Revival of Endovascular Visual Assessment of Anastomotic Patency in Coronary Artery Bypass Graft Surgery

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Abstract

Background : Coronary artery bypass graft surgery (CABG) is considered the most performed cardiac surgery nowadays. The outcome of CABG surgery has been linked to several aspects. Above all is graft patency which is a crucial element contributing to success of the surgery. Early graft failure following CABG has been recorded in up to 12% of grafts (left IMA 7%; saphenous vein graft 8%).

Objectives: The aim of the present study was to determine the efficacy and feasibility of the endovascular visualization to detect anastomotic errors.

Patients and methods: The study included 40 patients who presented with CAD and were candidates for coronary artery bypass grafting (CABG). All anastomoses were assessed using 1.9 mm telescope and endovascular visualisation score was recorded followed by routine assessment of grafts quality using transient time flow meter.

Results: In this prospective cross-sectional study, we included a total of forty patients who underwent CABG which enabled intraoperative assessment of the quality of 70 venous grafts. There is a statistically significant correlation between the endovascular visual score and the mean flow across the OM and RCA grafts. For the Diagonal grafts , the correlation was less evident due to the small sample number.

Conclusion: Coronary angioscopy is a simple and safe procedure and provides clinically relevant information. It provides immediate control of anastomotic quality and it can assist in the assessment of the native coronary artery. Together with transient time flowmeter, it provides a new alternative for the quality control of CABG surgery.

Keywords: CABG; Graft ; Patency; Endoscope; Quality Control.

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Introduction

Acute Coronary Syndrome (ACS) and coronary artery disease (CAD) are the leading causes of mortality globally and Disability Adjusted Life Years (DALYs) (**Nowbar et al., 2014**) Nowadays , coronary artery bypass graft surgery (CABG) became the most common performed cardiac surgery . In comparison with Percutaneous Coronary Intervention (PCI), the 4 years follow up after both procedures showed that there was a long term survival benefit with CABG (**Kirtane et al. ,2012**)

The long term outcome following CABG surgery depends on several factors , of utmost importance is the patency of bypass grafts. Accordingly, quality control of the anastomoses has gained attention over the last years to ensure optimal patency of the grafts (**Beerkens et al., 2022**)

Intraoperative graft assessment modalities during CABG include intraoperative coronary angiography (CAG) , thermal coronary angiography (TCA) ,intraoperative fluorescence imaging , endovascular visualization , Transit Time flow measurement (TTFM) and epicardial Doppler ultrasonography (**Ohmes et al,. 2017**) According to the ESC/EACTS guidelines on myocardial revascularization, routine intraoperative flow measurement should be considered (Class IIa, level of evidence B) (**Neumann , 2019**) However, flow measurement has well-known limitations, especially its low positive predictive value. When the flow measurements are suboptimal, differentiation between technical and non-technical reasons

becomes challenging, and evaluation of graft patency with flow measurements only may result in unnecessary revision of the anastomosis (**Hassanein et al., 2019**)

Angioscopy is defined as endoscopic visualisation of the blood vessel. It has been accepted as an intraoperative procedure during cardiac surgery since 1980s. Spears managed to observe the coronary ostia by the use of a fiberoptic bronchoscope from by the brachial artery in 1985 (**Spears et al .,1985**) **.** However, due to technical obstacles at that time, this technique was rarely used and it didn't gain enough popularity. The aim of the present study was to determine the efficacy and feasibility of the endovascular visualization to detect anastomotic errors.

Patients and methods

An approval of the research was obtained from our institution Ethics Committee (ethical code:0201549) and informed consents were gained from all the patients enrolled in the study. We conducted a prospective cross sectional study on 40 patients who presented to Alexandria Main University Hospital and Cardiothoracic House hospital from September 2021 till September 2022 with coronary artery disease undergoing coronary artery bypass grafting (CABG). Patients with no free grafts for CABG were excluded from the study.

All patients were subjected to detailed history taking, clinical examination and routine laboratory investigations. Patients were randomly scheduled for on pump and off pump CABG.

On-pump CABG: The cardiopulmonary bypass machine was primed and set up

according to the standard protocol. The pericardium was opened vertically, and the remnants of thymic tissue and pericardial fat were divided in the midline. Pericardial stay sutures were placed to improve exposure. Aortic and atrial cannulation was performed using curved tip and two-stage cannulas respectively according to the patient's weight. Cardiopulmonary bypass machines with roller-pumps were used in this study. Cardioplegic arrest was achieved using a cooled hyperkalemic blood solution. Distal anastomoses were constructed during a single period of cross-clamping using 7/0 prolene. Upon completion, quality check using endovascular visualization aided by irrigation by clear crystalloid cardioplegic solution and score was given for each graft. Proximal anastomoses were completed during the application of the side biting clamp **(Buxton and Hayward, 2013).**

By the end of the procedure, de-airing was achieved, gradual rewarming was accomplished, and mechanical ventilation commenced. When the patient was separated from CPB, protamine was used for reversal of heparin. The routine assessment of grafts quality using transient time flow meter was used to correlate with the endovascular visualization score.

Off-pump CABG: Conduits were harvested using the same technique of on-pump. Trendelenburg's position was set to aid the exposure of the posterior wall. After harvesting the conduits, the pericardium was incised in an inverted T configuration. To prevent injury of phrenic nerve and to ease cardiac displacement, the incision was extended laterally along the diaphragm. To expose the lateral wall of the left ventricle,

the left lateral pericardium was freed from the diaphragm to allow the pericardium to be retracted to displace the heart. To aid the lateral wall exposure and minimize compression of the right side of the heart during manipulation, the right pericardium was dissected along the diaphragm, or the right pleural space opened widely to allow the heart to fall into the right chest during lateral displacement. Several pericardial sutures were placed to allow the heart to be set in various positions. A deep pericardial suture was placed approximately two-thirds of the way between the inferior vena cava and left pulmonary vein at the point where the pericardium reflects over the posterior left atrium. In patients with severe LM disease and those who poorly tolerated the attempts of manipulation needed to place this stich, LAD anastomosis was completed first before placing this suture. Octopus (Medtronic Inc) and vacuum stabilizer systems were used to minimize the motion of the field **(Lawton et al., 2012)**

All anastomoses were examined using 1.9 mm rigid Richard Wolf GmbH PANOVIEW 8686.414 telescope as shown in (**Fig.1**) mounted to 6 Fr vascular sheath (to be used for irrigation) and introduced through the proximcal part of the free graft with viewing angle 0° . Irrigation with bubble-free crystalloid cardioplegia or normal saline solution was essential not only for visualization but also to decrease contact with grafts endothelium. The endovascular visualization score for each anastomosis was recorded .The score will range from 1 to 4 with the following criteria: 1.Non-functional anastomosis as shown in (**Fig.2**) ; 2.Major anastomotic error (as shown in (**Fig.3**). The

anastomosis is not occluded but must be

3.Suboptimal anastomosis but still
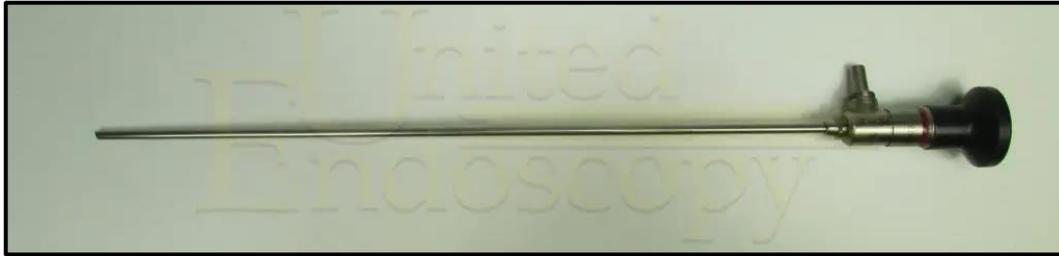
revised if it were in in a real operation ;   acceptable; 4.Good anastomosis (**Fig.4**) .

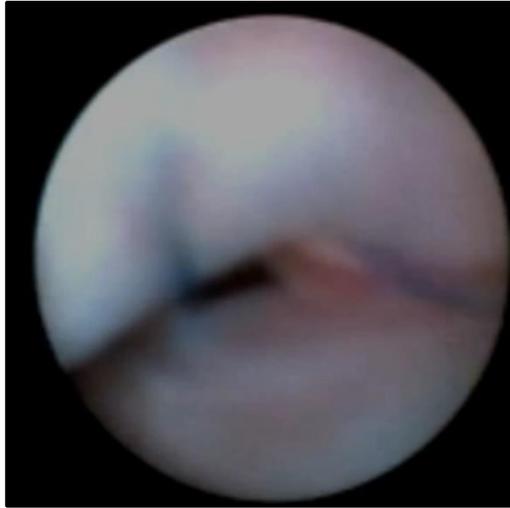**Fig.1.** Richard Wolf GmbH PANOVIEW 8686.414 telescope

Fig.2. Endovascular image of Non-functional anastomosis Score 1

Fig.3. Endovascular image of a major anastomotic error Score 2. Arrow pointing to atheromatous plaque in the floor of the anastomosis

Fig.4. Endovascular image of a well-functioning anastomosis score 1 .
Arrows pointing to prolene suture

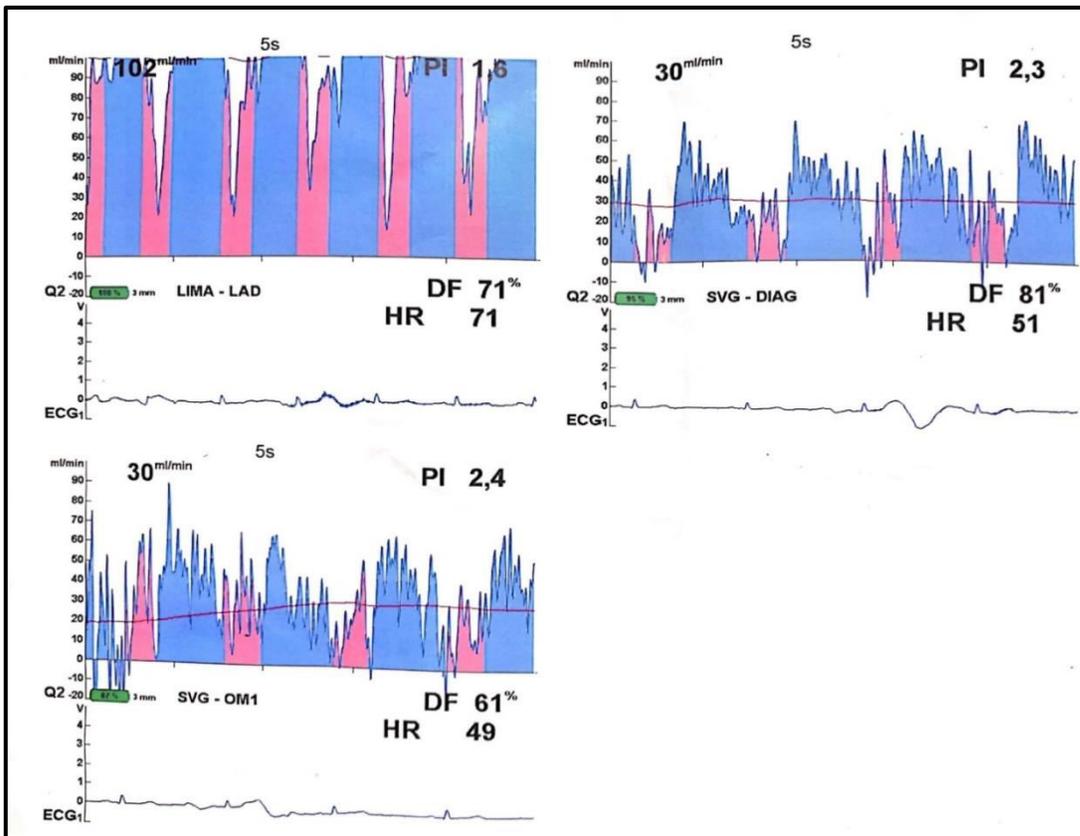**Fig.5.**TTFM of grafts of an OPCAB case.

The routine assessment of grafts quality using transient time flow meter (MiraQ system transit time flow measurement device) was used to correlate with the endovascular visualization score. In the off-pump group, the stabilizer was removed to allow return of the heart to the normal position. The suitable size of the probe was chosen to ensure good coupling

and to prevent over or underestimation of the flow in the vessel under question. The main parameters used to predict graft failure were the mean graft flow (MGF) the pulsatility index (PI) and the diastolic filling index (DFI). The MGF cutoff points vary according to the assessed graft. An MGF of 20 ml/min or greater were considered acceptable values. The pulsatility index is calculated according to the equation; PI = (maximum flow volume - minimum flow volume/mean flow volume). It reflects the vascular resistance. A high PI is a predictor of poor graft quality. A cutoff value of 5 was considered acceptable. The diastolic filling index is calculated as a percentage while synchronizing the ECG signals to detect the diastolic and systolic components of the graft flow waveform. A cutoff point for diastolic flow percentage of 50% or more are considered acceptable (**Fig.5**).

Statistical analysis

Data were analyzed using IBM SPSS software package version 20.0. Qualitative data were described using number and percentage. Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. The significance of the obtained results was judged at the 5% level. The used test was Spearman coefficient to correlate between two distributed abnormally quantitative variables.

Results

Demographic data: The present study included a total of 40 patients of them, were 9 female patients, representing 22.5% from the total. The mean age of the patients ranged from 37 to 75 years with a mean age of 59.32 years.

Operative data : Forty CABG surgeries were performed (21 off pump and 19 on pump), the number of grafts per surgery ranged from 2 grafts up to 4 grafts as shown in (**Table .1**).

Table 1. Distribution of the studied cases according to number of grafts

Number of grafts	No.	%
2	14	35.0
3	22	55.0
4	4	10.0

(**Table .2**) shows the visual score of the grafts as assessed by the endoscope and the measurements of transient time flowmeter. (**Fig.6**) shows descriptive analysis of the studied cases to according to TTFM Q mean in each vessel. (**Fig.7**) shows descriptive analysis of the studied cases to according to visual score in each vessel.

Table 2. Descriptive analysis of the studied cases according to grafts assessment in each vessel

	OM (n = 31)	RCA/Branches (n = 26)	Diagonal/Ramus (n = 13)
PI index			
Min. – Max.	1.20 – 3.70	1.40 – 4.0	1.50 – 3.50

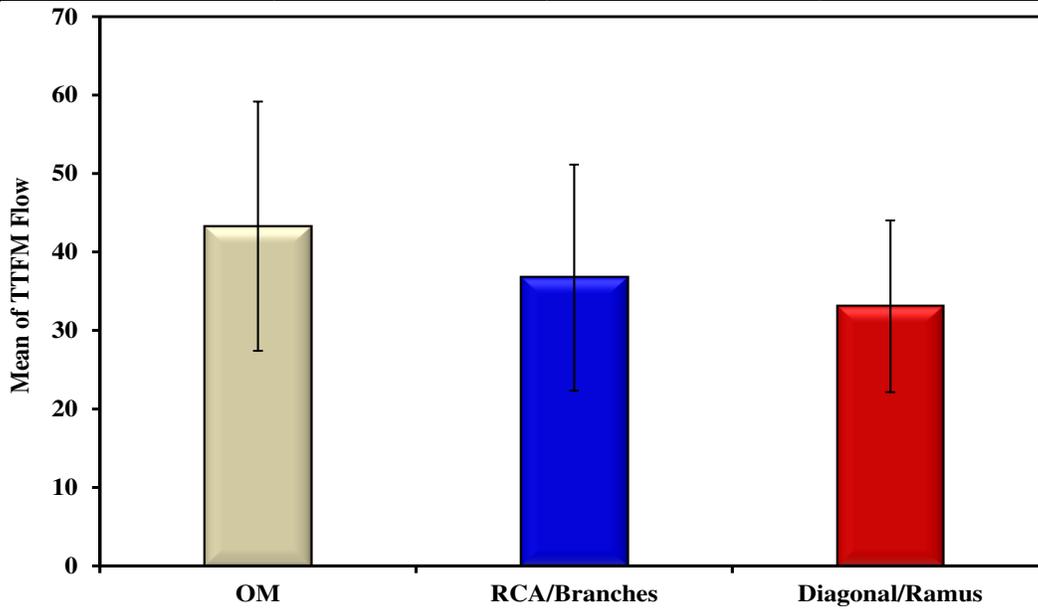| Mean ± SD.	2.15 ± 0.72	2.56 ± 0.90	2.16 ± 0.69
Mean Flow			
Min. – Max.	18.0 – 70.0	12.0 – 70.0	18.0 – 60.0
Mean ± SD.	43.29 ± 15.87	36.73 ± 14.41	33.08 ± 10.95
Visual score			
Min. – Max.	3.0 – 4.0	2.0 – 4.0	2.0 – 4.0
Mean ± SD.	3.81 ± 0.40	3.69 ± 0.55	3.54 ± 0.66

Fig.6. Descriptive analysis of the studied cases to according to TTFM Q mean in each vessel
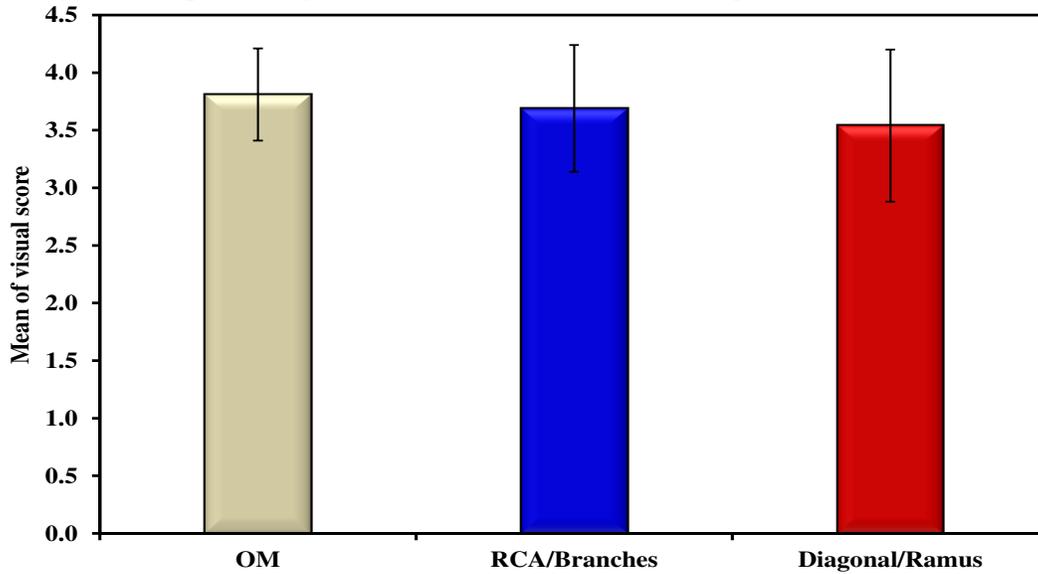

Fig.7. Descriptive analysis of the studied cases to according to visual score in each vessel

(**Table .3**) shows that there is a statistically significant correlation between the endovascular visual score and the mean flow across the OM and RCA grafts. For the Diagonal grafts the correlation was less evident due to the small sample number.

Table 3. Correlation between Visual score with TTFM PI index & TTFM Q mean in each vessel

Variables		OM (n = 31)	RCA/Branches (n = 26)	Diagonal/ Ramus (n = 13)
Visual score vs. TTFM PI index	r_s	-0.664	-0.468	0.003
	p	<0.001[*]	0.016[*]	0.992
Visual score vs. TTFM Q mean	r_s	0.563	0.550	0.346
	p	0.001[*]	0.004[*]	0.247

Intraoperative graft intervention for suboptimal grafts: Three grafts were found suboptimal intraoperatively and required revision (4.28%), two of them were revised after endovascular examination. One graft was regarded suboptimal by endovascular examination and TTFM confirmed graft's failure.

Post operative: Two patients developed postoperative MI (5%), the first patient encountered MI five hours after surgery and IABP was introduced, despite initial improvement ventricular arrhythmias caused mortality in the 2nd post operative day. While the second patient in the first day postoperative, patient hemodynamics were not significantly affected and managed by medical treatment.

Discussion

Endovascular visualization of the coronary anastomosis assures a satisfactory quality in coronary bypass grafting. The routine use of this method can turn it into a simple, easy, and effective method. Furthermore, the direct and clear image of the anastomoses can be stored electronically providing a proof of the anatomical patency of the graft, as well as a training method for junior staff during their training. There are no issues with this technique's safety. Since the scope is inserted under vision and uses saline irrigation to avoid touching the vessel walls, it is even safer than coronary probes. The relative rigidity of this scope is a considerable problem. It is quite challenging to inspect the proximal anastomosis with little flexibility.

Although old (**Litvack et al., 1985; Sanborn et al., 1986 ; Chaux et al., 1986; Bessou et al., 1993**) , this technique hasn't gained enough popularity and the studies regarding this procedure were limited until this technique has been revived by Hassanein et al tempted by the technological advancements in the light source systems. (**Hassanein et al., 2019**).

In 1985 Litvack et al., demonstrated the ability of angioscopies in delivering intravascular laser therapy, he examined fourteen patients undergoing cardiac bypass surgery, sixteen cadaver vascular segments and five dogs. Using a variety of flexible fiberoptic endoscopes with diameters ranging from 1.5 to 3.7 mm, he

was able to see intravascular features such as atheromatous plaques, suture lines, venous valves, and thrombi, without any complications of any sort. Livtack mentioned the poor light delivery impacted images' quality this issue was resolved by the technological advancement in the light source systems improved light intensity and the endoscope itself allowed better magnification and illumination. Livtack concluded that the information provided by angioscopy about anastomotic patency obliviate the necessity for intraoperative angiography (**Litvack et al., 1985**).

Sanborn et al in 1986, studied the viability of the endovascular visualization method to check the saphenous vein graft and native coronary arteries using a 1.7 mm fiberoptic catheter. The fiberoptic nature of the catheter allowed better ergonomics and access through side of the grafts' anastomosis, however images lacked clarity in some instances. To enhance imaging, he advocated vessel distention with a cold crystalloid solution during catheter imaging. The same technique we utilized in our study, in case of on pump surgery we used cold crystalloid cardioplegic solution, but in off pump surgeries small amounts of warm saline to aid the visualization (**Sanborn et al., 1986**).

Chaux et al. (1986) used various sizes of coronary angioscopies of 1.25 to 1.8 mm outer diameter to assess venous grafts and native coronary arteries in 58 patients. They managed to get satisfactory images only in 86% of patients. Owing to the smaller size of the angioscopy they were able to progress more distally and proximally revealing details in the native coronaries that

were unrecognizable by angiography such as atheromatous plaques with adherent thrombi and hemorrhagic ulcerated plaques. The progressive coronary examination was not feasible with our technique owing to the semi rigid nature of the endoscope which could harbor injury to the coronary vascular bed.

Bessou et al., they studied 38 patients with total number of distal anastomoses of 44 were examined revealing 31 grafts stenosis. Remarkably, they realized the presence of some tiny intimal fractures which were attributed to the introduction of the angioscope, these fractures were not elaborated in our study even with the more advanced magnification and better HD quality and avoiding examination of arterial conduits which are more precious and fragile. Moreover, the use of a vascular sheath protecting the grafts from direct contact between the vessel wall and the endoscope (**Bessou et al., 1993**).

The presented study correlated endovascular visualization to Transit-time flow measurement (TTFM) in evaluation of bypass grafts. The endovascular visualization score was not only positively correlated to TTFM MGF but also a negative correlation with the endovascular visualization score and the PI index.

TTFM is a reliable commonly used method to quality control of the graft anastomosis before completion of the surgery. A limitation of TTFM measurement is the deficiency of standard curves and flow values according to various types of grafts and anastomosed vessels. Not to mention, standardization of TTFM findings is not easy due to wide biologic variation among

different patients, and within the same patient **(Leviner et al. ,2021).** Also, there are increasing number of cases with multivessel coronary artery disease being referred for CABG with increased number of patients with sequential grafting **(Jingxing et al., 2019)** . However, there is no predictive value of TTFM for sequential grafting **(Kim et al,2011)**. Endovascular verification of graft patency can be used as an isolated tool or in combination to TTFM to enhance quality control of bypass grafts intraoperatively, because absolute cutoffs for graft failure cannot be established by the MGF and PI since they are highly dependent on the size, integrity, the distal runoff of the target artery, the degree of competitive flow and the type of conduit **(Sandner et al. ,2020)**

 Limitations of the study were limited number of patients, short duration of the study and absence of follow-up.

Conclusion

From the findings of our study, we conclude that coronary angioscopy is a simple and safe technique and provides clinically relevant information. It provides immediate control of anastomotic quality, and it can be of assistance in of the native coronary artery assessment. In combination with transient time flow meter, it provides a new alternative for the quality control of CABG surgery.

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