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ORIGINAL ARTICLE

Importance of Anastomotic Sequencing during Off-Pump Coronary Artery Bypass Surgery: A Pilot Strategy

Pompasız Koroner Arter Baypas Cerrahisi Sırasında Anastomoz Sıralamasının Önemi: Pilot Strateji

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Abstract

Introduction: Off-pump coronary artery surgery is a method preferred by many surgeons today to avoid the adverse effects of cardiopulmonary bypass. However, this method was quite popular at first but was later abandoned by some surgeons due to unfavorable results. We think the anastomosis sequence is an essential issue when performing off-pump surgery. We aimed to examine the effects of this strategy on the results of off-pump coronary artery surgery.

Methods: We included 601 patients with isolated coronary artery disease who underwent off-pump coronary artery bypass surgery between January 2020 and 2022. The main goal was to ensure sufficient blood was going through the myocardia while anastomosis was performed on one of the coronary arteries. We tried to create a strategy about the sequence in which we should do the coronary anastomosis.

Results: In 2 patients, conversion to on-pump surgery was required in elective conditions due to hemodynamic instability during the operation (0.33%). Only 4 patients required surgical revision because of bleeding (0.67%) in the early postoperative period. We recorded wound infections that could be solved with medical therapy and routine wound dressing in 5 patients (0.83%).

Discussion and Conclusion: After applying this strategy, we experienced much more minor and acceptable conversion rates than those reported in the literature. We believe this strategy will benefit other researchers who have just started practicing off-pump surgery.

Keywords: Anastomosis sequence; Coronary artery disease; Off-pump coronary artery bypass surgery

The most commonly performed heart surgery globally is coronary artery bypass surgery. The primary purpose of coronary artery bypass surgery is to keep the patient alive, increase life expectancy in the maximum time, and provide maximum patient comfort after surgery while providing these two. Methods used in parallel with technological developments from the beginning to the present day have been developed, aiming to minimize the adverse

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effects of surgery. In addition to the surgical conveniences that provide extracorporeal circulation used in classical coronary artery bypass surgery, it also harms the patient in many ways. In addition to systematic damages such as to the complement system, coagulation system, and kinin-kallikrein system, adverse effects have been shown in many organs such as renal functions,[1] pulmonary functions,[2,3] cerebral perfusion disorders,[4,5] and systemic inflammatory response syndrome.[6] Therefore, off-pump coronary artery surgery is increasingly preferred by some surgeons today to avoid the adverse effects of cardiopulmonary bypass (CPB). On the other hand, minimally invasive and robotic surgical methods are still being developed by reducing the incision sizes to increase postoperative patient comfort.

Off-pump surgery, widely preferred at first, was later partially abandoned due to the negative results.[7] Later, with the introduction of myocardial stabilizers and intracoronary shunts, it became widely used again. When applied successfully, the results of off-pump surgery have been seen to compete with on-pump surgery,[8] and it has even been reported that it gives much better results, according to some researchers.[9] While it will be preferred, surgeons who have unsuccessful results gradually abandon it.

The main problems experienced during off-pump surgery are hemodynamic instability, severe calcification of the target vessels, difficulties in positioning the heart (lack of devices such as stabilizers), the patient's ventricular functions not allowing off-pump surgery, and surgical inexperience. For such reasons, urgent conversion to on-pump surgery may be required. It is also reported that patients who have an emergency conversion from off-pump to on-pump have worse outcomes.[10,11]

According to our experience, the anastomosis sequence is an essential issue when performing off-pump surgery. The lesions of each patient are not the same. For this reason, the anastomosis strategy should not be the same for every patient. We believe that when performing off-pump coronary artery bypass surgery, the anastomosis sequence of the target coronary arteries should be determined individually for each patient. For example, in a patient with occlusion of both the Cx artery and the RCA, trying to anastomose the LIMA to the LAD artery in the first place will cause an acute hemodynamic instability as it will cause temporary occlusion of the single vessel that provides the circulation of the heart at that time. In this patient, even temporary closure of this vessel may require conversion to on-pump, as the LAD is the only vessel providing blood flow at that time.

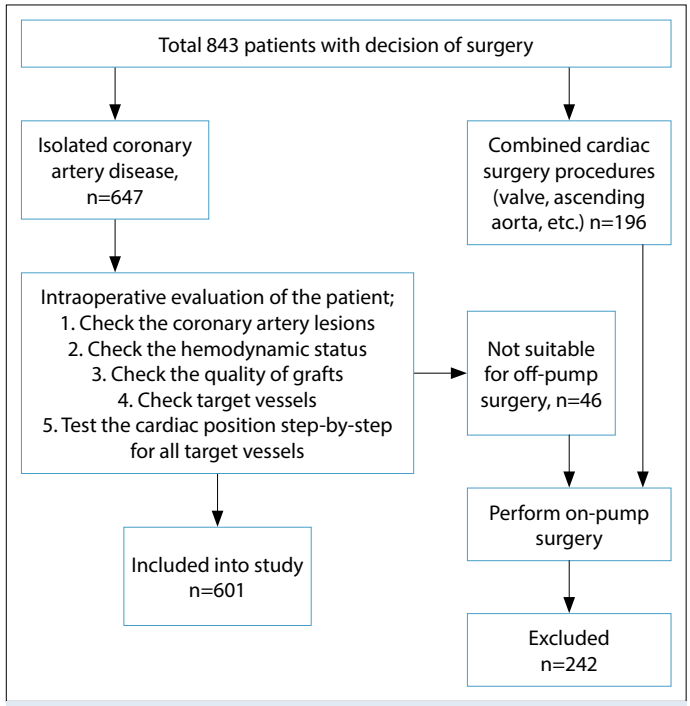

Figure 1. Patient inclusion algorithm.

For this reason, we thought that an anastomosis sequencing should be made according to the location of the coronary artery lesions to be determined separately for each patient who will undergo off-pump coronary artery bypass surgery. We aimed to examine the effects of this method on the results of off-pump coronary artery surgery. In this way, we thought we could eliminate some difficulties experienced while performing off-pump surgery.

Materials and Methods

By getting approval with number 2019/15 from the local ethics committee of our hospital, we included 601 patients with isolated coronary artery disease who underwent off-pump coronary artery bypass surgery between January 2020 and 2022. All patients included in the study were informed and signed a written consent form. The study was conducted in agreement with the Declaration of Helsinki. Our inclusion criteria for this study are shown in Figure 1. The demographic data of the patients are shown in Table 1.

All patients were given 1 g cefuroxime intravenously before surgery for antibiotic prophylaxis. Induction of anesthesia was provided by administration of 0.05 mg/kg midazolam, 3 μg/kg sufentanil, and 0.1 mg/kg vecuronium intravenously and maintained with a continuous infusion of 0.5 μg/kg/h sufentanil and 0.1 mg/kg/h propofol. A heat exchanger water blanket was routinely used to control body temperature in all patients.

Table 1. Demographic data of the patients

Age (years)	62.1±11.6
Female (9)	42.1
Body mass index (kg/m^2)	29.9±4.2
Left ventricle ejection fraction (%)	47.5±7.8
Diabetes mellitus (%)	34.6
Hypertension (%)	42.9
Smoking (%)	37.6
Peripheral arterial disease (%)	2.02
COPD (%)	8.08
Cerebrovascular disease (%)	2.99
Unstable angina pectoris (%)	4.65
Creatinine (mg/dL)	1.09±0.21
Preoperative hemoglobin (g/dL)	12.74±1.32

COPD: Chronic obstructive pulmonary disease.

During the surgeries, a perfusionist and cannulation materials were kept ready to be used in the operating room for possible emergent situations. A standard median sternotomy was performed just 2 cm below the suprasternal notch and 2 cm above the xiphoid cartilage. Just before completion of left internal mammary artery harvesting, intravenous heparin was administered at a dose of 100–150 IU/kg for all patients, and the adequacy of the amount was confirmed by measuring with activated clotting time (ACT) to be over 180 s. In cases where conversion from off-pump surgery to on-pump surgery was required, the heparin dose was completed to 300 IU/kg, and ACT was controlled to be 400–600 s. The pericardial sac was cut to hang with silk sutures.

At this point, we decided which technique to apply to the patient according to the criteria we determined in our previously published research[12] and our off-pump surgery experience. For this reason, we tested the condition of the target vessels first (calcifications and calibrations of the target vessels, etc.). Next, we tried whether the hemodynamic parameters would be permissible by positioning the heart as if coronary anastomoses would be performed. This intraoperative evaluation point is one of the most critical moments in deciding whether to perform the surgery on-pump or off-pump. At this stage, we decided that 46 of 647 patients were not suitable for off-pump surgery and performed on-pump surgery. After deciding on off-pump surgery, it is time to decide on another critical issue: in which sequence should we anastomose the target vessels? We determined a surgical strategy for this purpose (Fig. 2). The main goal was to ensure enough blood was going through the myocardia while anastomosis was performed on one of the coronary arteries:

1. LAD-LIMA anastomosis was first performed on each patient with LAD total obstruction. In patients who cannot use LIMA for various reasons, proximal anastomosis of the graft applied to the LAD (saphenous vein or radial artery, etc.) was made to the ascending aorta before starting the anastomosis of the other target coronary arteries and thus ensuring adequate blood supply to the LAD first.
2. If the LAD is not completely occluded, there is only a narrowing where blood flow is still maintained, and both Cx and RCA are occluded; performing LAD anastomosis first will lead to an acute cardiac instability as it will completely stop the blood flow of the heart and will most likely require an emergency conversion to on-pump technique. Therefore, we started with one of the target vessels wholly occluded (Cx or RCA) in patients with complete obstruction of all vessels other than LAD.

The combination of occlusion of major coronary arteries is shown in Figure 2. According to this distribution, our preference for the order of anastomosis is given in the last column.

Type of vascular lesion	(A) LAD artery	(B) Circumflex artery	(C) Right coronary artery	The order of anastomosis
1	●	O	O	A
2	●	O	●	A - C
3	●	O	◉	A - C
4	●	●	O	A - B
5	●	●	●	A - C - B
6	●	●	◉	A - B - C
7	●	◉	O	A - B
8	●	◉	●	A - C - B
9	●	◉	◉	A - B - C
10	◉	O	O	A
11	◉	O	●	C - A
12	◉	O	◉	A - C
13	◉	●	O	A - B
14	◉	●	●	C - A - B
15	◉	●	◉	B - A - C
16	◉	◉	O	A - B
17	◉	◉	●	C - A - B
18	◉	◉	◉	A - B - C

O : Vessels without lession. ◉ : Vessels with critical lession but not occluded.
● : Totally occluded vessel.

Figure 2. Anastomosis sequencing algorithm.

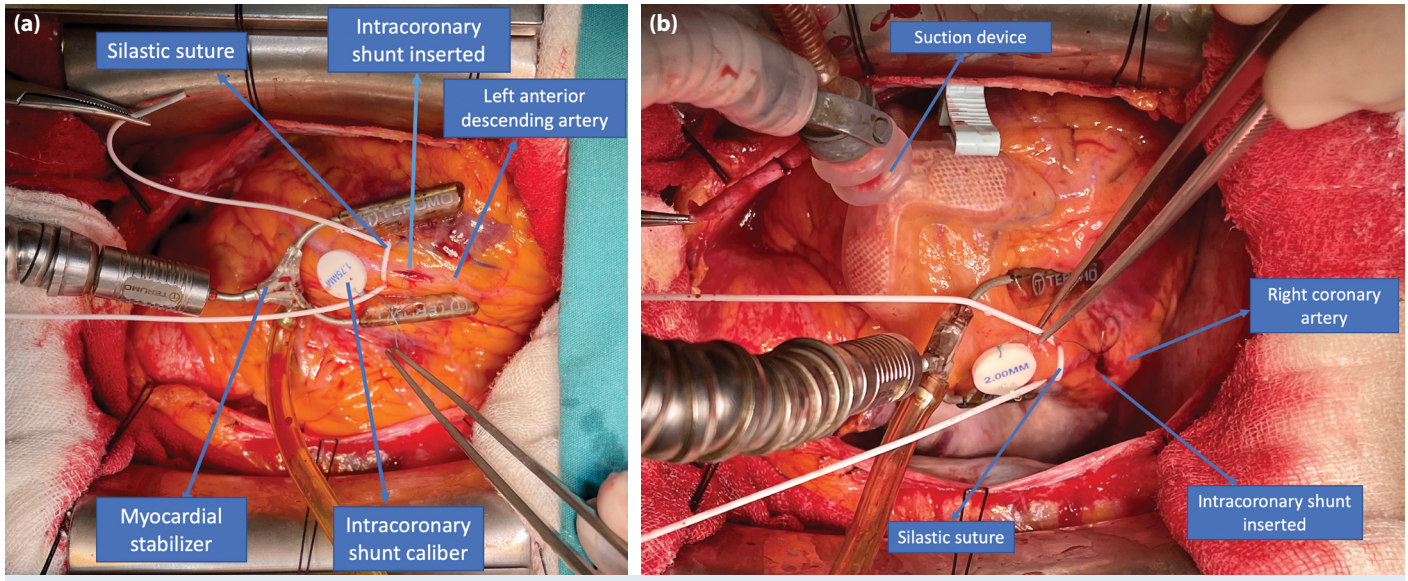

Figure 3. (a) Use of myocardial stabilizer and intracoronary shunt during LAD anastomosis. **(b)** Use of myocardial stabilizer, cardiac suction device, and intracoronary shunt during RCA anastomosis.

Table 2. Surgical results of the patients

Intraoperative conversion to on-pump surgery (%)	0.33
Total operation time (min)	109.8±18.9
Number of grafts per patient	3.38±0.86
One vessel bypass	10 patients (1.7%)
Two vessels bypass	38 patients (6.3%)
Three vessels bypass	438 patients (72.9%)
Four and more vessels bypass	115 patients (19.1%)
Total drainage amount (cc)	485.69 ± 101.94
Surgical revision (%)	0.6
Postoperative inotropic support (%)	3.9
Postoperative wound infection (%)	0.8
Postoperative stroke (%)	0
Postoperative renal impairment (%)	0.33
Stay in the intensive care unit (days)	2.02 ± 0.32
Total hospital stay (days)	4.85 ± 0.93
In-hospital mortality (%)	0.6

Statistical Analysis

Categorical data were presented as percentage and frequency. Parametric data were presented as mean and standard deviation. We used IBM SPSS for all calculations (IBM SPSS Statistics for Macintosh, Version 27.0. Armonk, NY: IBM Corp. Released 2020).

Results

It was decided to perform isolated coronary artery bypass surgery in 647 patients. During the preoperative and intraoperative evaluation of these patients, off-pump surgery was never tried in 46, and it was decided to perform on-pump surgery directly. Thus, off-pump coronary artery bypass surgery was performed on 601 patients. A single surgical team operated on all patients. Myocardial stabilization devices and intracoronary shunt were used when necessary (Fig. 3a, b). Average anastomosis times and mean surgery times are given in Table 2. In 2 patients, conversion to on-pump surgery was required in elective conditions due to hemodynamic instability during the operation (0.33%). Only 4 patients required surgical revision because of bleeding (0.67%) in the early postoperative period. We recorded wound infections that could be solved with medical therapy and routine wound dressing in 5 patients (0.83%). Anastomosed coronary arteries are shown in Table 3.

Discussion

Coronary artery bypass surgery is still one of the primary treatment methods for coronary artery disease. On the other hand, CPB and surgical treatment are the most damaging factor of this treatment method. Many researchers have examined the adverse effects of CPB, and many articles on this subject area are in the literature.[13–15] Although the off-pump surgical procedure is preferred to avoid the adverse effects of CPB, it has been abandoned by many centers with poor results. Many reasons, such as severe calcification of the target vessels, difficulties in positioning the heart, surgical inexperience, and lack of supporting equipment (e.g., myocardial stabilization devices), can cause poor results during off-pump surgery.

Table 3. Anastomosed target coronary arteries

Target vessels	Number of patients	Number of total patients
LAD	10	10
Two vessels bypass		38
LAD and D anastomosis	11	
LAD and Cx anastomosis	18	
LAD and RCA anastomosis	9	
Three vessels bypass		438
LAD, D, and Cx anastomosis	105	
LAD, D, and RCA anastomosis	160	
LAD, Cx, and RCA anastomosis	173	
Four vessels bypass		
LAD, D, Cx, and RCA anastomosis	88	88
Five vessels bypass		
LAD, D, Cx, Cx, and RCA anastomosis	27	27

LAD: Left anterior descending artery; D: Diagonal branch of LAD artery; Cx: Circumflex artery branches; RCA: Right coronary artery.

Researchers have shown that results of conversion to on-pump surgery during off-pump surgery, for whatever reason, are bad.[11,16] In the literature, conversion rates from off-pump to on-pump have been reported between 2.7% and 20.8%.[17–19] One of the most critical issues is that it is necessary to be meticulous in selecting patients for whom off-pump surgery will be preferred. The first step to consider when deciding on off-pump surgery is patient selection. The next and perhaps the most critical step is to apply this technique. In our case series, our conversion rate from off-pump to on-pump is far below the values reported in the literature (0.33%). This result shows that the method we applied is an effective strategy.

Many factors come into play at the stage of performing off-pump surgery. The most important of these is, of course, surgical experience. Technological devices such as myocardial stabilizers and intracoronary shunts facilitate this technique. We routinely used myocardial stabilization and apical suction devices (Fig. 3a, b). We used a silastic snare to create a bloodless area in the target vessel during anastomosis when needed.

In some cases, we used intracoronary shunts not to stop the coronary blood flow completely. Especially in proximal right coronary artery lesions, the hemodynamic parameters can deteriorate abruptly when we close the right coronary completely with a silastic snare. If we place an intracoronary shunt in this situation, a dramatic improvement in hemodynamic parameters can be observed in seconds. In some patients with LAD lesions who have good collateral flow with other coronary arteries, anastomosis can be performed without using an intracoronary shunt. Despite using an intracoronary shunt and a silastic snare, a completely bloodless area will not form in the target vessel. We wash with saline solution at body temperature and blow carbon dioxide during anastomosis to overcome this problem.

Even if we use all the technological equipment, some patients still risk conversion to on-pump surgery. Perhaps one of the most critical trick points here is the sequence of anastomosis. Logically, when starting anastomosis in a patient with wholly occluded two coronary arteries and severe stenosis in the third vessel, if we start anastomosis with the third vessel in the first place, which is the only blood supply for the myocardium at that time, it is most likely that during this procedure, the patient will experience sudden hemodynamic deterioration that may lead to even cardiac arrest.

Every surgical intervention is like a double-edged knife. While one side cuts the disease, the other side cuts the patient. The surgeon's goal is to administer less harmful treatment to the patient. For this reason, minimally invasive methods are developed to reduce surgical incisions. On the other hand, the adverse effects of CPB are tried to be eliminated by performing off-pump surgery. Our primary goal in this article is to seek a better strategy to reduce the negative effects experienced during off-pump surgery. The most crucial problem experienced by surgeons performing off-pump surgery is urgent conversion to on-pump surgery. Since the LAD is the essential target vessel in coronary artery surgery, many surgeons prefer to complete the LAD anastomosis first. However, it would be wrong to start with LAD anastomosis first in a patient with complete occlusion of both Cx and RCA arteries. Similarly, if we give an example for another vessel, it would be a wrong strategy to anastomose the RCA artery first in a patient with complete occlusion of both the LAD and Cx arteries. For this purpose, we tried to determine a separate anastomosis sequence for each patient according to occluded or narrowed vessels, as shown in Figure 2.

In summary, 647 patients initially decided to have coronary artery bypass surgery (on-pump and off-pump). We eliminated 46 patients (7.1%) during preoperative and intraoperative evaluations to perform direct on-pump surgery, as they were unsuitable for off-pump surgery (because of diffuse calcification of all vessels). Of the remaining 601 patients included in the study, only 2 required conversion to on-pump (0.33%). This rate is much less than the rates given in the literature. This result also strengthens the idea that our strategy is the right approach.

Conclusion

The main goal is to reduce conversion rates to on-pump in off-pump surgery. We need to determine the right strategy by making a good evaluation in both the preoperative and the intraoperative periods. Correct equipment and surgical experience affect the results of off-pump surgery, and the sequence of anastomosis is also an essential factor. After applying this strategy, we experienced much more minor and acceptable conversion rates than those reported in the literature. We believe this strategy will benefit other researchers who have just started practicing off-pump surgery. The importance of this strategy will be better demonstrated by studies carried out by many multicenter surgical teams.

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Conflict of Interest: None declared.

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