IZVIRNI ČLANEK/ORIGINAL ARTICLE

The value of corrected TIMI frame count measurements and measurements of coronary artery stenosis for predicting the flow through the coronary artery bypass

Vrednost meritev TIMI frame count in zožitve venčne arterije za napoved pretoka skozi obvod venčne arterije

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Izvleček

Izhodišča: Cilj te retrospektivne študije je bil oceniti napovedno vrednost meritev korigiranega parametra thrombolysis in myocardial infarction frame count (cTFC) ter vrednosti stopnje proksimalne zožitve koronarnih arterij v seriji bolnikov, pri katerih smo opravili izolirano operacijo premostitve koronarnih arterij.

Metode: Opravili smo retrospektivno analizo 98 bolnikov, ki so bili v naši ustanovi operirani med januarjem leta 2008 in marcem leta 2009, pri katerih je bila napravljena izolirana operacija premostitve koronarnih arterij. Pred posegom so vsi bolniki opravili angiografijo. Stopnjo epikardialne koronarne zožitve je vizualno ocenil kardiolog, cTFC tarčnih koronarnih arterij pa je bil pridobljen iz standardnih projekcij, pred operacijo posnetih koronarnih angiogramov, snemanih s hitrostjo 12,5 posnetka/s. Med operacijo smo pri vseh obvodih izmerili čas pretoka po obvodu oziroma tako imenovani transit-time flow measurement (TTFM).

Rezultati: Vsi obvodi so bili razdeljeni glede na rezultate v štiri skoraj enako velike skupine glede na cTFC in odstotek proksimalne zožitve koronarne arterije. Presečni vrednosti tako za cTFC in odstotek zožitve so njihove srednje vrednosti (cTFC–14 , odstotek zožitve–80 %). V vseh štirih skupinah so se pokazale statistično pomembne razlike v srednjem pretoku.

V skupini 1 (visok delež zožitve in visok cTFC) srednji pretok 38,3 ± 20,3 ml/min, v skupini 2 (nizek delež zožitve in visok cTFC) srednji pretok 29,0 ± 15,1 ml/min, v skupini 3 (visok delež zožitve in nizek cTFC) srednji pretok 48,2 ± 26,3 ml/min, v skupini 4 (nizek delež zožitve in nizek cTFC) srednji pretok 35,3 ± 14,8 ml/min. Razlike med posameznimi skupinami so bile pomembne za vse kombinacije, razen v primerjavi skupine 1 s skupino 4.

Zaključek: Združitev podatkov, pridobljenih s koronarno angiografijo in cTFC je pokazala, da imajo le-ti dobro napovedno vrednost glede na po posegu izmerjeni koronarni pretok pri premostitveni operaciji koronarnih arterij. Kirurgu bi podatki lahko pomagali pri izbiri tarčnih arterij za premostitveno operacijo ali pa pri odločitvi za revizijo že napravljenega obvoda.

Abstract

Objectives: The aim of this retrospective study was to evaluate the prognostic value of corrected thrombolysis in myocardial infarction frame count (cTFC) measurements and different cut-off values of the degree of proximal coronary artery stenosis in a series of patients who had undergone elective isolated coronary artery bypass surgery.

Methods: A retrospective analysis of 98 patients who had elective isolated coronary artery bypass surgery performed at our institution between January 2008 and March 2009 was made. Preoperatively, all patients had undergone angiography. The degree of epicardial coronary stenosis was estimated visually by the cardiologist, and cTFC of the target coronary arteries was obtained from standard projections on preoperative coronary angiograms with frame rate of 12.5 frames/s. All bypass grafts were evaluated by intraoperative transit time flow measurement (TTFM).

Results: All bypass grafts were divided according to the results into four nearly equally sized groups using cTFC and percentage of proximal coronary artery stenosis. The cut-off values for both cTFC and percentage of stenosis were their median values (cTFC–14, percentage of stenosis–80 %). Bypass grafts in the four groups showed significant differences in mean flow.

In group 1 (high percent stenosis and high cTFC) mean bypass graft flow was 38.3 ± 20.3 ml/min, in group 2 (low percent stenosis and high cTFC) mean bypass graft flow was 29.0 ± 15.1 ml/min, in group 3 (high percent stenosis and low cTFC) mean bypass graft flow was 48.2 ± 26.3 ml/min, and in group 4 (low percent stenosis and low cTFC) mean bypass graft flow was 35.3 ± 14.8 ml/min. Differences between individual groups were significant for all combinations except when comparing group 1 with group 4.

Conclusion: Combining the data obtained from coronary angiography and TFC has shown to have a good predictive value for postoperative coronary bypass graft flow, and could thus help surgeons in making choice of target vessels for bypass surgery or help them decide whather revision of a bypass graft would be beneficial.

Introduction

Transit-time flow measurement (TTFM) is a commonly used method of quality control in coronary artery bypass surgery. It has been shown that good flow in all bypass grafts is associated with lower rate of postoperative myocardial infarction, lower mortality, shorter stay in intensive care unit, lower rate of intra-aortic baloon pump use and lower rate of re-revascularizations.[1-3] Low graft flow was also predictive of early and midterm graft failure.[4,5] Among the most important factors that affect bypass graft flow is the degree of proximal coronary artery stenosis and the run-off of the distal coronary artery bed.

The conventional method of estimating the degree of coronary artery stenosis is by visual assessment of coronary angiogram. Coronary angiography and more elaborate methods, such as quantitative coronary angiography or fractional flow reserve (FFR), provide only information on the degree of proximal coronary artery stenosis, but no information regrading the run-off of the coronary artery.[6] Thrombolysis in myocardial infarction frame count (TFC), on the other hand, is an estimate of flow velocity in the coronary arteries, which is affected both by stenoses in the epicardial coronary arteries and by changes in coronary microcirculation, producing the so called slow coronary flow (SCF).[7] TFC was higher in coronary arteries with significant stenoses and myocardial bridging, it normalized after stenting [8] and decreased with the use of coronary vasodilators.[9] SCF with normal epicardial coronary arteries was observed in diabetics,[10] patients with end-stage renal disease,[11,12] hypertrophic cardiomyopathy [13] and non-ischemic cardiomyopathy.[14] Coronary microvascular dysfunction in patients with SCF was associated with reduced coronary flow reserve,[15] activation of platelets with increased mean platelet volume[16] and elevation of high sensitivity CRP.[17]

TFC is defined as the number of coronary angiography cineframes required for contrast to reach a standardized distal coronary landmark in the target vessel.[7,18,19] The method is simple, reproducible, objective, quantitative and it can be used by a cardiologist or a surgeon. TFC of the LAD is corrected for its longer length by dividing it by 1.7 to derive the corrected TIMI frame count (cTFC).[7] The original description of the TFC method was based on angiograms acquired at 30 frames/s.[7] Modern digital angiograms are acquired at lower frame rates (12.5 and 25 frames/s) and the TFC is then multiplied by conversion factor of 2.4 or 1.2 to obtain values of TFC comparable to the previously published results.[20]

Combining the data from FFR and cTFC has shown highest cardiac event rate in the group with low FFR and high cTFC.[21] Similarly, by combining the data from coronary angiography and cTFC, a more accurate prediction of coronary bypass graft flow could be made.

Methods

A retrospective analysis of 98 patients who had elective isolated coronary artery bypass surgery performed at our institution between January 2008 and March 2009 was made. The degree of epicardial coronary stenosis was estimated visually by the cardiologist at the time when angiography was performed. TFC of the target coronary arteries was obtained from standard projections on preoperative coronary angiograms with a frame rate of 12.5 frames/s. The first frame in the TIMI frame count was defined by a column of contrast extending across 70 % of the arterial lumen with antegrade motion. The last frame counted was when contrast entered a distal landmark. The landmarks were: the first branch of the posterolateral artery in the right coronary artery; the distal branch of the lateral left ventricular wall artery furthest from the coronary ostium in the circumflex system; and the distal bifurcation in the left anterior descending artery.[7] All TFC values were multiplied by 2.4 to make the values comparable to those obtained with frame rate of 30 frames/s in the original studies.[7,20] TFC of the LAD was further corrected for its longer length by dividing it by 1.7 to derive the corrected TIMI frame count (cTFC).[7]

The surgical approach was full median sternotomy in all patients. All bypass grafts used for the analysis had a single distal anastomosis. Saphenous vein grafts (SVG) were anastomosed proximally to the aorta. Left internal thoracic artery (LITA) grafts were used as a pedicle. TTFM was performed intraoperatively by using VeriQ flowmeter (Medistim, Oslo, Norway) after finishing all anastomoses in off-pump cases and after weaning from cardiopulmonary bypass in on-pump cases. TTFM included the flow curve, mean flow, pulsatility index (PI), diastolic filling (DF), probe size used for the measurement and heart rate (HR). At each TTFM systolic and diastolic radial arterial pressure was recorded.

Table 1: Patient data (n = 98).

Age (years)	66.5 ± 10.4
Male gender	79 (80.6 %)
LVEF (%)	55.8 ± 11.1
Euroscore (95 % CI)	8,3 % (6,1 % – 10,4 %)
BSA (m^2)	1.93 ± 0.19
BMI (kg/m^2)	27.7 ± 3.7
Comorbidities and risk factors	
Diabetes	34 (34.7 %)
Arterial hypertension	87 (88.8 %)
Hyperlipidemia	77 (78.6 %)
Smoking	11 (11.2 %)
Previous myocardial infarction	47 (48.0 %)
Operative procedures	
Off pump CABG	33 (33.7 %)
Number of grafts per patient	3.3 ± 0.9
Use of ITA	82 (83,7 %)
Crossclamp time in on pump cases (min)	104.4 ± 30.2

LVEF – left ventricular ejection fraction, BSA – body surface area, BMI – body mass index, CABG – coronary artery bypass grafting, ITA – internal thoracic artery

Statistical methods

Data were compiled and analyzed with Microsoft Access 2007 (Redmond, Wash) and SPSS Statistics 11.5 (Chicago, IL, SPSS Inc.). Because most of the continuous variables were not normally distributed, they were compared by using Mann-Whitney U test or Wilcoxon signed-rank test when comparing the related data. Categoric variables were compared by using χ^2 or Fisher exact tests. Results for the continuous variables are reported as the mean ± standard deviation in the text and tables.

Results

Patient data

Patient data with risk factors, comorbidities and procedural data are presented in Table 1.

Bypass grafts

Only bypass grafts with single distal anastomosis, adequate preoperative angiogram where cTFC was assessable and adequate intraoperative flow measurement, with flow higher than 10 ml/min were included in the analysis. Out of 325 bypass grafts, 232 were included in our study. The main reason for the exclusion of bypass grafts were incomplete measurements. In some cases the cardiologist could not assess the degree of stenosis, for example, when there were diffuse atherosclerotic changes of the target coronary artery. We also excluded bypass grafts where we could not assess cTFC on the preoperative coronary angiography, or those grafts where intraoperative flow measurements were not performed or the measurement was unreliable. In 27 cases intraoperative flow measurement was less than 10 ml/min, therefore these measurements were also excluded from the study.

The total of 232 bypass grafts with complete measurements of cTFC, preoperative angiogram and intraoperative flow measurements were divided into four groups using cTFC and percentage of proximal coronary artery stenosis. The cut-off values for both cTFC and percent stenosis were their median values (cTFC 34, percent stenosis 80 %), which resulted in four nearly equally sized groups (Table 2). The bypass grafts in the four groups showed significant differences in mean flow (Table 2, Figure 1). Differences between individual groups were significant for all combinations except when comparing the group 1 (high percent stenosis and high cTFC) with group 4 (low percent stenosis and low cTFC) (Table 3). There were no significant differences in PI, DF, heart rate, ar-

Table 2: Bypass graft data grouped into four groups based on cTFC and percent of coronary artery stenosis.

	1–High % stenosis and high cTFC	2–Low % stenosis and high cTFC	3–High % stenosis and low cTFC	4–Low % stenosis and low cTFC	p
n	64	56	55	57	NS**
Mean % stenosis	94 ± 5	69 ± 8	95 ± 4	68 ± 9	< 0.001*
Mean cTFC	55 ± 24	48 ± 12	24 ± 7	24 ± 7	< 0.001*
Mean flow	38.3 ± 20.3	29.0 ± 15.1	48.2 ± 26.3	35.3 ± 14.8	< 0.001*
PI	2.8 ± 1.4	2.7 ± 1.4	2.8 ± 1.4	2.9 ± 1.8	NS*
DF (%)	64.9 ± 11.7	65.2 ± 12.4	68.6 ± 11.8	65.3 ± 11.0	NS*
Heart rate (bpm)	76.2 ± 12.7	78.6 ± 17.0	76.4 ± 12.7	81.2 ± 16.0	NS*
Systolic pressure (mmHg)	99.5 ± 15.1	103.9 ± 14.9	98.8 ± 14.0	103.0 ± 15.7	NS*
Diastolic pressure (mmHg)	49.8 ± 9.3	51.9 ± 11.1	48.7 ± 8.4	53.2 ± 13.7	NS*
Hematocrit	0.36 ± 0.05	0.37 ± 0.06	0.36 ± 0.05	0.35 ± 0.07	NS*
Platelet count	147 ± 41	139 ± 38	156 ± 52	149 ± 46	NS*
MPV (fl)	9.00 ± 1.35	8.90 ± 1.10	8.57 ± 1.04	8.79 ± 0.89	NS*
Number of ITA grafts	14	11	15	14	NS**
Off pump CABG	23	14	14	20	NS**

*cTFC – corrected time frame count, NS – statistically non-significant difference, PI – pulsatility index, DF – diastolic filling, MPV – mean platelet volume, CABG – coronary artery bypass grafting, ITA – internal thoracic artery, *Kruskal-Wallis test, **Pearson Chi-Square test*

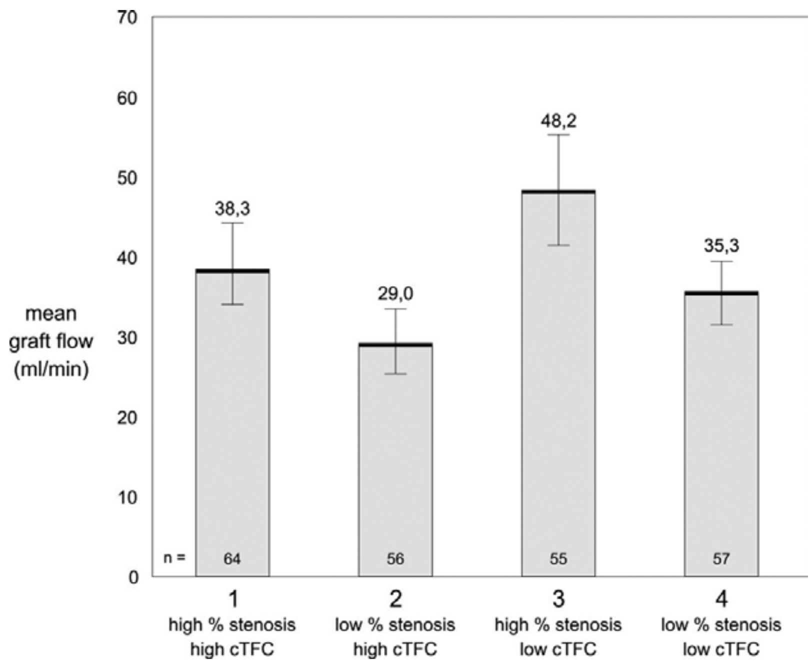

Figure 1: Mean bypass graft flow with 95% confidence interval of mean as a function of high or low cTFC and percentage of proximal coronary artery stenosis. The bypass graft flow was lowest in group 2 with competitve flow (low percentage of proximal stenosis) and poor run-off (high cTFC). The highest mean bypass graft flow was in group 3, where competitive flow was low (high percentage of proximal coronary stenosis) and run-off was good (low cTFC). Differences between the groups were significant for all combinations except when comparing group 1 and group 4 (Table 3).

terial pressure, laboratory values, percent of ITA use and percent of cases done without cardiopulmonary bypass between the four groups (Table 2).

Discussion

In this research we combined the data from coronary angiography and cTFC in order to make a more accurate prediction of coronary bypass graft flow. We hypothesised that high degree of proximal coronary artery stenosis (low competitive flow) and low cTFC (good run-off) would result in high bypass graft flow, whereas low or nonsignificant coronary artery stenosis (high competitive flow) and high cTFC (poor run-off) would result in low bypass graft flow.

Table 3: Differences in mean bypass graft flow between the four groups.

Group	p
1 vs. 2	0.014*
1 vs. 3	0.018*
1 vs. 4	NS*
2 vs. 3	<0.001*
2 vs. 4	0.008*
3 vs 4	0.002*

Mann-Whitney U test

We gathered the data of 98 patients who had elective isolated coronary artery bypass surgery performed at our institution between January 2008 and March 2009, and a retrospective analysis was made. The data was divided into 4 groups according to the corrected TFC and percentage of proximal coronary artery stenosis. The cut-off values for both cTFC and percentage of stenosis were their median values (cTFC–14, percentage of stenosis–80 %), which resulted in four nearly equally sized groups (Figure 1 and Table 2).

The groups were separated only by bypass graft flow, except for the differences in the cTFC and percentage of stenosis.

In group 1 (high percent stenosis and high cTFC) mean bypass graft flow was 38.3 ± 20.3 ml/min, in group 2 (low percent stenosis and high cTFC) mean bypass graft flow was 29.0 ± 15.1 ml/min, in group 3 (high percent stenosis and low cTFC) mean bypass graft flow was 48.2 ± 26.3 ml/min, in group 4 (low percent stenosis and low cTFC) mean bypass graft flow was 35.3 ± 14.8 ml/min.

Differences between individual groups regarding the bypass graft flow were statisticaly significant for all combinations except when comparing group 1 with group 4 (Table 3).

There were no significant differences in PI, DF, heart rate, arterial pressure, laboratory values, percent of ITA use and percent of cases done without cardiopulmonary bypass between the four groups (Table 2).

As expected, the results show that the bypass graft flow was lowest in Group 2 where there was a high competitive flow (low percentage of proximal stenosis) and poor run-off (high cTFC). The highest mean bypass graft flow was in Group 3, where competitive flow was low (high percentage of proximal coronary stenosis) and run-off was good (low cTFC).

In Groups 1 and 4, either the competitive flow or poor run-off was present but not both at the same time, therefore, there was an intermediate flow rate.

In 27 cases, the measurements were excluded from the study, as intraoperative flow measurement was less than 10 ml/min. The reason for this result is most likely a technical error in the construction of the bypass. It is also possible that the measurement has been poorly executed. In the event that the measurements are accurate, the most likely reason for the low bypass flow is certainly technicaly inadequate bypass construction. Such measurement should raise suspicion of bypass malfunction and a surgeon should in most cases revise the anastomosis. Revision of the bypass graft was not made in any of the cases that were included in our study.

Limitations of the study

This was a retrospective analysis of bypass graft flow in patients who were very similar in demographics and co-morbidities. However, in our case, not all operations were performed by the same surgical team, so we cannot rule out the influence of their surgical technique and postoperative management on the course of their patients' recovery. The estimation of the degree of coronary artery stenosis from coronary angiography is also subjective and was made by different cardiologists.

Conclusion

Combining the data obtained from coronary angiography and TFC has shown to have a good predictive value for postoperative coronary bypass graft flow.

Therefore, each surgeon should be able to review angiographic images and measure the cTFC prior to surgery. This would give the surgeon the prognostic information about the expected postoperative bypass graft flow. The results could help the surgeon to make choice of target vessels for bypass operation and raise suspicion of bypass malfunction, despite the relatively high bypass graft flow and low PI in the event that the measured bypass graft flow would be significantly lower than expected. Similarly, if low bypass graft flow would be expected and then measured, surgeon would rarely decide to revise the anastomosis, which could greatly extend the duration of the surgical procedure.

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