The preoperative myocardial perfusion and internal mammary artery graft blood flow relationship in patients with ischemic cardiomyopathy

Sergey S. Gutor
Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Academy of Sciences
Sergey L. Andreev
Cardiology research institute, Tomsk National Research Medical Centre, Russian Academy of Schiences
Vladimir V. Shipulin (shipartphoto@gmail.com)
Tomsk National Research Medical Center, Russian Academy of Sciences https://orcid.org/0000-0001-9887-8214
Andrey V. Mochula
Cardiology Research Institute, Tomsk National Research iMedical Centre, Russian Academy of Sciences
Vasiliy V. Zatolokin
Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Avademy of Sciences
Andrey S. Pryahin
Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Academy of Sciences
Vladimir M. Shipulin
Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Academy of Schiences
Boris N. Kozlov
Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Academy of Sciences
Konstantin V. Zavadovsky
Cardiology Research Institute, Tomsk National Research Medical Centre, Russian Academy of Sciences

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Abstract

Objective. The purpose of this study was to determine whether myocardial perfusion in stress/rest conditions estimated by SPECT can be used to predict transit time blood flow characteristics and early graft failure in left internal mammary artery (LIMA) to left anterior descending artery (LAD) grafts in patients with ischemic cardiomyopathy.

Methods. The study group consisted of 47 patients with ischemic cardiomyopathy. Intraoperative transit-time flow measurement (TTFM) of LIMA to LAD grafts were performed in all patients. All patients were also examined with preoperative stress and rest myocardial perfusion SPECT with ^{99m}Tc-MIBI. Anastomotic patency was considered satisfactory with a normal waveform of blood flow, diastolic-dominant blood filling, and a mean flow value greater than 11.5 ml/min.

Results. All 47 patients with LIMA to LAD grafts were divided into two groups; those with graft satisfactory patency (n=40) and those with unsatisfactory patency (n=7) as determined by TTFM. We found differences among these groups in global summed rest score (t=3.7, p=0.003), total perfusion deficit (t=3.0, p=0.014), and LAD territory TPD (t=2.4, p=0.04) characteristics in preoperative rest myocardial perfusion SPECT imaging. Additionally, the flow characteristics were different in patients with and without surgical left ventricle reconstruction (U=153.5, p=0.012).

Conclusions. Preoperative myocardial perfusion characteristics have associations with blood flow in LIMA to LAD graft in patients with ischemic cardiomyopathy and LAD territory rest TPD have the potential to be a predictor of early graft failure.

Introduction

Coronary artery bypass grafting (CABG) is a widely used treatment for coronary artery disease (CAD), and it is mandatory for patients with ischemic cardiomyopathy (ICMP). While most chronic atherosclerotic narrowing of coronary arteries can be successfully bypassed, revascularization failures do happen [1, 2]. Thus, the literature suggests that roughly 10% of all by-pass grafts occluded in the short-term and some of the authors call graft patency the "Achilles heel" of CABG [3, 4].

Graft patency is influenced by many factors including intramyocardial tension, graft conduits and design (Y and T configuration), graft destination artery, and pacing modality and atrioventricular delay value [5].

Thus, internal mammary arteries (IMAs) are frequently used for CABG as the most reliable conduit. It is very crucial to select coronary artery for IMAs graft carefully because in some cases internal graft flow might be low by severe vasoconstriction or morphological state of the target artery myocardium territory and lead to graft failure in the end [6–8].

Until recently, there was not an "on-table" complete and user-friendly technique for graft patency assessment which would not drastically increase operation time. Transit-time flow measurement (TTFM), however, became such a method. Before the early 2000s, some scientists had questioned the capabilities of this method and then TTFM became the most common intraoperative small variable method of assessing graft function [9]. In 2010 it was included in the ESC (European Society of Cardiology) and EACTS (European Association for Cardio-Thoracic Surgery) Guidelines on myocardial revascularization (it is present in the version of 2018) [3, 10–15].

However, there is an ongoing dispute about the cut-point values for this method in modern literature and many researchers are trying to find cut-point value for each conduit type. For arterial conduits, H. Oshima et al (2016), for example, set the mean flow (Q) value at 11.5 ml/min as the cut-off value between satisfactory and not-satisfactory grafts [1].

Despite recurring studies of the topic, L. Niclauss critical review (2017) suggests the influence of quantity (vessel territory distribution) and quality (myocardial morphological state) of the graft perfusion area on TTFM and conduits outcome have not included by anyone and should be studied [16]. In eComment to H. Oshima et al. article, N. Hudorovic suggest preoperative SPECT as useful to predict the regional functional recovery in the akinetic area after CABG, but only 29% of patients underwent preoperative SPECT in the study [1]. Moreover, routinely used preoperative SPECT with and without stress can provide doctors and medical scientists with vital information about coronary vessel perfusion area, including stable (most probably post-infarction scar) and unstable (ischemic) defects. This study investigated whether myocardial perfusion in stress and rest conditions estimated by SPECT can be used to predict blood flow characteristics and early graft failure in LIMA to LAD grafts in patients with ICMP.

Materials And Methods

Study population

The study group comprised of 47 consecutive patients (mean age 61.1±5.1 years, 95.7% male) with ICMP, who underwent CABG with LIMA to LAD graft and left ventricle (LV) reconstruction according to standard indications [17]. Within a week of surgery, stress and rest myocardial perfusion SPECT with ^{99m}Tc-MIBI and interoperation TTFM of LIMA grafts were performed on all patients.

Inclusion criteria were: 1) at least 3 months after acute myocardial infarction; 2) ≥75% stenosis of left main or proximal left anterior descending artery (LAD) or ≥75% stenosis of two or more major epicardial vessels; 3) left ventricular ejection fraction (EF) ≤40%; 4) left ventricular end-systolic index ≥60 ml/m2 (by transthoracic echocardiography) [17].

Exclusion criteria were: 1) rheumatic or inflammatory heart disorders; 2) acute coronary syndrome; 3) recent (< 6 months) cerebral ischemic attack; 4) acute or chronic right ventricle failure (by transthoracic echocardiography); 5) severe pulmonary hypertension; 6) contraindications for cardiopulmonary bypass; 7) contraindication to adenosine administration.

The study was approved by the Local Ethical Committee and conformed to the Declaration of Helsinki on Human Research. Written informed consent was obtained from each patient after explanation of the protocol, its aims, and potential risks.

Surgical technique

All operations were performed under conditions of norm-thermal cardiopulmonary bypass standard procedure. A great saphenous vein and a LIMA were harvested according to the routine procedure, the last one was wrapped with papaverine solution in surgical drape to prevent spasms [18].

In all cases, the LIMA was grafted to the left anterior descending artery and the great saphenous vein was sewn for other target vessels. No sequential anastomoses were included in this series. The LV reconstruction using the D. Cooley or V. Dor method with L. Menicanti modification was made in the case of an LV aneurysm based on preoperative examination and intraoperative evaluation [19, 20].

Coronary angiography

Quantitative coronary angiography was performed after catheterization of the femoral artery by the Seldinger's technique on the Axiom Artis coronary angiography system (Siemens; Erlangen, Germany) in a single scheme: a multi-projection right then left coronary angiography according to the method of M. Judkins [21]. All coronary angiographies were done during the preoperative period.

TTFM and evaluation criteria for anastomosis satisfactory

Transit-time flow measurement was performed with VeriQ System (Medi-StimAS, Oslo, Norway) after all anastomoses, ventricle and valves reconstructions were completed, the heart-lung machine was disconnected and hemodynamic parameters became stable (mean arterial pressure fixed of 75-85 mmHg) [3, 22]. Flow parameters recorded in this study included mean graft flow (Q, ml/min), higher pulsatility index (PI), and diastolic filling (DF, %).

A Q value greater than 11.5 ml/min, a normal waveform of blood flow, and diastolic-dominant blood filling was considered as a surrogate marker for satisfactory anastomotic patency [1].

Myocardial perfusion imaging

Patients were instructed to refrain from caffeine, substances containing methylxanthine, and to avoid nitrates, calcium channel blockers, and beta-blockers for at least 24 h before the scan. All scans were performed after overnight fasting.

All patients underwent a 2-day stress/rest protocol. A pharmacological stress-test (adenosine, 140 mg/kg/min for 6 minutes) combined with low-level exercise was performed in all patients [23]. The heart rate, systemic blood pressure, and 12-lead electrocardiogram were monitored before, during, and after the stress test. A dose of 370 MBq of ^{99m}Tc-sestamibi was injected after 3 minutes of stress testing and the same dose on the next day for rest study like described in ASNC guidelines for SPECT nuclear cardiology procedures [23]. Pharmacologic stress testing did not lead to atria-ventricle (AV) conduction delay and/or to ST-segment depression in any patient. The total effective radiation dose was 6-7.3 mSv.

The SPECT data were acquired one hour after injection for both the rest and the stress studies with a solid-state detector CZT cardiac SPECT/CT system (GE Discovery NM/CT 570c). The acquisition time was 7 minutes. The myocardial perfusion imaging (MPI) scans were acquired using low energy multi-pinhole collimator and 19 stationary detectors which simultaneously imaged 19 different views without detector rotation. The acquisition matrix was 32×32 pixels (pixels sizes 4×4×4 mm). Each detector contains 32×32 pixelated (2.46×2.46 mm) CZT elements. A 20% energy window at 140 keV was used. Patients were imaged in the supine position with arms placed over their heads.

CZT images were reconstructed on the dedicated workstation (Xeleris 4.0; GE Healthcare, Haifa, Israel) using maximum-penalized-likelihood iterative reconstruction (60 iterations; Green OSL Alpha 0.7; Green OSL Beta 0.3) to acquire perfusion images in standard cardiac axes (short axis, vertical long axis, and horizontal long axis). The software Myovation for Alcyone (GE Healthcare, Haifa, Israel) was used for image reconstruction, and Butterworth post-processing filter (frequency 0.37; order 7) was applied to the reconstructed slices. The reconstruction was performed in a 70×70 pixels matrix with 50 slices.

MPI interpretation

Raw MPI-CZT data at stress and rest were visually assessed for motion and attenuation artifacts. Stress/rest images were analyzed with a commercially available software package Cedars QGS/QPS (Cedars-Sinai Medical Center, Los Angeles, CA, USA).

Left ventricle myocardium was presented in a 17-segment polar map format and was computed separately for each vascular territory by the AHA guidelines [24]. Each of the 17 segments was scored based on a semi-quantitative 5-point scoring system: 0 – normal uptake; 1 – mild uptake reduction; 2 – moderate uptake reduction; 3 – severe uptake reduction; and 4 – an absence of radiotracer.

Myocardium perfusion was assessed globally (Global) and from left anterior descending artery (LAD) territory by following parameters: summed stress score (SSS), summed rest scores (SRS), summed difference score (SDS, was calculated as the difference between SSS and SRS), stress TPD (STPD), rest TPD (RTPD), TPD difference (DTPD, was calculated as the difference between STPD and RTPD) [24, 25, 26].

Statistical analysis

The distribution of continuous variables was checked by using the Shapiro-Wilk's W-test. Normally distributed continuous variables were presented as the mean ± standard deviation and not normally distributed parameters were shown as the median and interquartile range (Q25, Q75). Categorical variables were presented as numbers and percentages. Group comparisons were analyzed with Student t-test or the Mann—Whitney U-test for continuous variables, and the χ2 or Fisher's exact test for categorical variables. The Spearman test was used to estimate the correlation coefficient between quantitative variables. The receiver-operating-characteristic (ROC) curve analysis was performed to evaluate the sensitivity and specificity of tests. Areas under the ROC curves were compared using the DeLong method. A value of $p<0.05$ was considered statistically significant. All analyses were performed using SPSS statistical software 19.0 (SPSS Inc., Chicago, IL, USA) and MedCalc version 17.4 (MedCalc Software, Mariakerke, Belgium).

Results

Clinical Outcomes

The characteristics of the study groups are presented in Table 1. In 12 cases intra-aortic balloon counterpulsation was used intraoperatively or in the early postoperative period for circulatory assistance. The early mortality rate (within 30 days after surgery) was 11% (5/47). The causes of early death were associated with acute heart failure in four cases and gastrointestinal bleeding in one case.

Coronary angiography results

The stenosis of the main left coronary artery ranged from 40 to 75% was found in 8 cases. There were chronically totally occluded (CTO) left descending artery in 20 cases (42.6%), more than 75% stenosis in 21 cases (44,7%), and less than 70% in 6 cases (12.7%). There were the following numbers of cases with stenosis in range 30 to 100 percentage: median artery in 4 cases, a diagonal branch of LAD in 16 cases, left circumflex artery in 9 cases, left marginal artery in 28 cases, a right coronary artery in 24 cases, a posterior descending artery in 11 cases.

The results of CABG

There were two cases of LIMA to LAD graft only, two grafts in 13 cases, three grafts in 24 cases, and more than three in the last 8 cases.

All 47 patients with LIMA to LAD grafts were divided into two groups: with graft satisfactory patency (Group 1, n=40, 85%) and not-satisfactory patency (Group 2, n=7, 15%) by TTFMs (cut-off value for Q = 11.5 ml/min).

Transit-time flow measurement

The blood flow characteristics in the grafts are presented in Table 2. Patient groups had a statistically significant difference in the pulsatory index (PI). The Q had correlations with PI ($r=-0.613$, $p<0.001$) and diastolic flow ($r=0.418$, $p=0.003$) values.

Despite the presence of LAD CTO in 20 cases, we did not find a statistically significant difference in flow measurements between patients with and without LAD CTO, and further analysis was carried out without division on that basis. The flow characteristics were different in patients with and without surgical left ventricle reconstruction (Table 3).

SPECT myocardial perfusion imaging

All patients had at least 3 segments with abnormal myocardial perfusion. We found differences for both global and LAD territory myocardial perfusion characteristics only on rest MPI but not on stress (Table 4). The representative examples of myocardial SPECT with satisfactory and not-satisfactory TTFM are presented in Fig. 1.

According to the ROC analysis, TPD (rest) was the best predictor of the LIMA to LAD graft satisfactory: area under curve = 0.771, cut-off value = 26.85 with 83.3% sensitivity and 78.1% specificity.

The correlations between LIMA to LAD graft flow TTFMs with global and LAD territory MPI parameters are presented in Fig. 2.

Discussion

The preoperative rest myocardial perfusion in LAD territory can predict unsatisfactory blood flow in LIMA grafts in ICMP patients. Perfusion defect estimated as global and LAD territory SRS and TPD by rest myocardial SPECT with the necessity of SVR reasoned by apex/anterior LV aneurysm may lead in ICMP patients to low transit time flow measurements in LIMA to LAD grafts and consequently to graft failure.

TTFM is influenced by many factors, including vasoconstriction, graft diameter, perfusion area, morphological myocardial state, myocardial viability, myocardial oxygen consumption, blood pressure, and coronary vascular resistance [5]. Some of them will appear during or after the operation, but another part exists before the operation. The assessment of rest myocardial perfusion by SPECT before operation allows a surgeon to avoid a coronary vessel for LIMA graft destination with a high risk of graft occlusion via vessel territory TPD more than 26.85.

TTFM and graft patency

Despite all coronary grafts occlude in no less than in 30% by 1 year [27] it strongly depends on graft type. Thus, there were only 7% in H. Oshima's et al (2016) and 6.5% in P. Lehnert et al (2014) studies of failed artery grafts [1]. However, it was 15% of LIMA grafts with mean flow less than 11.5 ml/min in our investigation which can be explained with worse preoperative conditions of ICMP patients.

The low TTFM characteristics are correlated with the risk of LIMA graft failure at the one-year angiographic follow-up [13]. Even in the earliest studies, the pulsatory index was shown as a promising parameter (while there was no Q) it turned out that a significant difference was shown in Q between patent and non-patent grafts, but not in pulsatory index or diastolic flow [28].

According to the literature, the Q for non-satisfactory arterial grafts is less than 10 to 20 ml/min [5, 29]. Lehnert et al defined the Q threshold of IMAs as 20 ml/min and Honda et al and G. Di Giammarco et al pointed out that reduced Q<15 ml/min was found in non-satisfactory IMA grafts [11, 13, 30]. We considered a graft satisfactory with a normal waveform of blood flow, diastolic-dominant blood filling, and a mean flow value greater than 11.5 ml/min.

A PI value may be elevated in very long arterial conduits because resistance to blood flow is determined by, among other factors, vessel length and increase PI associated with worse outcome [16, 31]. However, some authors supposed that PI is clinically irrelevant [22]. In our data PI value was irritated in patients with not-satisfactory patency of LIMA to LAD grafts.

The TTFM measurements basis

According to literature, TTFM is a quick and reproducible intraoperative method with the prognostic ability of graft potency in 5 years of the postoperative period. However, few investigators have written about reasons for low Q or high PI and possibilities of their prediction [5, 14, 30]. It is known that the technical problems in grafts can lead to changes in TTFM. This means it can be used for the detection of technical errors, but technical errors are only one source from many others of TTFM values shifts [32].

Blood vessels

The condition of the blood vessels, including graft state, obviously, has an impact on the graft flow. The measure in proximal graft end can be viewed as a sum of the graft capacitive flow and flow that passes through the distal anastomosis and the last one depends on many factors, such as graft destination, coronary artery stenosis, collateral, and competitive flows and sequential grafts [22]. The TTFM measurements are independent of graft diameter [33].

There is no direct study about graft destination impact to TTFMs, probably, because it is impossible to isolate this factor from others. However, Y. Tokuda et al (2007) declare different cut-off value of mean graft flow for different coronary arteries (15 mL/min for LCA and 20 mL/min for RCA) that indirectly suggest the presence impact of the destination artery [34].

K. Honda et al showed that graft flow increases and pulsatory index decreases with progressing of native coronary stenosis [30]. Niclauss L in his review (2017) mentioned a correlation between blood flow and the severity of artery stenosis [16]. However, our data suggest that the CTO of the destination artery doesn’t have an impact on TTFM in grafts and the low mean bypass graft flow and high pulsatory index measured by the TTFM are not specific for anastomotic stenosis. These blood flow characteristics might be explained with the competitive flow and poor coronary run-off [22].

Other vessel conditions poorly studied: Verhoye et al (2007) showed evidence and type of relationship of collateral blood flow between left coronary artery bypass grafts and chronically occluded right coronary artery in patients with triple vessel disease [35], but the influence of collateral circulation on graft patency is still not well known [1]; there is some evidence that competitive blood flow has a strong impact on graft’s satisfactory in the literature [36]. The competition of blood flows can occur in the case of arterial Y grafting directed to different coronary territories with unbalances stenosis [11]. The above data was a reason for excluding any sequential grafts from the analysis in this study.

Ischemia

The current science knowledge lacks information about the impact of transitory ischemia on any TTFM measurements after CABG. H. Oshima et al (2016) wrote that they had assessed patients using preoperative SPECT but did not describe their results in the context of TTFM prediction [1]. In other literature, SPECT of myocardial perfusion is used for assessing coronary artery bypass graft disease state post CABG, but it didn't use for any associative analysis [37–42]. In our data, the preoperative myocardial perfusion SPECT characteristics related to ischemia in graft's destination coronary artery pool didn't affect Q, PI, or DF.

Myocardial scar and SVR

Some previous studies, including T. Murashita et al (2003), tried to use Gate-SPECT to improve the prediction of regional functional recovery after CBPG. They demonstrated that perfusion uptake of more than 50% was an indicator of functional recovery after revascularization [43]. We used the 17-segment model to estimate myocardium perfusion and had only SRS and TPD for LAD territory. The perfusion uptake was calculated by software for each segment and cannot be evaluated for LAD territory. That did impossible to compare our data in a clear manner, nevertheless, our cut-off point for LAD territory RS before the operation is 15.5/28 (55.4%) and it is very close to the T. Murashita data.

Moreover, the perfusion uptake less than 50% in rest myocardial perfusion SPECT test is evidence of scar presenting in this area, which had to be in ICMP patients with LV aneurysm. The LV aneurysms in ICMP patients were fixed through SVR during the complex surgical treatment. In our study, Q was less and PI higher in IMA to LAD grafts in patients with SVR because of apex/anterior LV aneurysm what can be related to the part collateral circulation reduction or worse morphological myocardium condition before operation. In favor of the second theory, the patients with SVR had worse all myocardial perfusion characteristics except global and LAD territory SDS before the operation.

According to our study, the most suitable criteria for TTFM prediction in LIMA to LAD grafts in ICMP patients is total perfusion deficit (TPD) computed for vascular territory. The parameter, which combines pixel-based defect extent and severity, estimates an overall magnitude of hypoperfusion [44]. TPD more than 14% is significantly abnormal results [45] and our data suggests that TPD in LAD territory more than 26.85% is a criterion for the prediction of early LIMA graft failure in patients with ischemic cardiomyopathy.

Study limitations

The present study has a few limitations: there was a relatively small number of patients with non-potent grafts; the wall motion in the LAD territory was not assessed and we used cut-off value for mean conduit flow revealed by H. Oshima et al (2016), despite an ongoing dispute about the cut-point values in modern literature.

Conclusion

We must agree with T. Kieser et al, who determined that the use of TTFM is only half of the picture [4]. TTFM is a reliable tool for preventing technical mistakes during CABG, however, its use is limited by variability in presurgical myocardial condition. The TPD in LAD territory by preoperative myocardial rest perfusion SPECT can predict early graft failure in LIMA to LAD grafts in patients with ischemic cardiomyopathy, indicating that SPECT imaging can reduce risks of most reliable IMA graft failures.

Declarations

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Statements and Declarations

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The study was approved by the Local Ethical Committee (Committee on Biomedical Ethics, Cardiology Research Institute; Approval Number: 178) and conformed to the Declaration of Helsinki on Human Research. Written informed consent was obtained from each patient after explanation of the protocol, its aims, and potential risks.

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Tables

Table 1 The clinical characteristics of study groups

Groups	n	Ages (years)	Comparison
Group 1, (Q>11,5 ml/min)	n = 40	61.4±4.9	t = 0.73, p=0.48
Group 2, (Q≤11,5 ml/min)	n = 7	59.4±6.2	
Diabetes Mellitus (2nd type)	Group 1	Group 2	
Prevalence, n (%)	n = 8 (20%)	n = 1 (14%)	p>0.05
NYHA class, n (%)	Group 1	Group 2	
I	n = 1 (3%)	n = 1 (14%)	p>0.05
II	n = 22 (55%)	n = 2 (28%)	
III	n = 14 (35%)	n = 4 (58%)	
IV	n = 3 (7%)	n = 0 (%)	
CCS angina class, n (%)	Group 1	Group 2	
I	n = 1 (3%)	n = 1 (14%)	p>0.05
II	n = 11 (27%)	n = 4 (58%)	
III	n = 27 (67%)	n = 2 (28%)	
IV	n = 1 (3%)	n = 0 (%)	
The operation type, n (%)	Group 1	Group 2	
CABG	n = 25 (63%)	n = 2 (28%)	p>0.05
CABG+SVR (D. Cooley)	n = 7 (17%)	n = 1 (14%)	
CABG+SVR (L. Menicanti)	n = 8 (20%)	n = 4 (58%)	
Ultrasound data	Group 1	Group 2	
LV ESV	136 (120, 184)	173 (154, 182)	U=199, p=0.08
LV EDV	201 (189, 251)	249 (223, 265)	U=204, p=0.06
LV EF (%)	31.1±6.1	30.29±5.5	t = 0.37, p=0.72
Others	Group 1	Group 2	
Body-mass index (kg/m^2)	27.4 (25.3, 30.9)	28.6 (26.5, 31.1)	U=117, p=0.85
EuroSCORE	4.5±2.1	3.9±2.1	U=104, p=0.36

Table 2 Results of intraoperative transit-time flow measurements in LIMA to LAD grafts

Transit-time flow measurements	Group 1	Group 2	Comparison
Q (ml/min)	43 (23, 61.8)	9 (5.5, 10)	N.A.
PI*	3.0 (2.4, 3.7)	7.1 (4.5, 10.8)	U=240.5, p=0.003
DF (%)	69.5 (58.5, 74.5)	60 (37.5, 66)	U=89, p=0.131

* - a statistically significant difference, p<0.05.

Table 3 The impact of CTO and SVR on results of intraoperative transit-time flow measurements in LIMA to LAD grafts

Transit-time flow measurements	with LAD CTO	without LAD CTO	Comparison
Q(ml/min)	36.5 (13.5, 53.5)	30 (16, 57)	U=287, p=0.723
PI	3.6 (2.8, 5.3)	3.0 (2.4, 4.0)	U=227.5, p=0.366
DF (%)	67.5 (56.8, 73.3)	69 (62, 76)	U=292, p=0.643
Transit-time flow measurements	with SVR	without SVR	Comparison
Q(ml/min)*	17 (11.5, 40.8)	45 (25, 67.5)	U=386.5, p=0.013
PI*	3.9 (3.2, 7.4)	2.9 (2.3, 3.6)	U=135.5, p=0.004
DF (%)*	63.5 (44.5, 70.8)	72 (66.5, 77)	U=372, p=0.029

* - a statistically significant difference, p<0.05.

Table 4 Results of SPECT MPI

SPECT	Group 1	Group 2	Comparison
Global SPECT estimates			
SSS	27.3±8.3	32.7±5.7	t=2.2, p=0.051
TPD (stress)	38.7±10.4	45.7±8.5	t=2.0, p=0.081
SRS*	20.7±7.5	28.8±4.3	t=3.7, p=0.003
TPD (rest)*	32.0±11.4	43.7±8.1	t=3.0, p=0.014
SDS	4 (2, 7)	3 (3, 4.5)	U=93.5, p=0.936
LAD territory SPECT estimates			
SS	12.7±6.0	15.3±7.7	t=0.9, p=0,421
TPD (stress)	21.4±8.9	25.1±11.7	t=0.8, p=0.449
RS	10.8±5.4	16.2±5.1	t=2.3, p=0.052
TPD (rest)*	19.7±9.6	28.4±7.7	t=2.4, p=0.040
DS	0 (0, 2)	1 (0.3, 1.8)	U=111.0, p=0.532

Figures

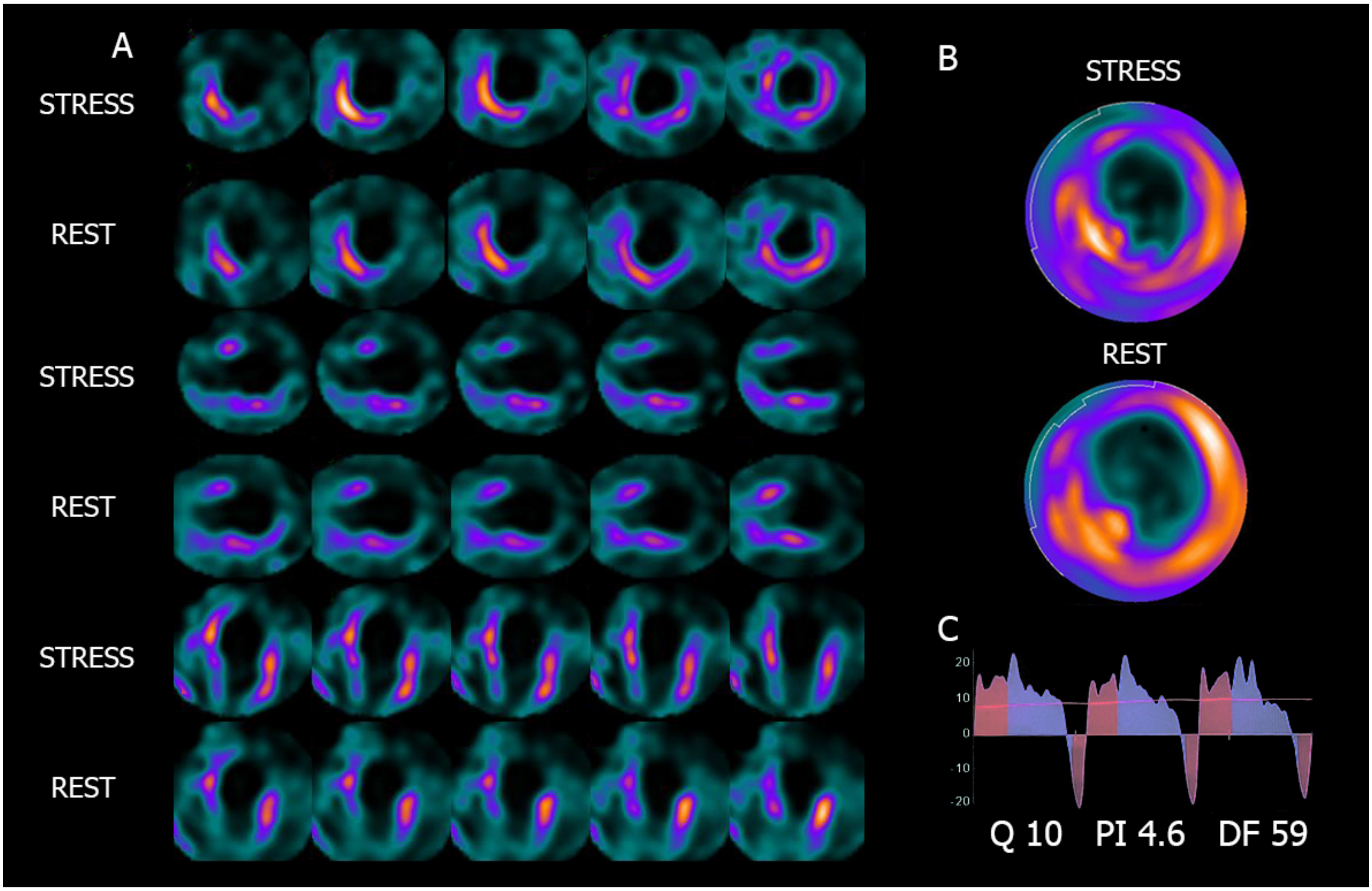

Figure 1

The myocardial perfusion stress-rest SPECT (a, b) in ICMP patients with non-satisfactory (Q<11.5, left) and satisfactory (Q>11.5, right) flow in IMA grafts during CABG (c)

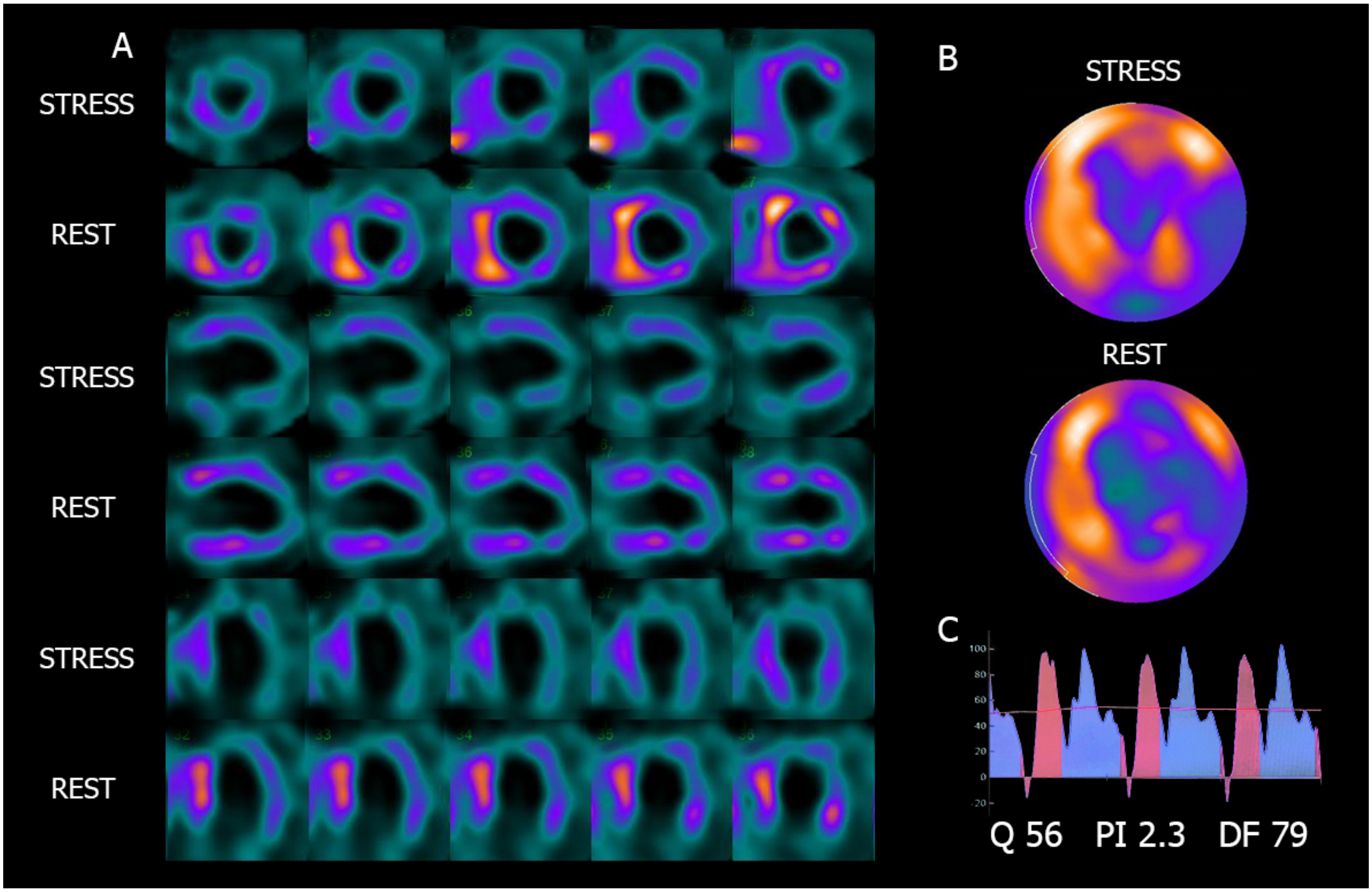

Figure 2

Correlations between TTFM and MPI estimators. * - statistically significant correlation, p<0.05