Does Off-Pump CABG Reduce Gastrointestinal Complications?

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Background. The aim of this study was to compare gastrointestinal complications and associated risk factors among patients undergoing cardiac surgery using off- and on-pump revascularization techniques.

Methods. A total of 1146 adult patients who underwent coronary artery surgery during a 6-year period were evaluated retrospectively. Group 1 consisted of 546 patients operated using off-pump techniques and group 2 consisted of 600 cases operated with cardiopulmonary bypass. Patients were compared and evaluated for gastrointestinal complications and possible associated risk factors using univariate and multivariate logistic regression analysis.

Results. Overall mortality was 1.6% in group 1 and 2.2% in group 2 ($p = 0.523$). Mortality due to gastrointestinal complications was 38.5% and 35.7% respectively in group 1 and group 2. The mean EuroSCORE value was 5.1 ± 2.8 in group 1 and 3.8 ± 2.4 in group 2 ($p < 0.001$). The most common gastrointestinal complication in the off-pump group was gastrointestinal bleeding. The leading complication in group 2 was intestinal ischemia.

Conclusions. The incidence rates of gastrointestinal complications were similar in the on- and off-pump coronary artery bypass groups, the type of gastrointestinal complications, however, was different. Mortality rate due to these complications was also similar and remained high, regardless of the type of surgery. Cardiopulmonary bypass did not emerge as a risk factor for gastrointestinal complications, but prolonged cardiopulmonary bypass (longer than 98 minutes) resulted in a high incidence of such complications. Old age and advanced arteriosclerosis emerged as risk factors in both groups resulting in gastrointestinal complications suggesting the ischemic nature of the injury.

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Gastrointestinal (GI) complications secondary to cardiac surgery are rare (0.4% to 2%), but result in a significantly high mortality rate [1]. This is mainly because these complications are difficult to diagnose, and symptoms can be masked in the early postoperative period due to sedation and mechanical ventilation causing a delay in diagnosis [2]. Some risk factors associated with GI complications after cardiac surgery are low perioperative cardiac output or hypotension, long duration of cardiopulmonary bypass (CPB), older age, prolonged ventilation time, valve surgery, reexploration of the chest, and history of peptic ulcer [3].

Off-pump coronary artery bypass (OPCAB) has been argued to reduce the inflammatory response during coronary artery bypass grafting (CABG) [4]. Based on this argument, it was believed that OPCAB surgery could reduce subsystem and end organ damage seen after conventional CABG leading to less morbidity. There are numerous studies in the literature comparing the outcome between off-pump and on-pump coronary artery revascularization techniques. However, there are few data comparing GI complications following these two different methods of revascularization [5].

The aim of this study was to compare GI complications and associated risk factors among patients undergoing cardiac surgery using off-pump and on-pump coronary artery revascularization techniques.

Patients and Methods

The Ethical Committee of the hospital approved the study. An informed consent was obtained from each patient. The study consisted of 1,146 cases that have undergone CABG in Florence Nightingale Hospital between January 1997 and September 2002. Cases with concomitant procedures such as valve repair, valve replacement, or resection of left ventricle aneurysm were not included in the study. Cases were divided into two groups: group 1 consisted of 546 CABG patients operated with off-pump technique. Group 2 included 600 patients selected with stratified sampling technique between the same years through weighting by year among 2351 patients that received CABG with on-pump technique. Randomized numbers table was used for selection. All

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patients were operated on by the same surgical team using the same technique for myocardial protection and operative strategy for revascularization.

The following preoperative variables were identified: patient age, gender, diabetes mellitus, hypertension, hypercholesterolemia, smoking, functional capacity (New York Heart Association [NYHA] classification), history of GI events, cerebrovascular accident, carotid artery disease, peripheral artery disease, renal artery stenosis, abdominal aortic aneurysm, renal dysfunction (creatinine > 1.5 mg/dl), aortic arteriosclerosis, malignancy, chronic obstructive pulmonary disease (COPD), reoperation, and history of myocardial infarction. Five operative variables were examined: urgency of operation, number of bypasses, left ventricle ejection fraction (LVEF), duration of CPB (for on-pump group), and duration of operation. Postoperative data regarding intensive care unit (ICU) stay, use of inotropic agents, intraaortic balloon pump (IABP), reexploration, blood transfusions, hemodialysis, and atrial fibrillation rate were recorded for both groups.

The GI complications were GI bleeding, duodenal perforation, intestinal ischemia, pancreatitis, hepatic dysfunction, acute cholecystitis, and paralytic ileus. Definitions for GI complications are derived from the STS database [6].

Operative Protocol

Antiaggregant medication (aspirin, plavix) was discontinued 5 days before the operation. All surgical procedures were performed through sternotomy. Conduits for coronary bypass including the internal thoracic artery (ITA), radial artery, and saphenous vein were harvested in standard methods. In the on-pump group, CPB was performed by cannulation of the ascending aorta and the right atrium. Both antegrade and retrograde tepid (32°C) blood cardioplegia were used for myocardial protection. The perfusate was allowed to cool to 32°C, and all patients received nonpulsatile flow at rates of 2.2 to 2.4 $L \cdot min^{-1} \cdot m^{-2}$. All proximal and distal anastomoses were performed with a single cross clamp technique. Epinephrine infusion at 0.01 to 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$ was the first choice of inotropic medication during weaning from CPB. Dobutamine was added as a second choice when deemed necessary. Heparin dose was neutralized with protamine according to the activated clotting time (ACT).

The technique that we used during off-pump CABG has been described in our previous study [7]. Initially a half dose of heparin was administered followed by an hourly additional dose that was regulated with the ACT. In order to minimize aortic manipulation, T or Y grafts were performed using ITAs or the radial artery. Following the completion of the ITA anastomoses, the proximal anastomoses of saphenous vein grafts were done, first with a partial aortic clamp then the distal anastomoses were performed. Stabilization of the coronary arteries was accomplished using the Octopus II or III (Medtronic Inc., Minneapolis, MN) stabilization systems. At the end of the operation, a half dose of protamine was administered for neutralization of heparin and the Hepcon Hemostasis Management System (Medtronic Inc.) was used to assess if an extra dose of protamine was needed.

Aspirin (150 mg) was administered from the nasogastric tube in both groups 3 hours after arrival at the ICU. In addition, the off-pump group received oral plavix (clopidogrel; 75 mg) medication for the duration of one month starting on the first postoperative day. Cefuroxime was administered for antibiotic prophylaxis. Famotidin (40 mg) was applied intravenously upon anesthesia induction as prophylaxis for GI bleeding; oral Famotidine (40 mg) and antacid medication were maintained during hospital stay. Patients with a preoperative history of GI bleeding received oral Omeprazole (40 mg) instead of Famotidine.

Statistical Analysis

All of the statistical analyses were performed by Stats Direct statistical software (Ver 2.2.0; StatsDirect, Ltd, Cheshire, United Kingdom). Descriptive statistics were shown as arithmetic mean ± standard deviation. We first used the Kolmogorov-Smirnov method to test the normality assumptions for the variables. In order to compare the variables for two groups, the Mann-Whitney *U* test was performed. The effects of the other variables on GI system complications were first tested by Univariate logistic regression analysis for each group separately. Multivariate logistic regression analysis was then applied. Cox-Snell R^2 values were also calculated. For the cut-off point of CPB, we used the region of interest curve and calculated the area under the curve. The *p* values less than or equal to 0.05 were considered as statistically significant.

Results

In group 1, 13 patients (2.4%) developed GI system complications postoperatively, whereas 14 patients (2.4%) developed GI complications postoperatively in group 2 ($p = 0.963$). The most commonly observed GI complication was GI bleeding (n = 4) in group 1 and intestinal ischemia (n = 5) in group 2. Mortality rate of the patients with GI complications was 38.5% in group 1 and 35.7% in group 2 (Table 1).

The risk profile for both groups was evaluated with the use of the EuroSCORE system. Mean risk score was 5.1 ± 2.8 for group 1 and 3.8 ± 2.4 for group 2 ($p < 0.001$). Although group 1 patients had a higher EuroSCORE, both groups were classified as medium risk patients under the EuroSCORE system. Preoperative clinical variables of the patients are presented in Table 2. The rate of emergency operations was 6% in group 1 and 6.8% in group 2 ($p = 0.587$). The mean number of anastomoses was 2.2 ± 0.8 in group 1 and 2.97 ± 0.9 in group 2 ($p < 0.001$). The number of patients with LVEF lower than 35% accounts for 5.1% of group 1 and 10.2% of group 2 ($p < 0.001$). Average CPB time (for group 2) was 73.7 ± 19.1 minutes. Duration of operation was 154 ± 0.8 minutes in group 1 and 178.8 ± 0.9 minutes in group 2 ($p < 0.001$). ICU stay was 28.6 ± 20.8 hours in group 1, and 51.9 ± 60.4

Table 1. Type of Gastrointestinal Complications

GI Complications	Group 1 (n = 546)		Group 2 (n = 600)			
	n	Mortality	n	Mortality	*z* Value	*p* Value
GI bleeding	4	1	2			
Duedonal perforation	1	1	1	1		
Intestinal ischemia	2	2	5	3		
Pancreatitis	1		1			
Hepatic dysfunction	2	1	1	1		
Acute cholecystitis	1		1			
Paralytic ileus	2		3			
Total	13	5	14	5	0.046	0.963

GI = gastrointestinal.

hours in group 2 ($p < 0.001$). Postoperative inotropic support (epinephrine) was 0.03 ± 0.07 $\mu g \cdot kg^{-1} \cdot min^{-1}$ in group 1 and 0.08 ± 0.06 $\mu g \cdot kg^{-1} \cdot min^{-1}$ in group 2 ($p < 0.001$). The use of IABP was 0.9% in group 1 and 2.5% in group 2 ($p = 0.04$). Reexploration rate was 1.6% in group 1 and 2.3% in group 2 ($p = 0.285$). The blood transfusion in the ICU was 1.41 ± 0.9 U in group 1 and 2.23 ± 1.2 U in group 2 ($p < 0.001$). Postoperative hemodialysis rate was 2.9% in group 1 and 1.4% in group 2 ($p = 0.059$). Incidence of postoperative atrial fibrillation was 10.3% in group 1 and 16.3% in group 2 ($p = 0.003$). Mortality rate was 1.6% in group 1 and 2.2% in group 2 ($p = 0.523$).

Factors that could contribute to postoperative GI complications were evaluated in the whole series (n = 1146) first with univariate and then with multivariate analysis. These factors are shown in Table 3. Age, peripheral artery disease, aortic arteriosclerosis, low LVEF, use of epinephrine, blood transfusion, atrial fibrillation, and a high EuroSCORE emerged as significant risk factors for GI complications in the whole series. CPB did not emerge as a risk factor. A further analysis was performed to evaluate the risk factors contributing to GI system complications for each group (Table 4). This was followed by a multivariate analysis of the factors that came forward during the univariate analysis (Table 5). In group 1, advanced age, carotid artery disease, peripheral artery disease, atherosclerotic aorta, number of anastomoses, LVEF less than 35%, and a high EuroSCORE were found to be risk factors for GI system complications. However, in group 2, advanced age, peripheral artery disease, COPD, high dose inotrope use, excess blood transfusion,

Table 2. Preoperative Clinical Characteristics and Comorbidities of Patients

Variables	Group 1 (n = 546)		Group 2 (n = 600)			
	n	Percent	n	Percent	*z* Value	*p* Value
Age (mean ± SD)	67.2 ± 8.9		60.4 ± 9.3		12.067	< 0.001
Gender					1.233	0.218
Female	167	30.6	204	34		
Male	379	69.4	396	66		
Diabetes mellitus	142	26	124	20.7	2.138	0.03
Hypertension	245	44.9	185	30.8	4.9	< 0.001
Hypercholesterolemia	486	89	469	78.2	4.918	< 0.001
Smoking	354	64.8	288	48	5.732	< 0.001
NYHA						
Class I	13	2.4	11	1.8	0.647	0.259
Class II	350	64.1	505	84.2	7.794	< 0.001
Class III	177	32.4	61	10.2	9.274	< 0.001
Class IV	6	1.1	23	3.8	2.944	0.003
History of GI event	100	18.3	46	7.7	5.397	< 0.001
Cerebrovascular accident	20	3.7	4	0.7	3.536	< 0.001
Carotid artery disease > 50%	192	35.2	56	9.3	10.601	< 0.001
Peripheral artery disease	63	11.5	26	4.3	4.55	< 0.001
Renal artery stenosis > 50%	6	1.1	23	1	1.116	0.264
Abdominal aorta aneurysm	6	1.1	2	0.3	1.116	0.264
Renal dysfunction	78	14.3	8	1.3	8.308	< 0.001
Aortic atherosclerosis	83	15.2	12	2	8.092	< 0.001
Malignancy	11	2	2	0.3	2.683	0.007
COPD	158	28.9	40	6.7	9.956	< 0.001
Reoperation	4	0.7	13	2.2	2.005	0.045
History of MI	197	36.1	164	27.3	3.182	0.042

COPD = chronic obstructive pulmonary disease; GI = gastrointestinal; MI = myocardial infarction; NYHA = New York Heart Association; SD = standard deviation.

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Table 3. Multivariate Analysis of Risk Factors of GI System Complications for All Patients (n = 1146)

Variables	Odds Ratio	95% Confidence Intervals	*p* Value
Age	1.13	1.09–1.16	< 0.001
Gender	1.34	0.97–1.84	0.074
Hypercholesterolemia	0.86	0.52–0.98	0.376
Carotid artery disease	1.88	1.17–3.03	0.01
Peripheral artery disease	0.51	0.3–0.87	< 0.001
Aortic atherosclerosis	0.12	0.07–0.21	< 0.001
COPD	0.54	0.33–0.88	0.013
Number of anastomosis	0.85	0.58–1.24	0.394
LVEF < 35%	0.4	0.34–0.72	< 0.001
History of GI event	1.09	0.76–1.56	0.634
Operating time (min.)	1.01	0.99–1.02	0.104
Epinephrine (mg/kg/min)	3.95	2.84–5.51	< 0.001
CPB time (min)	1.02	0.88–1.14	0.073
Transfusion (unit)	2.61	2.15–3.19	< 0.001
Atrial fibrillation	0.43	0.28–0.67	< 0.001
EuroScore	1.38	1.27–1.5	< 0.001

Cox-Snell $R^2 = 0.737$.

COPD = chronic obstructive pulmonary disease; GI = gastrointestinal; LVEF = left ventricle ejection fraction.

atrial fibrillation, a high EuroSCORE, and prolonged CPB time are found to be risk factors for GI system complications. The cut-off point for CPB was found to be 98 minutes. For this point, the sensitivity and specificity values were 0.857 and 0.926, respectively (Fig 1). History of GI event emerged as a risk factor for both groups in univariate analysis, but not in multivariate analysis.

Comment

The etiology and risk factors contributing to GI complications after coronary artery surgery have been defined extensively [8]. The combined stress of anesthesia, surgery, anticoagulation, hypothermia, and cardiopulmonary bypass triggers a hormonal stress response and a massive defense reaction compounded by hemodilution and nonpulsatile flow, which as a whole can lead to organ damage. Like all other organ systems, the GI system is exposed to vasoactive substances and microembolism during CPB, but usually few clinical manifestations occur. Most of the GI complications after CABG have been attributed to low cardiac output and visceral hypoperfusion resulting in mucosal ischemia and necrosis. Stress ulceration, mucosal atrophy, bacterial overgrowth from stress ulcer prophylaxis, and loss of barrier function with increased permeability may lead to bacterial translocation, sepsis, and multiorgan failure [9]. CPB causes reduction in mucosal blood flow and leads to mesenteric sequestration of neutrophils and stimulates systemic inflammatory response [10]. It has been demonstrated that significant intestinal mucosal ischemia can occur during CPB despite the normal indices of global perfusion. Factors released during CPB such as vasopressin, catecholamines, tromboxane A2 and B2 lead to redistribution of blood flow away from the mucosa because of

Table 4. Univariate Analysis of Risk Factors for Gastrointestinal Complications

	Off-Pump (n = 546)			On-Pump (n = 600)		
Variables	Odds Ratio	95% Confidence Intervals	*p* Value	Odds Ratio	95% Confidence Intervals	*p* Value
Age	1.05	1.04–1.06	< 0.001	1.06	1.05–1.07	< 0.001
Gender	5.34	2.51–11.19	< 0.001	3.49	1.92–6.37	< 0.001
Hypercholesterolemia	0.02	0.02–0.04	< 0.001	0.09	0.07–0.14	< 0.001
Smoking	1.21	0.22–6.54	0.826	0.76	0.15–4.01	0.649
Carotid artery disease	3.73	1.53–9.87	< 0.001	8.3	3.57–19.35	< 0.001
Peripheral artery disease	6.88	3.27–14.41	< 0.001	6.87	3.27–14.41	< 0.001
Renal dysfunction	0.67	0.34–1.33	0.255	1.21	0.87–1.69	0.227
Aortic atherosclerosis	3.39	2.11–5.45	< 0.001	1.33	0.49–3.59	< 0.001
COPD	1.87	0.92–3.81	< 0.001	2.99	1.46–6.12	0.018
Number of anastomosis	0.77	0.64–0.93	0.006	0.85	0.68–1.07	0.176
LVEF < 35%	0.29	0.2–0.43	< 0.001	0.02	0.01–0.04	< 0.001
History of GI event	8.09	4.33–15.14	< 0.001	4.75	2.22–9.18	< 0.001
Operating time (min)	1.02	1.02–1.03	< 0.001	1.02	1.01–1.05	< 0.001
Epinephrine (μg/kg/min)	0.33	0.27–0.41	< 0.001	0.22	0.18–0.28	< 0.001
CPB time (min)				1.05	1.04–1.08	< 0.001
Transfusion (unit)	6.06	4.64–7.92	< 0.001	3.95	3.24–4.83	< 0.001
IABP	0.67	0.11–3.99	0.657	2.17	0.68–5.85	0.206
Reexploration	1.66	0.39–6.97	0.484	1.8	0.61–5.37	0.292
Atrial fibrillation	6.99	3.17–15.43	< 0.001	8.8	4.58–16.93	< 0.001
Euroscore	1.85	1.69–2.05	< 0.001	2.01	1.79–2.26	< 0.001

COPD = chronic obstructive pulmonary disease; CPB = cardiopulmonary bypass; GI = gastrointestinal; IABP = intraaortic balloon pump; LVEF = left ventricle ejection fraction.

Table 5. Multivariate Analysis of Risk Factors for GI System Complications

	Off-Pump (n = 546)			On-Pump (n = 600)		
Variables	Odds Ratio	95% Confidence Intervals	*p* Value	Odds Ratio	95% Confidence Intervals	*p* Value
Age	0.02	0.86–0.98	0.02	6.65	6.42–6.89	< 0.001
Gender	1.11	0.97–1.18	0.122	1.67	0.51–6.23	0.367
Hypercholesterolemia	0.89	0.43–1.83	0.752	1.02	0.98–1.05	0.391
Carotid artery disease	7.69	1.65–35.86	< 0.001	0.81	0.59–1.13	0.214
Peripheral artery disease	5.5	1.48–20.4	< 0.001	0.29	0.2–0.43	< 0.001
Aortic atherosclerosis	0.45	0.21–0.96	< 0.001	0.99	0.97–1	0.345
COPD	1.02	0.96–1.08	0.442	2.84	1.19–6.75	< 0.018
Number of anastomosis	3.04	1.85–4.99	< 0.001	1.2	0.89–1.63	0.254
LVEF < 35%	1.55	0.26–9.18	< 0.001	7.59	2.34–22.6	0.002
History of GI event	0.69	0.33–1.48	0.345	1.18	0.95–1.46	0.144
Operating time (min)	0.99	0.78–1.04	0.645	0.67	0.36–1.24	0.54
Epinephrine (μg/kg/min)	3.73	1.28–10.83	0.116	18.31	8.3–40.38	< 0.001
CPB time (min)				11.2	10.86–11.57	< 0.001
Transfusion (unit)	2.65	1.33–10.28	0.116	1.16	1.14–1.18	< 0.001
Atrial fibrillation	0.26	0.14–1.37	0.184	3.69	0.95–14.26	< 0.001
EuroSCORE	1.27	1.06–1.53	0.011	3.23	2.98–3.51	0.004

Cox-Snell R^2 = 0.736 for off-pump group and 0.750 for on pump group.

COPD = chronic obstructive pulmonary disease; CPB = cardiopulmonary bypass; GI = gastrointestinal; LVEF = left ventricle ejection fraction.

regional vasoconstriction, and may contribute to mucosal ischemia [11].

Off-pump coronary artery surgery reduces systemic inflammatory response, allowing an environment that is physiologically more favorable for the organ systems [4]. It has been reported by many series that off-pump surgery reduces the need for early systemic vasoconstrictor or inotropic requirement. This may contribute to improved organ function, particularly in critically ill patients [12]. Therefore, off-pump coronary artery surgery has recently gained popularity for being a method that is physiologically more appropriate for maintaining the functional integrity of major organ systems and reducing morbidity [13]. Although many studies share the view that OPCAB operations result in significant attenuation of the inflammatory response seen after CPB, the clinical reflections of these findings have not been definitive [14].

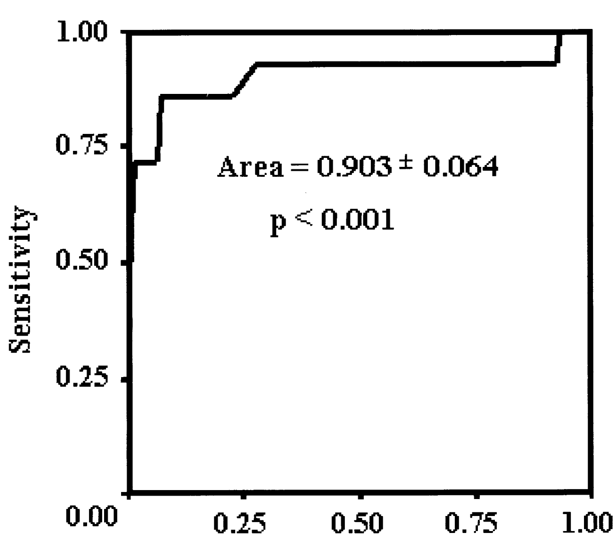

Fig 1. Region of interest curve for cardiopulmonary bypass time. A cardiopulmonary bypass time more than 98 minutes was significant for gastrointestinal complications.

There have been numerous reports comparing the results of on- and off-pump surgery in terms of morbidity and mortality [12–15]. Most of these studies have been retrospective. The results of two prospective randomized studies were published recently: the beating heart against cardioplegic arrest study could not reveal any difference between on-pump and off-pump CABG in terms of mortality, however, the morbidity rate was lower in the off-pump group [15]. Another study by van Dijk and associates [16] has failed to demonstrate any difference in terms of morbidity, although the off-pump group had a shorter ventilation time and hospital stay duration. Similar comparative studies focusing on GI complications have been limited at this time. A recent study by Musleh and colleagues [5] has failed to show any difference in terms of GI complications between on- and off-pump groups undergoing CABG surgery.

It was speculated that nonpulsatile flow during CPB could be hazardous to mucosal ischemia, which may have implications for the development of postoperative GI complications [17]. Despite this possible connection between nonpulsatile flow and GI complications, a definitive correlation could not be determined. A diligent study by Velissaris and associates [18] showed that gastric mucosal hypoxia occurred equally in on- and off-pump CABG groups, with worsening trends for the OPCAB group early postoperatively. Therefore, the splanchnic pathophysiology and gastric mucosal circulation during off-pump revascularization should be further explored before drawing any conclusions.

During off-pump coronary artery surgery, manipulations on the beating heart can depress cardiac functions, and tilting the heart can induce low cardiac output. This situation can be balanced with volume replacement, use of inotropic agents, and putting the patient in Trendelenburg position. The effect of Trendelenburg position on distal perfusion to abdominal organs is not clear. On the other hand, avoiding CPB reduces micro- and macroembolism due to cannulation and cross-clamping of the aorta, which can theoretically lead to less distal organ malperfusion [19]. However, side clamping the aorta for proximal anastomosis during off-pump surgery can still cause embolisation to distal organs, though atherosclerotic embolism is a less common cause of mesenteric ischemia [20].

Hypotension is frequently observed during CPB. Measures to restore aortic pressure during CPB consist of increasing pump flow or administering vasoactive medication. Intestinal tissue perfusion during CPB is primarily dependent on blood flow rather than perfusion pressure [21]. Thus, the use of systemic vasoconstrictors for managing hypotension during CPB may not improve mesenteric perfusion since the perfusion pressure is increased [22]. Vasoconstrictors may cause a selective vasoconstriction of mesenteric vessels and lead to the development of acidosis and mesenteric ischemia [10]. We observed a significantly higher requirement for vasoconstrictors in the on-pump group compared to the off-pump group, which might have been one of the factors contributing to the higher incidence of mesenteric ischemia in this group.

Our findings were similar in some ways with a recent study conducted by Musleh and colleagues [5], who were unable to differentiate patients undergoing on-pump and off-pump CABG in terms of GI complications. Although the OPCAB patients in our study had higher EuroSCORE levels, both groups were in medium risk class according to the EuroSCORE system. Significant risk factors identified for the development of GI complications include advanced age, peripheral vascular disease, prolonged CPB time, use of IABP support, need for postoperative blood transfusion, use of high dose inotropic agents, smoking, and diabetes mellitus [23–26]. The postoperative hypotension, low cardiac output state requiring inotropic support, and the use of IABP are significant predictors for mesenteric ischemia [27]. There has been a documented shift toward increasing age and more comorbid factors among the patients undergoing coronary artery surgery [28, 29], and our series is not an exception. Multivariate analysis showed that age, carotid artery disease, peripheral artery disease, aortic arteriosclerosis, number of anastomoses, LVEF less than 35%, and a high EuroSCORE were risk factor for the off-pump group, whereas age, peripheral artery disease, COPD, use of inotropic agents, prolonged CPB (longer than 98 minutes), blood transfusion, postoperative atrial fibrillation, and a high EuroSCORE were risk factors for the on-pump group. Unexpectedly, a previous history of GI events did not appear to be a risk factor for GI complications neither in the off-pump nor in the on-pump group.

Excessive blood transfusions can also impair organ function and cause damage [30]. Off-pump coronary artery surgery is known to reduce the need for blood transfusion [31] and may contribute to reducing GI complications. There was significantly lower transfusion requirement in the off-pump group in our study.

Mesenteric ischemia is usually noted in the elderly who have prolonged low cardiac output states requiring pharmacological or mechanical support. Nonocclusive mesenteric ischemia from a low cardiac output state or long pump duration is the most common etiology [20]. We observed that intestinal ischemia was predominantly seen in the on-pump group. During the multivariate analysis for the whole series, CPB did not emerge as a risk factor contributing to GI complication. However, multivariate analysis of the on-pump group alone revealed that prolonged CPB (longer than 98 minutes) emerged as a risk factor, contributing to GI complications.

Gastrointestinal bleeding usually results from stress ulceration and is more common in both the elderly and in those with preexisting ulcer disease. This has been our observation as well. There were more GI bleedings observed in the off-pump group, though H_2 receptor blockers were routinely administered for prophylaxis against stress ulcerations in both groups. This higher incidence of GI bleeding in the off-pump group may stem from an aggressive anticoagulation management and higher incidence of preoperative GI event of these patients. There are several published data indicating higher postoperative bleeding and GI side effects by using plavix in combination with aspirin [32, 33]. This protocol has been recently changed and plavix has been discontinued due to high rates of hemorrhagic complications. The results of this protocol change remains to be seen.

In conclusion, the rates of major GI complications were similar in both groups, although the types of complications were different. GI bleeding was more common in off-pump group, whereas intestinal ischemia was more prevalent in the on-pump group. The relationship between prolonged CPB and GI complications was shown. Previous history of GI event emerged as a risk factor for both groups during univariate analysis, but not during multivariate analysis. The observed mortality rates between the two groups after the development of such complications were also similar and remained high.

This study has several limitations: The number of patients compared in each group is low, reducing the preponderance of the study. Multicenter studies with a greater number of patients would enhance the results of similar studies. Although patients in each group were at medium risk according to EuroSCORE, numerical values were different. We tried to neutralize these effects by performing univariate and multivariate analysis, first for the whole series, then separately. However, the study has the advantage of being a single center, single surgeon study, thus greatly reducing the effects of different surgical techniques and perioperative or postoperative protocol.

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