7
Diagonal	26/580	4.5
Circumflex system	67†/1,010	6.6
Right coronary arterial system	32‡/870	3.7
Revised grafts		
Left internal mammary artery	18 (1,230)	1.5
Radial artery	6 (128)	4.7
Saphenous vein graft	120 (2,230)	5.4
Cephalic vein graft	2 (8)	25

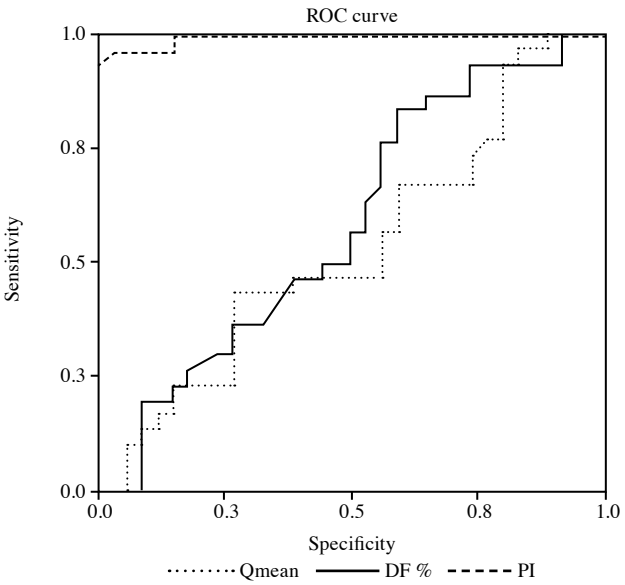
LIMA: Left internal mammary artery; * Distal anastomosis revision in five patients, patch plasty to the distal left anterior descending artery in three patients and distal bypass performed in three patients, free left internal mammary artery was used ten patients; † Relocation of anastomosis was performed in three patients; ‡ Anastomosis revision was performed in four patients, distal bypass was performed in four patients.

Electromagnetic flow meters which were initially adopted for use in coronary surgery have recently been replaced by ultrasonic technology (Doppler and TTFM). Several authors who have adopted using the TTFM technique have reported very successful results in detecting technical errors during CABG and in resolving any problem which develops during the same operation.[1,7,9,10-12] In their study, Schmitz et

Table 5. Postoperative characteristics of patients (n=1,240)

Parameters	n	%	Mean±SD
Total morbidity	90		
Re-exploration for bleeding	56		
Deep sternal infection	12		
Intra-aortic balloon pump placement	16*		
Peri- or postoperative infarction	6†		
Total mortality	28	2.3	
Intensive care unit duration (days)			2.6±0.8
Duration of hospital stay (days)			8.9±3

SD: Standard deviation; * Performed preoperatively in four patients; † Infarction was detected before the perioperative sternum was closed in four patients and the graft was revised. Two patients also underwent postoperative stenting, one of whom died during the early stage.



	Area	95% CI	*p*	Sensitivity	Specificity
DF %	0.624	0.490-0.687	0.643	0.56	0.65
Qmean	0.543	0.454-0.625	0.349	0.67	0.78
PI	0.985	0.972-1.006	0.003	0.93	0.21

CI: Confidence interval; Qmean: mean flow; DF%: Diastolic filling percentage; PI: Pulsatility index.

Figure 4 Transit time flow measurement ROC analysis values to estimate early graft failure.

ROC: Receiver operating characteristic.

al.[15] compared on-pump and off-pump patients with regards to TTFM and graft flows and demonstrated that on-pump patients had better flow values, whereas in the study by Zhuang et al.[16] similar flow values were reported in both groups; in both studies the authors suggested that it could be an effective method in the revision of graft failure during the operation. Comparison of graft flows in on-pump and off-pump patients was not normally performed, since on-pump CABG patients were included in the study. However, in a total of 3,596 grafts performed in the 1,240 patients who were included in the study, 146 (4.1%) showed that the necessity of revision during intraoperative TTFM measurement could be an effective method for evaluating and revising perioperative graft failure, and may also improve operative success.

In a study evaluating 157 patients and 304 grafts with intraoperative TTFM and postoperative angiography, TTF measurement data were reported to be independent predictors of graft failure, were suggested to be considered for occlusion in the presence of high PI and low flow states.[7] Studies suggest that good intraoperative TTFM findings may be a determining factor in predicting early and late graft patency.[2,7,10] On the other hand, no comment could be made in our study as to whether TTFM measurement data are independent predictors of graft failure since our study did not include long-term follow-up data of patients undergoing intraoperative TTFM measurements.

D'Ancona et al.[11] and Walpoth et al.[17] reported that a technical failure with TTFM, of 6% and 8% of all patients could be detected and this problem could be resolved during the same operation. This provides a considerable benefit in protecting the patient from perioperative complications. However, the revision rate of grafts in our study was found to be 4.1%.

The three important flow parameters in TTFM are; flow, DF% and PI. Flow *(i)* is expressed by a flow curve showing the systolic and diastolic filling of the graft via color coding (systolic: light red, diastolic: light blue) and *(ii)* mean flow value (mL/min). In order to accurately distinguish systolic blood flow from diastolic flow, the curves should always be combined with correctly connected electrocardiography (ECG) monitoring. Mean flow is dependent on many variables such as, blood viscosity, graft size and quality, resistance in the graft, distal vessel quality, native coronary artery diameter and spasms in arterial grafts. Absolute blood flow value is not a good indicator of anastomotic quality and should be considered together with the other two indicators and clinical findings (ECG, hemodynamic values). DF% indicates coronary filling rate during diastole. Using ECG synchronization, DF% is defined as the blood volume filled during diastole divided by the total blood volume in a heart cycle. DF% is particularly important in conditions with low flow where the average flow rate is less than 10 mL/min. The reason for this is the fact that DF% constitutes the metabolic component of the flow. Recent studies indicate that the most important indicator for confirming intraoperative graft patency is DF%.[18] Pulsatility index, which is expressed as an absolute number, is a good indicator of flow and hence the quality of anastomosis. This number is obtained by dividing the difference between maximum flow and the minimum flow by the average flow value. Pulsatility index is proportional to vascular resistance. Consequently, a high PI is an indicator of poor quality graft or anastomosis.

Becit et al.[18] compared 200 patients who underwent isolated on-pump coronary bypass surgery with median sternotomy, and who had similar demographic characteristics and preoperative risk factors in our clinic in 2006. Comparison was made by dividing

patients into two groups as those who were subjected to TTFM measurements and those who were not, and it was demonstrated that lower mortality, peri/postoperative myocardial infarction and IABP insertion rates in the TTFM measurement and when necessary, in the revision group, was an indication of statistical significance ($p<0.05$). In their studies, it was shown that the determination of intraoperative graft dysfunction with TTFM improved surgical outcomes. After this study that conducted in our clinic, routine application of intraoperative TTFM measurement was instituted during CABG operations to increase bypass quality and also improve surgical outcomes. As indicated in the study by Becit et al.[18] regarding the group using TTFM, our study demonstrated that peri/postoperative complications, morbidity/mortality rates and surgical outcomes were similar.

In this study, the protocol recommended by D'Ancona et al.[10-12] was used to determine graft dysfunction. Immediately after completing the anastomosis during cardiopulmonary bypass, the TTFM measurement was performed and several more TTFM measurements were undertaken to identify problems that could arise from possible graft twisting or pressure from the manipulation, before the sternum was closed-up. Systemic pressure should closely be monitored under condition where arterial grafts are used. Low systemic pressure, manipulation, and decreased blood flow can cause graft spasm. In patients with low blood pressure, inotropic agents were used to maintain a systolic pressure of 90-100 mmHg. The probe size used to measure the flow and good contact with the probe is important for accurate measurement. The importance of TTFM in the evaluation of coronary artery bypass grafts is based on interpretation of the data. As a result, the flow curves, PI, DF% and the mean flow values were measured simultaneously to correctly interpret TTFM findings, which are very important to reduce the number of undetected technical errors in our study. Studies show that graft dysfunction was present in 0.6-3.2% of grafts and in 1.8-8.1% of patients.[11,16-22] In in our study these values were demonstrated as 4.1% and 11.5%, respectively.

Our results suggest that TTFM may be effective in detecting intraoperative graft dysfunction.

Transit time flow measurement provides important intraoperative information about the condition and patency of coronary grafts. It can ensure accurate diagnosis of problems in the distal anastomotic region such as anastomotic stenosis, plaque rupture, dissection; and technical problems such as curled, twisted, or stenotic/dissected grafts, allowing for intraoperative revision in the event of graft failure and helping to resolve many unrecognized graft problems.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Bauer SF, Bauer K, Ennker IC, Rosendahl U, Ennker J. Intraoperative bypass flow measurement reduces the incidence of postoperative ventricular fibrillation and myocardial markers after coronary revascularisation. Thorac Cardiovasc Surg 2005;53:217-22.
2. Sanisoglu I, Guden M, Balci C, Sagbas E, Duran C, Akpinar B. Comparison of intraoperative transit-time flow measurement with early postoperative magnetic resonance flow mapping in off-pump coronary artery surgery. Tex Heart Inst J 2003;30:31-7.
3. Mujanovic E, Kabil E, Hadziselimovic M, Softic M, Azabagic A, Bersland J. Transit time flow measurements in coronary surgery: the experience from a new center in Bosnia. Heart Surg Forum 2002;5:233-6.
4. Hu S, Wang X, Song Y, Lu F. Graft patency in off-pump and conventional coronary artery bypass grafting for treatment of triple vessel coronary disease. Chin Med J (Engl) 2003;116:436-9.
5. Stover EP, Siegel LC, Parks R, Levin J, Body SC, Maddi R, et al. Variability in transfusion practice for coronary artery bypass surgery persists despite national consensus guidelines: a 24-institution study. Institutions of the Multicenter Study of Perioperative Ischemia Research Group. Anesthesiology 1998;88:327-33.
6. Leong DK, Ashok V, Nishkantha A, Shan YH, Sim EK. Transit-time flow measurement is essential in coronary artery bypass grafting. Ann Thorac Surg 2005;79:854-7.
7. Di Giammarco G, Pano M, Cirmeni S, Pelini P, Vitolla G, Di Mauro M. Predictive value of intraoperative transit-time flow measurement for short-term graft patency in coronary surgery. J Thorac Cardiovasc Surg 2006;132:468-74.
8. Sönmez B, Arbatli H, Tansal S, Yagan N, Unal M, Demirsoy E, et al. Real-time patency control with thermal coronary angiography in 1401 coronary artery bypass grafting patients. Eur J Cardiothorac Surg 2003;24:961-6.
9. Hirotani T, Kameda T, Shirota S, Nakao Y. An evaluation of the intraoperative transit time measurements of coronary bypass flow. Eur J Cardiothorac Surg 2001;19:848-52.
10. D'Ancona G, Karamanoukian HL, Bergsland J. Is intraoperative measurement of coronary blood flow a good predictor of graft patency? Eur J Cardiothorac Surg 2001;20:1075-7.
11. D'Ancona G, Karamanoukian HL, Ricci M, Schmid S, Bergsland J, Salerno TA. Graft revision after transit time flow measurement in off-pump coronary artery bypass grafting. Eur J Cardiothorac Surg 2000;17:287-93.

12. Jokinen JJ, Werkkala K, Vainikka T, Peräkylä T, Simpanen J, Ihlberg L. Clinical value of intra-operative transit-time flow measurement for coronary artery bypass grafting: a prospective angiography-controlled study. Eur J Cardiothorac Surg 2011;39:918-23.
13. Kjaergard HK. Baseline flow in coronary bypass grafts. J Card Surg 2005;20:205-7.
14. Gwozdziewicz M. Cardiomed coronary flow meter for prevention of early occlusion in aortocoronary bypass grafting. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub 2004;148:59-61.
15. Schmitz C, Ashraf O, Schiller W, Preusse CJ, Esmailzadeh B, Likungu JA, et al. Transit time flow measurement in on-pump and off-pump coronary artery surgery. J Thorac Cardiovasc Surg 2003;126:645-50.
16. Zhuang Y, Chen X, Lua Zq, Xu M, Jiang Ys, Xiao Lq. Evaluation of graft flow between on-pump and off-pump coronary artery bypass grafting. Asian Biomedicine 2012;6:265-71.
17. Walpoth BH, Bosshard A, Genyk I, Kipfer B, Berdat PA, Hess OM, et al. Transit-time flow measurement for detection of early graft failure during myocardial revascularization. Ann Thorac Surg 1998;66:1097-100.
18. Becit N, Erkut B, Ceviz M, Unlu Y, Colak A, Kocak H. The impact of intraoperative transit time flow measurement on the results of on-pump coronary surgery. Eur J Cardiothorac Surg 2007;32:313-8.
19. Groom R, Tryzelaar J, Forest R, Niimi K, Cecere G, Donegan D, et al. Intra-operative quality assessment of coronary artery bypass grafts. Perfusion 2001;16:511-8.
20. Jakobsen HL, Kjaergard HK. Severe impairment of graft flow without electrocardiographic changes during coronary artery bypass grafting. Scand Cardiovasc J 1999;33:157-9.
21. Gwozdziewicz M, Nemec P, Simek M, Hajek R, Troubil M. Sequential bypass grafting on the beating heart: blood flow characteristics. Ann Thorac Surg 2006;82:620-3.
22. Ozkaynak B, Yıldırım O, Aksüt M, Alper OO, Kayalar N, Omeroğlu SN, et al. Very long-term angiographic results of off-pump coronary artery bypass graft surgery. Turk Gogus Kalp Dama 2014;22:260-5.