Transit-Time Flow Measurement of Saphenous Vein Graft Used for Surgery of Acute Type A Aortic Dissection with Coronary Malperfusion.

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journal or publication title	Annals of thoracic and cardiovascular surgery : official journal of the Association of Thoracic and Cardiovascular Surgeons of Asia
volume	28
number	4
page range	271-277
year	2022-08-20
URL	http://hdl.handle.net/10422/00013403

doi: 10.5761/atcs.oa.21-00255(https://doi.org/10.5761/atcs.oa.21-00255)

Ann Thorac Cardiovasc Surg 2022; 28: 271–277
Online April 5, 2022
doi: 10.5761/atcs.oa.21-00255

Original Article

Transit-Time Flow Measurement of Saphenous Vein Graft Used for Surgery of Acute Type A Aortic Dissection with Coronary Malperfusion

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Purpose: Transit-time flow measurement (TTFM), consisting of pulsatility index (PI), mean graft flow, and diastolic filling, is mainly used as a bypass assessment for coronary artery disease (CAD). However, little was known about TTFM in the case of coronary malperfusion (CMP). This study aimed to clarify the difference in the results of TTFM between two different diseases.
Methods: Between 2010 and 2020, 138 patients underwent aortic surgery and coronary artery bypass grafting (CABG) with vein grafts. Patients were divided into two groups: CMP (n = 26) and CAD (n = 27). Their results were compared. The primary endpoints were the results of TTFM. Secondary endpoints were the relation between TTFM and mortality, morbidity, and short-term patency in each group.
Results: The PI in the CMP group was significantly higher than the other group (4.7 ± 2.9 vs. 3.4 ± 1.9, p = 0.04). There was no statistical significance in the other two elements. In both groups, the short-term graft patency, mortality, and morbidity but for cardiac tamponade did not significantly change depending on the TTFM results.
Conclusions: Patients with CMP tended to have a higher PI than those with CAD. With additional CABG for aortic dissection, insufficient TTFM results did not necessarily mean poor short-term graft patency, complications, or case mortality.

Keywords: acute type A aortic dissection, malperfusion syndrome, transit-time flow measurement, coronary artery bypass grafting

Introduction

Coronary malperfusion (CMP) is a rare but lethal complication of acute type A aortic dissection (ATAAD),[1] and coronary artery bypass grafting (CABG) remains the optimal treatment. It is important to evaluate graft quality during surgery. Transit-time flow measurement (TTFM) device (Medistim Inc., Oslo, Norway) is widely used for intraoperative graft evaluation.

On the other hand, compared to CABG for coronary artery disease (CAD), TTFM usage for CMP was poorly understood. This study compared the data of TTFM of patients undergoing aortic surgery and CABG and compared their mortality, morbidity, and short-term patency for both patients with CMP and those with CAD.

Patients and Methods

The Japan Cardiovascular Surgery Database was searched for all patients who had undergone aortic

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Received: November 29, 2021; Accepted: March 6, 2022
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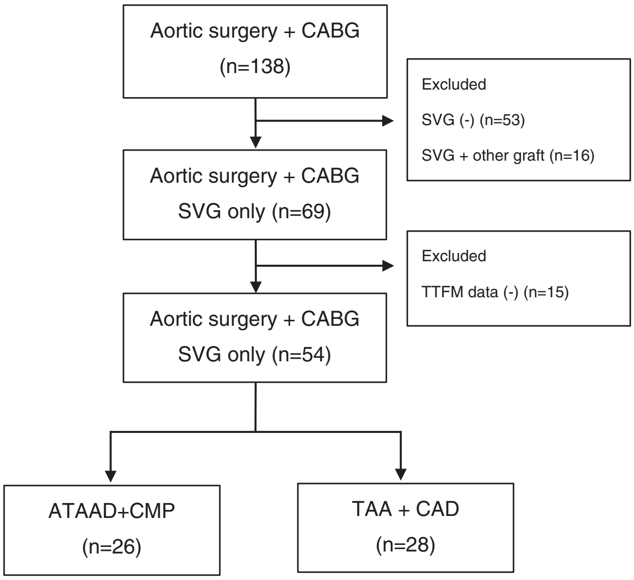

Fig. 1 Patient selection flowchart. CABG: coronary artery bypass grafting; SVG: saphenous vein graft; TTFM: transit-time flow measurement; ATAAD: acute type A aortic dissection; CMP: coronary malperfusion; TAA: thoracic aortic aneurysm; CAD: coronary artery disease

surgery and CABG at Shiga University of Medical Science from 2010 to 2020. This search yielded 33 patients with ATAAD complicated with CMP. The database was also searched for patients who had undertaken operation for aortic aneurysm and CAD (n = 105). Among all these 138 patients, patients without saphenous vein graft (SVG) (n = 53), patients using SVG and internal thoracic artery/gastroepiploic artery as a graft (n = 16), and patients without TTFM or other data (n = 16) were excluded. Finally, there were 53 patients who underwent aortic surgery and CABG with SVG alone. They were divided into two groups (**Fig. 1**):

CMP group (26 patients, 29 anastomoses): patients underwent aortic surgery and CABG for ATAAD complicated with CMP. Three patients had two anastomoses. All operations were performed as an emergency operation.

CAD group (27 patients, 29 anastomoses): patients underwent aortic surgery and CABG for aortic aneurysm and CAD. Two patients had two anastomoses. All operations were done as elective surgery.

Patients who had two anastomoses were counted for each anastomosis. Primary end points included as follows: mean graft flow (MGF) volume (mL/min), pulsatility index (PI) (maximum flow volume - minimum flow volume)/(mean flow volume), and diastolic filling (DF) (flow volume of the diastolic phase)/(flow volume of the systolic phase + flow volume of the diastolic phase). Secondary end points were short-term graft patency, mortality, and postoperative major complications including reintubation, stroke, coma, paraparesis, cardiac tamponade, and atrial fibrillation.

As previously reported,[2,3] we defined "Abnormal" TTFM as a graft having at least one of the following: MGF <15 mL/min, PI >5.0, or DF <50%. The other was defined as "Normal."

Surgical technique and findings

As for elective surgery, preoperative examinations were performed. On the other hand, in the case of ATAAD, all operations were performed as an emergency without delay.

The operation started with median sternotomy and standard extracorporeal circulation.[4] Ascending aorta or axillary artery or femoral artery was used as the arterial cannulation site, and superior and inferior vena cava were used for venous drainage. Retrograde cardioplegia was performed via the coronary sinus. At a tympanic temperature of about 25°C, circulatory arrest was achieved, and then, the ascending aorta was incised. After the aorta incision, the first retrograde cardioplegia was injected, and cardiac arrest was achieved. Selective cerebral perfusion was used for arch replacement. After circulatory arrest, distal anastomosis was performed, and then, antegrade systemic circulation was started via the side branch of the prosthesis graft. In the CMP group, dissected layers were manually glued with glue before proximal anastomosis, and then, coronary circulation started after removing air bubbles. The open harvest technique was used for SVG harvesting. Distal anastomosis of CABG was performed at first, and then, SVG was anastomosed into the vascular prosthesis. Before chest closure, TTFM was measured under stable hemodynamics. The probe size was 3 mm or 4 mm. If intra-aortic balloon pumping was used, it was stopped during measurement.

If the result of TTFM was not sufficient, the anastomosis was morphologically observed by ultrasonography. If there was no anastomotic problem, reanastomosis was not done. The patency of the vein graft was confirmed by contrast-enhanced computed tomography (CT) during hospital stay (8–35 postoperative days). Postoperative CT was not performed for patients with severe renal dysfunction. For the morphology of CMP, we referred the Neri et al.'s classification (**Fig. 2**).[5]

Statistical analysis

We analyzed all data with Statistical Package for the Social Sciences software version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive data were presented as

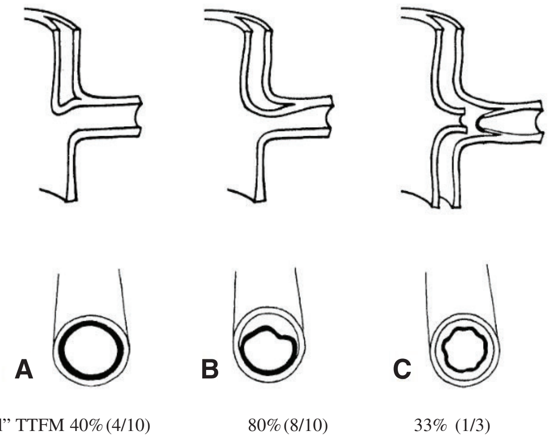

Fig. 2 Neri et al.'s classification and rate of "Abnormal" TTFM result. Type A: ostial dissection, type B: dissection with a coronary false channel, and type C: circumferential detachment with an inner cylinder intussusception. "Abnormal" TTFM rate was 40%, 80%, and 33% in type A, B, and C, respectively (based on Neri E, Toscano T, Papalia U, et al. Proximal aortic dissection with coronary malperfusion: presentation, management, and outcome. J Thorac Cardiovasc Surg 2001; **121**: 552-60). TTFM: transit-time flow measurement

counts (percentages), normally distributed data as mean ± standard deviation, and skewed data as median (25th–75th quartile). Normality was assessed by the Kolmogorov–Smirnov test. We used the t-test to compare quantitative data, and the Fisher's exact test and the χ^2 test to compare proportions. All p-values <0.05 were considered statistically significant. No matching was performed because the patient background was different.

Results

Preoperative patient background and operative data are presented in **Table 1**. Both groups had a male predominance (73% vs. 70%). A higher proportion of CMP group patients had a preoperative acute myocardial infarction (p <0.01), shock condition before operation (p <0.01), and cardiopulmonary resuscitation before operation (p = 0.04). On the other hand, a greater proportion of CAD group patients had preoperative angina pectoris (p <0.01), more medications than those in the CMP group (p <0.01).

Among the patients in the CMP group, ascending aorta replacement was the most frequent aortic surgery (22/26, 85%). On the other hand, total arch replacement was the most frequent aortic surgery (16/27, 59%) in the CAD group. A higher proportion of CAD group patients had concomitant procedures (8% vs. 41%). There was statistical significance in mean operative time (260 ± 80 minutes vs. 309 ± 79 minutes, p <0.01), mean cardiopulmonary bypass time (155 ± 60 minutes vs. 172 ± 48 minutes, p <0.01), and mean circulatory arrest time (22 ± 9 minutes vs. 35 ± 16 minutes, p <0.01).

Results of TTFM between the two groups are listed in **Table 2**. There was no statistical difference in MGF between both groups (50.3 ± 27.0 vs. 52.6 ± 30.0, p = 0.71). However, patients in the CMP group had a higher PI (4.7 ± 2.9 vs. 3.4 ± 1.9, p = 0.04) and a higher percentage of "Abnormal" TTFM (55.2% vs. 24.1%, p = 0.02) than those in the CAD group.

Postoperative data of enhanced CT were available for 80% (n = 21) of patients in the CMP group and 78% (n = 21) of patients in the CAD group. No CAD was observed in the postoperative CT in the CMP group. **Table 3** shows the relationship between TTFM and mortality, morbidity, and short-term patency in each of the "Normal" and "Abnormal" TTFM groups. There was no statistical difference in mortality and morbidity between "Normal" and "Abnormal" TTFM patients in the CMP and CAD groups. Only patients in the CMP group with "Normal" TTFM had an increased rate of cardiac tamponade compared to those with "Abnormal" TTFM results (p = 0.04). In the CMP group, 14.3% (3/21) of the patients had graft occlusion, and there was no statistical significance in the occlusion rate between "Normal" and "Abnormal" TTFM patients (88.9% vs. 83.3%, p = 0.88). Similarly, in the CAD group, 10.0% (2/21) of patients had graft occlusion, and there was also no significant difference in the occlusion rate, regardless of whether TTFM was "Normal" or "Abnormal" (87.5% vs. 100%, p = 0.55).

Discussion

Previously, there were reports about the usefulness of TTFM for graft evaluation about CABG for CAD.[6,7] Since CMP has a different pathophysiology from CAD, it is unknown whether the TTFM of the CAD patients can be used for graft evaluation in the CMP patients. However, the number of cases of CMP was much smaller than that of CAD, and it was not easy to obtain TTFM data. This time, we examined the results of TTFM of bypass surgery using SVG to clarify how the TTFM data in the CMP group differ from those in the CAD group.

CMP, occurring in approximately 7% of ATAAD cases, is an independent predictor of mortality.[1] Sometimes, additional CABG is required to treat CMP concomitant with aortic surgery for ATAAD. During

Table 1 Patient background

	CMP (n = 29)	CAD (n = 29)	p
Age	64.6	75	0.09
Height	166.8	159.5	0.21
Weight	68.5	60	0.46
Male	19 (73%)	19 (70%)	0.76
Smoking	12	21	0.02
Diabetes mellitus	5	11	0.08
Hyperlipidemia	12	12	1
Dialysis	1	3	0.3
Hypertension	20	25	0.11
COPD	1	5	0.09
History of PCI	5	6	0.73
History of cardiac surgery	5	6	0.73
Angina pectoris	6	21	<0.01
Acute myocardial infarction	18	2	<0.01
Shock	11	0	<0.01
Cardiopulmonary resuscitation	4	0	0.04
Atrial fibrillation	2	3	0.64
Preoperative medication			
Beta blocker	4	7	<0.01
CCB	4	14	<0.01
ARB	1	15	<0.01
Antiplatelet	0	15	<0.01
Statin	4	12	<0.01
Loop diuretics	0	6	<0.01
Target vessel	(n = 29)	(n = 29)	
RCA only	13	13	N/A
LAD only	8	5	N/A
Cx only	2	2	N/A
PD, Cx	0	3	N/A
PD, Dx	0	1	N/A
PD, Dx, OM	0	1	N/A
LAD, Dx	2	1	N/A
Dx, OM	1	0	N/A
LAD, PD	0	1	N/A
Concomitant operation			N/A
AVR	0	7	N/A
MAP	0	1	N/A
ASD closure	1	0	N/A
Open stent	0	2	N/A
Maze procedure	0	1	N/A
Stent removal	1	0	N/A
Operation			N/A
AAR	22	8	N/A
Root	0	3	N/A
TAR	3	16	N/A
TAR + root	1	0	N/A
Operative time	260 ± 80	309 ± 79	<0.01
CPB time	155 ± 60	172 ± 48	<0.01
CA time	22 ± 9	35 ± 16	<0.01

CMP: coronary malperfusion; CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease; PCI: percutaneous coronary intervention; CCB: calcium channel blocker; ARB: angiotensin receptor blocker; RCA: right coronary artery; LAD: left anterior descending coronary artery; Cx: left circumflex branch; Dx: diagonal branch; PD: poster descending branch; OM: obtuse marginal branch; AVR: aortic valve replacement; MAP: mitral valve annuloplasty; ASD: atrial septal defect; AAR: ascending aorta replacement; TAR: total arch replacement; CPB: cardiopulmonary bypass; CA: circulatory arrest; Root: root replacement; N/A: not applicable

Table 2 TTFM data

	CMP	CAD	p
MGF	50.3 ± 27.0	52.6 ± 30.0	0.71
PI	4.7 ± 2.9	3.4 ± 1.9	0.04
DF	54.6 ± 16.6	60.0 ± 10.1	0.15
HR	97.7 ± 19.6	88.1 ± 13.6	0.04
"Abnormal" TTFM	16 (55.2%)	7 (24.1%)	0.02
"To and fro" waveform	14 (48%)	14 (48%)	NS

"Abnormal" TTFM denotes at least one of the following: MGF <15 mL/min, PI >5.0, or DF <50%. CMP: coronary malperfusion; CAD: coronary artery disease; TTFM: transit-time flow measurement; MGF: mean graft flow volume; PI: pulsatility index; DF: diastolic filling; HR: heart rate; NS: not significant

Table 3 Relation between the TTFM results and mortality, morbidity, and short-term patency

CMP group	"Normal" (n = 13)	"Abnormal" (n = 16)	p
Mortality	3	3	0.78
Morbidity	7	7	0.61
Reintubation	2	1	0.42
Stroke	3	7	0.24
Coma	2	4	0.52
Paraparesis	1	2	0.67
Cardiac tamponade	3	0	0.04
Atrial fibrillation	0	2	0.18
Short-term patency	8/9 (89%)	10/12 (83%)	0.88
CAD group	"Normal" (n = 22)	"Abnormal" (n = 7)	
Mortality	1	0	0.57
Morbidity	4	1	0.81
Reintubation	1	0	0.57
Stroke	2	0	0.41
Coma	2	0	0.41
Paraparesis	0	0	NS
Cardiac tamponade	0	0	NS
Atrial fibrillation	1	0	0.57
Short-term patency	14/16 (88%)	5/5 (100%)	0.55

TTFM: transit-time flow measurement; CMP: coronary malperfusion; CAD: coronary artery disease; NS: not significant

emergency operation, fast and easy intraoperative graft evaluation is important to minimize the operative time. Among various ways of graft evaluation (direct contrast, indocyanine green angiography, electromagnetic flowmeter, Doppler echocardiogram, etc.), TTFM can evaluate graft flow less invasive and less time consuming. In addition, it is independent of diameters of vessels, the angle between the probe and vessels, hematocrit, and does not require calibration.

This study revealed that compared to patients with CAD, those with CMP tended to have worse TTFM results (24% vs. 55%, p = 0.02). Proximal stenosis is an important factor for MGF.[8,9] However, the most significant difference between the CAD and CMP groups was the difficulty of evaluating the degree of stenosis preoperatively by coronary angiogram (CAG). In the case of CMP, proximal stenosis is made by not arteriosclerosis but aortic dissection. Neri et al. made a classification of CMP according to a morphological difference of dissection (**Fig. 2**).[5] Notably, 80% of patients of Neri et al.'s type B CMP had "Abnormal" TTFM. On the other hand, those with type C CMP had a lower percentage of insufficient graft. The result that the rate of "Abnormal" TTFM was different for each type of Neri et al.'s classification suggested that morphologically there would be a difference in coronary artery among each type even after completion of central repair. The timing of coronary artery evaluation is also essential. It would be better if the degree of stenosis could be evaluated before surgery, but in the case of CMP, the degree of proximal stenosis varies time dependently. For example, the native flow of the coronary artery would differ due to the wall flap movement of the aorta. Besides, aortic dissection may develop over time. As for CAD, preoperative CAG-guided or fractional flow reserve-guided CABG would improve outcomes.[10] However, it is dangerous to perform preoperative CAG to measure the degree of stenosis for patients with CMP accurately. Surgeons must decide to perform CABG based on clinical findings, even if CAG was not available.

The CABG graft assessment is complex. Among the various graft evaluations, the following was known for TTFM. The lower MGF and higher percentage of backward flow were predictors of short-term and mid-term graft failure.[7,11] D'Ancona et al. reported that PI >5 was a predictive factor of graft failure and perioperative death.[12] The cause of increasing PI was not well understood. However, the quality of anastomosis would be the one reason. Considering that all operations in the CMP groups were emergency operations, we assumed that the quality of anastomosis in the CMP group would be lower than that in the CAD group done as elective operations. The condition of emergency surgery should be taken into account when assessing the PI. Since there is no difference in early graft patency and the top priority of emergency surgery for ATAAD was saving the life, performing reanastomosis is not always necessary, even if the PI is low.

It was reported that the actual TTFM results were influenced by vascular resistance of coronary arteries, graft diameter, and vascular bed of target vessels.[13] In this study, the right coronary artery and left anterior descending artery were the first and second most common target arteries. The vascular beds are different between both the right and left coronary arteries. Therefore, the results of TTFM may also be affected by the right or left coronary artery. Further studies are required to find more detailed data for each coronary artery.

Limitations

The limitations of this study include its retrospective study, the single-center database, and the lack of randomization. Moreover, preoperative information about CAD in the CMP group was unknown. However, there was no past history of angina pectoris in the patients of the CMP group as far as we searched. Another limitation is the lack of mid-term or long-term patency. However, it is clear to mention that the top priority of surgery for ATAAD is lifesaving. Since the surgical purpose of CABG for CMP is also free from sudden death, short-term patency is more important than long-term patency.

Conclusion

The CMP group had significantly higher PI than the CAD group, but there was no statistical significance in MGF and DF between both groups. Although a greater proportion of patients of the CMP group had "Abnormal" TTFM results, there was no statistically significant difference between "Abnormal" TTFM and short-term graft patency, mortality, and morbidity but for cardiac tamponade.

Informed Consent

Not applicable.

Ethical Approval

The ethics committee of our institute approved this study (REC number: R2019-209).

Disclosure Statement

None declared.

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