Activation of Coagulation and Fibrinolysis During Coronary Artery Bypass Grafting: A Comparison Between On-Pump and Off-Pump Techniques

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Abstract Coronary artery bypass grafting (CABG) with cardiopulmonary bypass (CPB) is associated with intense activation of hemostatic mechanisms. But the precise knowledge of the effects of eliminating CPB in patients undergoing off-pump coronary artery bypass grafting (CABG) are not well established. The present study was carried out to compare and document the changes in selected coagulation and fibrinolysis variables in patients undergoing on-pump and off-pump CABG (OPCAB). A total of 42 patients of on-pump and 31 patients of off-pump CABG were selected for the study. Platelet count, prothrombin time (PT), activated partial thromboplastin time (APTT), thrombin time

(TT), Fibrinogen and D-dimer levels were measured immediately, 24 h and 7 days after operation and compared with the baseline preoperative values. Statistical analysis was done by mixed ANOVA for repeated measures and Post-hoc tests using the Bonferroni correction, Chi square and unpaired *t* test. All the parameters were significantly changed ($P < 0.05$) with the time. Platelet counts, fibrinogen and D-dimer levels were significantly different between on-pump and off-pump CABG patients on immediate and 24 h postoperative period and attained almost same level after 7 days of operation. Fibrinogen level and platelet counts were increased after a sharp fall in the immediate postoperative period whereas D-dimer levels were persistently increased with a sharp peak of rise in the immediate postoperative period in on-pump group. On-pump surgery was associated with excessive fibrinolytic activity immediately after operation. The off-pump group demonstrated less activation of coagulation and fibrinolysis and delayed postoperative response that became almost equal to the on-pump group in the later postoperative period.

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Introduction

Off-pump coronary artery bypass grafting (OPCAB) has been established as an alternative to on-pump coronary artery bypass grafting with cardiopulmonary bypass (CPB). OPCAB can be performed on all coronary artery systems with good early [1] and midterm [2] results. The potential advantages of OPCAB are still issues of debate; however,

the whole body inflammatory reaction caused by CPB may be attenuated. Studies, mainly performed in patients undergoing coronary artery bypass grafting (CABG), have shown that CPB use is associated with activation of several metabolic pathways and cellular components leading to a systemic inflammatory response [3]. This response has mainly been documented to occur in the early hours after surgery, but some studies have shown a marked activation of the hemostatic, thrombotic, and inflammatory systems to persist for several weeks after coronary surgery [4–7]. The clinical advantage of OPCAB versus standard on-pump CABG is, however, still debated [8, 9]. It is also unclear whether CPB is the main cause of the postoperative inflammatory and procoagulant responses that occur after cardiac surgery; recently, it has been hypothesized that surgical trauma, in addition to CPB, may cause activation of inflammatory and coagulation-fibrinolytic pathways [10]. Despite efforts to improve the biocompatibility of the circuits for extracorporeal circulation, activation of inflammatory pathways of coagulation and fibrinolysis remains of major concern for the potential pathologic consequences. We therefore investigated whether activation of coagulation and fibrinolysis differed between patients undergoing on-pump and off-pump CABG at the end of surgery.

Materials and Methods

Study Design

The present study was conducted in 73 consecutive patients, who came to the department of Cardiothoracic Surgery in one and half year (01.01.2011–30.06.2012) of the study period requiring elective CABG according to guidelines [11] for surgical revascularization established by the American College of Cardiology (ACC) and American Heart Association (AHA), considered suitable for both on-pump and OPCAB procedures, were enrolled in the study. Patients were assigned to undergo on-pump ($n = 42$) or off-pump ($n = 31$) surgery depending on simple random allocation method. The study was carried out after obtaining the proper approval from the ethical committee of the institution and after getting the informed consent from patient party.

Inclusion Criteria

1. Patients with ejection fraction $>35\%$
2. Willingness to undergo myocardial revascularization with either method (CPB or OPCAB).

Exclusion Criteria

1. Age >80 years
2. Ejection fraction $\leq 35\%$
3. Serum creatinine $>150 \mu\text{mol/L}$
4. Tight main stem stenosis
5. Redo operation
6. Diffuse distal coronary artery disease
7. Unstable angina and Class 4 angina
8. History of cerebrovascular disease
9. Renal or liver dysfunction
10. Intake of drugs affecting platelet function, coagulation or fibrinolysis within 10 days before surgery or known pre-existing hemolytic or coagulative disorders
11. Excessive ($>1,000 \text{ mL/day}$) postoperative bleeding or re exploration for bleeding, perioperative myocardial infarction
12. Emergency surgery, concomitant major surgery, unstable angina requiring emergency revascularization, valvular disease, left ventricular aneurysm requiring repair, heart failure.

Surgery and Anesthesia

The patients underwent a standard median sternotomy operation. Similar standardized anesthetic protocol was used in both types of surgery. On-pump surgery was performed with CPB in combination with cold crystalloid cardioplegia for myocardial protection. Off-pump surgery was performed on the beating, normothermic heart with local cardiac wall immobilization with an Octopus tissue stabilizer. During on-pump surgery, patients were cooled to 32°C , whereas during off-pump surgery, patients were actively warmed to maintain a core temperature not lower than 35°C . Before connection to CPB in on-pump group, heparin was administered at a dose of 300 IU/kg to achieve an activated coagulation time (ACT) of more than 450 s . At the end of CPB, heparin was neutralized by protamine chloride at a dose of 3 mg/kg and additional protamine was administered until the ACT was less than 150 s . Before the anastomosis was started, heparin at a dose of 150 IU/kg was administered to achieve an ACT of more than 250 s in off-pump (OPCAB) group. At the end of the operation, protamine ($25\text{--}50 \text{ mg}$) was administered if an ACT $>150 \text{ s}$ was measured. All patients were admitted postoperatively in the intensive care unit and extubated when hemodynamically stable, fully rewarmed, awake, without surgical bleeding, and with optimal blood gases.

Blood Sampling

Venous blood samples were drawn at the following intervals: preoperatively after the induction of anesthesia (Time

1), immediately after completion of surgery (Time 2), 24 h (Time 3) and 7 days (Time 4) later. Plasma samples were obtained within 1 h after venipuncture from blood anticoagulated with trisodium citrate after centrifugation for 20 min at $2,000\times g$ and frozen at -80°C until assayed.

Assay Methods

Hematocrit, hemoglobin, and platelet counts were measured with an automated hematology analyzer (KX-21, Sysmex Corporation, Japan). Platelet counts were cross-checked with well-prepared peripheral blood films. Prothrombin time (PT), activated partial thromboplastin time (APTT), thrombin time (TT) and fibrinogen level were analyzed by automated blood coagulation analyzer (CA-50, Sysmex Corporation, Japan) using Thromborel S (Siemens, Germany), Dade Actin FSL (Siemens, Germany), Test Thrombin (Siemens, Germany) and Dade fibrinogen determination reagents (Dade Behring, Germany) respectively. D-dimer levels were assessed quantitatively by immunoturbidimetric method (STA-Liatest, Diagnostica

Stago). The analysis was conducted for both unadjusted data and for data adjusted for dilution depending on hematocrit value using the following formula: corrected parameter = (measured parameter $\times$ initial hematocrit)/measured hematocrit.

Statistical Methods

Statistical analysis was done by mixed ANOVA for repeated measures with a Greenhouse–Geisser correction and Post-hoc tests using the Bonferroni correction, Chi square and unpaired *t* test using IBM SPSS statistics version 20 and MedCalc software. *P* value <0.05 was considered statistically significant.

Results

Patient characteristics are listed in Table 1. Demographic and perioperative variables were similar in both groups,

Table 1 Perioperative clinical variables in the study population

Variable	CPB group (<i>n</i> = 42)	OPCAB group (<i>n</i> = 31)	<i>P</i> value	Test (Chi square/ <i>t</i> test)
Age (Year)	60.21 $\pm$ 6.88	61.74 $\pm$ 7.29	0.364, NS	<i>t</i>
Sex (M/F)	29/13	24/7	0.428, NS	CS
Weight (Kg)	75.95 $\pm$ 9.80	74.52 $\pm$ 10.0	0.541, NS	<i>t</i>
Body surface area (m ²) ^a	1.863 $\pm$ 0.15	1.857 $\pm$ 0.15	0.874, NS	<i>t</i>
BMI (Kg/m ²)	27.75 $\pm$ 2.67	26.49 $\pm$ 3.48	0.085, NS	<i>t</i>
MI	23 (54.8%)	19 (61.3%)	0.577, NS	CS
DM	14 (33.3%)	13 (41.9%)	0.452, NS	CS
Hypertension	25 (59.5%)	20 (64.5%)	0.665, NS	CS
Smoker	16 (38.1%)	14 (45.2%)	0.544, NS	CS
COPD	11 (26.2%)	11 (35.5%)	0.392, NS	CS
Hyperlipidemia	32 (76.2%)	25 (80.6%)	0.649, NS	CS
Angina class (≤ 2 & 3) ^b	31 & 11	22 & 9	0.788, NS	CS
Type of vessel Involved (S,D,T,LM)	4,13,24,1	3,7,20,1	0.882, NS	CS
Ejection fraction (%)	53.79 $\pm$ 6.04	56.45 $\pm$ 5.50	0.057, NS	<i>t</i>
Creatinine ($\mu\text{mol/L}$)	93.38 $\pm$ 6.94	93.48 $\pm$ 6.32	0.948, NS	<i>t</i>
Blood transfusion	12 (28.6%)	7 (22.6%)	0.564, NS	CS
No. of units transfused	0.69 $\pm$ 1.18	0.55 $\pm$ 1.12	0.605, NS	<i>t</i>
Bleeding during surgery (mL)	591.31 $\pm$ 90.52	632.13 $\pm$ 115.19	0.108, NS	<i>t</i>
Post-operative bleeding (mL)	546.67 $\pm$ 65.08	566.90 $\pm$ 93.41	0.306, NS	<i>t</i>
Duration of surgery (min)	298.07 $\pm$ 26.64	347.94 $\pm$ 44.26	0.000, <i>s</i>	<i>t</i>
Heparin (1,000 IU)	22.904 $\pm$ 2.95	11.213 $\pm$ 1.5	0.000, <i>s</i>	<i>t</i>
Protamine (mg)	257.05 $\pm$ 33.79	18.45 $\pm$ 20.44	0.000, <i>s</i>	<i>t</i>
Antifibrinolytic therapy	9 (21.4%)	4 (12.9%)	0.347, NS	CS
ICCU stay (days)	2.52 $\pm$ 0.80	2.77 $\pm$ 0.99	0.470, NS	CS
Hospital stay (days)	9.64 $\pm$ 1.59	10.10 $\pm$ 1.85	0.328, NS	CS

s significant, *NS* non-significant, *t* unpaired *t* test, *CS* Chi Square test, *S* single vessel disease, *D* double vessel disease, *T* triple vessel disease, *LM* left main stenosis

^a Body surface area calculated according to Mosteller's formula

^b Severity of angina was graded according to Canadian Cardiovascular Society (CCS)

Table 2 Changes in laboratory variables in patients who underwent the two methods of surgery

Parameters	Time 1			Time 2			Time 3			Time 4		
	CPB	OPCAB	P value (t test)	CPB	OPCAB	P value (t test)	CPB	OPCAB	P value (t test)	CPB	OPCAB	P value (t test)
Hemoglobin (g/dL)	13.00 ± 1.26	12.77 ± 1.09	0.409 NS	9.85 ± 1.00	10.78 ± 1.06	<.001 S	10.26 ± 1.10	10.91 ± 1.06	0.013 S	12.52 ± 1.15	12.39 ± 1.04	0.609 NS
Hematocrit (%)	39.28 ± 3.73	38.46 ± 3.29	0.330 NS	29.86 ± 3.02	32.02 ± 3.26	0.005 S	31.11 ± 3.24	32.77 ± 3.18	0.032 S	37.77 ± 3.44	37.25 ± 3.12	0.511 NS
Platelets (10 ⁹ /L)	192.8 ± 31.0	178.3 ± 36.2	0.070 NS	112.4 ± 12.2	152.0 ± 28.1	<.001 S	163.6 ± 23.5	178.9 ± 33.1	0.024 S	244.8 ± 40.7	227.0 ± 42.0	0.073 NS
Corrected platelets (10 ⁹ /L)	192.8 ± 31.0	178.3 ± 36.2	0.070 NS	150.9 ± 23.1	182.3 ± 36.7	<.001 S	208.4 ± 36.8	210.4 ± 39.6	0.824 NS	255.6 ± 51.0	234.5 ± 44.4	0.069 NS
PT (sec)	12.01 ± 0.99	11.80 ± 0.89	0.339 NS	16.11 ± 2.35	16.20 ± 2.48	0.878 NS	14.31 ± 2.11	14.30 ± 2.35	0.987 NS	12.34 ± 1.47	12.11 ± 1.28	0.490 NS
Prothrombin ratio (PR)	1.02 ± 0.09	0.99 ± 0.09	0.097 NS	1.36 ± 0.19	1.41 ± 0.22	0.364 NS	1.22 ± 0.21	1.21 ± 0.21	0.925 NS	1.04 ± 0.11	1.04 ± 0.13	0.930 NS
INR	1.05 ± 0.17	0.98 ± 0.10	0.052 NS	1.64 ± 1.79	1.44 ± 0.23	0.471 NS	1.24 ± 0.22	1.23 ± 0.23	0.871 NS	1.04 ± 0.12	1.04 ± 0.13	0.912 NS
APTT (sec)	31.11 ± 0.94	31.55 ± 1.85	0.188 NS	34.59 ± 1.06	31.40 ± 0.93	<.001 S	30.08 ± 0.98	32.73 ± 1.01	<.001 S	28.02 ± 1.26	29.22 ± 1.19	<.001 S
APTT ratio	1.10 ± 0.02	1.11 ± 0.03	0.340 NS	1.24 ± 0.03	1.11 ± 0.03	<.001 S	1.07 ± 0.02	1.16 ± 0.03	<.001 S	0.99 ± 0.04	1.03 ± 0.03	<.001 S
TT (sec)	16.97 ± 1.52	17.32 ± 1.27	0.309 NS	17.99 ± 1.27	17.79 ± 1.33	0.495 NS	16.57 ± 1.30	16.47 ± 1.23	0.724 NS	15.55 ± 1.31	15.17 ± 1.31	0.215 NS
Fibrinogen (mg/dL)	402.6 ± 23.6	392.8 ± 39.2	0.222 NS	314.7 ± 21.9	334.6 ± 32.0	0.004 S	567.6 ± 26.1	539.7 ± 38.3	0.001 S	763.0 ± 29.0	775.8 ± 23.5	0.041 S
Corrected fibrinogen (mg/dL)	402.6 ± 23.6	392.8 ± 39.2	0.222 NS	420.0 ± 51.7	405.8 ± 50.4	0.246 NS	720.0 ± 87.4	635.1 ± 60.5	<.001 S	794.4 ± 57.9	801.6 ± 49.6	0.580 NS
D-dimer (mg/L)	0.51 ± 0.05	0.50 ± 0.03	0.204 NS	1.71 ± 0.20	0.61 ± 0.05	<.001 S	0.81 ± 0.14	0.76 ± 0.05	0.056 NS	1.12 ± 0.17	1.13 ± 0.09	0.895 NS
Corrected D-dimer (mg/L)	0.51 ± 0.05	0.50 ± 0.03	0.204 NS	2.27 ± 0.32	0.73 ± 0.07	<.001 S	1.03 ± 0.21	0.89 ± 0.07	<.001 S	1.17 ± 0.18	1.17 ± 0.12	0.935 NS

Corrected values were derived after adjusting the values for hemodilution in the postoperative period

S significant, NS non-significant

except for the use of heparin and protamine and duration of surgery. Values of all the variables of two groups of patients at four time points are summarized in the Table 2 where most of the variables are showing significant differences (P value <0.05) between two groups of patients on 2nd and 3rd time points except PT, PR, INR and TT. Repeated measures ANOVA with a Greenhouse–Geisser correction (Table 3) revealed an overall significant difference over time for all the parameters, time-group interactions were significant in all the parameters except PT, PR and INR, overall group differences were significant only in adjusted fibrinogen level, unadjusted and adjusted D-dimer levels. Most of the parameters demonstrated significant differences (P value <0.05) on pair-wise comparison of laboratory variables between two time-points by Bonferroni's Post-hoc test (Table 4). Changes in hemoglobin level with time are clearly depicted in Fig. 1 in two groups of patients. Platelet counts, fibrinogen and D-dimer levels were significantly different between on-pump and off-pump CABG patients on immediate and 24 h postoperative

period and attained almost same level after 7 days of operation. Platelet counts and fibrinogen levels were increased after a sharp fall in the immediate post-operative period (Figs. 2a, b, 3a, b) whereas D-dimer levels (Fig. 4a, b) were persistently increased with a sharp peak of rise in the immediate post-operative period in on-pump group.

Discussion

The abnormalities of coagulation and fibrinolysis variables associated with CPB heart surgery have been extensively investigated because of the occurrence of hemorrhagic perioperative syndromes, which significantly complicates the outcome of heart surgery patients [12]. Recently, OPCAB has been revisited because of the introduction of stabilizer systems permitting satisfactory results, [13, 14] and an increasing number of centers have adopted this modality of surgery as their first choice [15–18]. Because of the obvious difference in the degree of hemodilution occurring with the two surgical modalities, we chose to adjust the changes in hemostatic variables for those observed in hematocrit values. Our results show that after correction for the variables, differences in platelet counts between two groups were reduced, sharp fall in fibrinogen level in immediate postoperative period was corrected to a greater extent and the sharp peak of rise of D-dimer level in the immediate post-operative period more increased in on-pump group. This prospective study demonstrated a tendency towards decreased activation of both coagulation and fibrinolysis in low risk patients during elective OPCAB compared with CPB. To exactly evaluate the role of CPB the same level of heparinization would have been needed.

Casati et al. [19] reported consumption of antithrombin and fibrinogen in both groups but plasminogen activation and D-dimer formation during surgery in the CPB group only. Englberger et al. [20] found reduced activation of both coagulation and fibrinolysis in OPCAB patients. Several investigators [21–23] have previously demonstrated increased levels of F1 + 2 in patients undergoing cardiac operations with CPB. Casati et al. [19] reported a decrease in platelet count during surgery and an increase 24 h after surgery in the CPB and no important changes in the OPCAB group. Møller and Steinbrüchel [24] demonstrated an increase in platelet activation after OPCAB and a temporary platelet dysfunction in the CPB group. A limitation of our study was that we did not measure the platelet functions.

The incidences of thrombotic events such as stroke and myocardial infarction were similar in the on-pump and off-pump groups. The technique of coronary bypass surgery

Table 3 Changes in laboratory variables in respect to time, group (on-pump and off-pump) and time-group interaction as analyzed by repeated measures ANOVA with Greenhouse–Geisser correction

Parameters	P value of within subject effect (i.e. time effect)	P value of time-group interaction effect	P value of between subject effect (i.e. group effect)
Hemoglobin (g/dL)	<0.001 , S	<0.001 , S	0.186, NS
Hematocrit (%)	<0.001 , S	<0.001 , S	0.359, NS
Platelets ($10^9/L$)	<0.001 , S	<0.001 , S	0.278, NS
Corrected platelets ($10^9/L$)	<0.001 , S	<0.001 , S	0.928, NS
PT (sec)	<0.001 , S	0.804, NS	0.777, NS
Prothrombin ratio (PR)	<0.001 , S	0.371, NS	0.997, NS
INR	0.004, S	0.592, NS	0.402, NS
APTT (sec)	<0.001 , S	<0.001 , S	0.091, NS
APTT ratio	<0.001 , S	<0.001 , S	0.654, NS
TT (sec)	<0.001 , S	<0.001 , S	0.768, NS
Fibrinogen (mg/dL)	<0.001 , S	<0.001 , S	0.158, NS
Corrected fibrinogen (mg/dL)	<0.001 , S	<0.001 , S	0.001, S
D-dimer (mg/L)	<0.001 , S	<0.001 , S	<0.001 , S
Corrected D-dimer (mg/L)	<0.001 , S	<0.001 , S	<0.001 , S

S significant, NS non-significant

Table 4 Comparison of laboratory variables between two time-points by Bonferroni's Post-hoc test

Parameters	<i>P</i> values of pairwise comparisons between time points (1,2,3,4) (<i>n</i> = 73)					
	T1 vs. T2	T1 vs. T3	T1 vs. T4	T2 vs. T3	T2 vs. T4	T3 vs. T4
Hemoglobin (g/dL)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
Hematocrit (%)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
Platelets ($10^9/L$)	<0.001, S	0.016, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
Corrected platelets ($10^9/L$)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
PT (sec)	<0.001, S	<0.001, S	0.631, NS	<0.001, S	<0.001, S	<0.001, S
Prothrombin ratio (PR)	<0.001, S	<0.001, S	0.493, NS	<0.001, S	<0.001, S	<0.001, S
INR	0.012, S	<0.001, S	1.000, NS	0.377, NS	0.017, S	<0.001, S
APTT (sec)	<0.001, S	1.000, NS	<0.001, S	<0.001, S	<0.001, S	<0.001, S
APTT ratio	<0.001, S	0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
TT (sec)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
Fibrinogen (mg/dL)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
Corrected fibrinogen (mg/dL)	0.135, NS	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S
D-dimer (mg/L)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	0.434, NS	<0.001, S
Corrected D-dimer (mg/L)	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S	<0.001, S

S significant, *NS* non-significant

Fig. 1 Hemoglobin level at four time points in two groups of patients. Data points represent mean

was not identified as independent predictors of long-term (10 years) mortality [25].

Other studies have consequently compared the activation of the coagulation system in patients undergoing CABG with or without CPB. Englberger et al. [20] analyzed 27 patients assigned in a randomized fashion to undergo myocardial revascularization either with the off-pump technique (9 patients) or with CPB (16 patients). Plasma levels of fibrin monomer, thrombin-antithrombin complex and D-dimer were significantly higher in the on-

Fig. 2 a Platelet count at four time points in two groups of patients without correction for hemodilution. Data points represent mean. **b** Platelet count at four time points in two groups of patients after correction for hemodilution. Data points represent mean

pump group immediately after surgery, whereas they were similar 18 h postoperatively. Lo et al. [26] evaluated 40 patients who underwent coronary surgery with or without

Fig. 3 **a** Fibrinogen level at four time points in two groups of patients without correction for hemodilution. *Data points represent mean.* **b** Fibrinogen level at four time points in two groups of patients with correction for hemodilution. *Data points represent mean*

Fig. 4 **a** Concentration of D-dimer at four time points in two groups of patients without correction for hemodilution. *Data points represent mean.* **b** Concentration of D-dimer at four time points in two groups of patients with correction for hemodilution. *Data points represent mean*

CPB. Compared with the on-pump CABG group, prothrombin fragment 1.2 (F1.2) and D-dimer levels were significantly lower in patients having CABG surgery performed off-pump. In OPCAB patients, F1.2 and D-dimer levels increased more gradually and peaked on day 4. In both groups, plasma concentrations of von Willebrand factor increased from the first postoperative day compared with baseline and peaked at 4th postoperative day.

Paulitsch et al. [27] observed that concentrations of PAI-1 and D-dimer were greater early after surgery in patients undergoing on-pump surgery. And opined that the prothrombotic state might be a consequence of extracorporeal

bypass, compensation in response to bleeding or both. Vedin et al. [28] similarly observed lower concentrations of fibrin D-dimer and prothrombin fragment 1 + 2 during surgery in the off-pump group ($P < 0.001$). Paparella et al. [29] concluded that thrombin formation was more pronounced in patients having on-pump bypass grafting. Patients subjected to off-pump bypass grafting had normally functioning platelets and a weak activation of the fibrinolytic system. Parolari et al. [30] observed that activation of coagulation and of fibrinolytic pathways as well as of endothelium were relatively delayed in off-pump group compared to on-pump group. And suggested that the

avoidance of extracorporeal circulation protects from the early appearance of a prothrombotic state. All these observations are comparable to that of our study.

In this prospective study of OPCAB versus on-pump CABG, we found two temporally different patterns: the CPB group had a significantly more pronounced activation of coagulation and fibrinolysis in the immediate postoperative period, whereas the OPCAB group demonstrated a delayed postoperative response that became almost equal in magnitude to that of the CPB group in the later postoperative period.

Conclusions

On-pump surgery was associated with excessive fibrinolytic activity immediately after operation. The off-pump group demonstrated relatively less activation of coagulation and fibrinolysis and delayed postoperative response in comparison to on-pump group.

Conflict of interest The authors declare that they have no conflict of interest.

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