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Technique of OPCAB Using Universal Arm

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Abstract

Objectives: Although there is a debate over whether coronary artery bypass grafting (CABG) should be performed using method off-pump, on-pump, or under cardiac arrest, the off-pump coronary artery bypass (OPCAB) with guaranteed the quality of bypass is considered to have a significant advantage. The purpose of this study is to report on the usefulness of Universal Arm, device for OPCAB, which would contribute to improving the quality of bypass. **Methods:** Of the 94 CABG cases performed by the first author in our department between April 2019 and August 2024 (all through median sternotomy/under cardiac pulsation), 72 OPCAB cases (off-pump rate of 77%) were included. Two Universal Arms were used, one in combination with a stabilizer as usual, and the other as the fulcrums for lifting and traction of the fixed tubes of Tentacles, which is a suction heart positioner for cardiac decompression. **Results:** Mean number of bypass branches is 2.9 (1 - 5), grafts used: left internal thoracic artery (LITA) of 70 branches and 2 composite (72/72 patients: 100%), right internal thoracic artery (RITA) of 8 composite (8/72 patients: 11%), radial artery (RA) of 76 branches (54/72 patients: 75%), great saphenous vein (SV) of 57 branches (44/72 patients: 61%), and right gastro-epiploic artery (GEA) of 1 branch (1/72 patient: 1%). Early postoperative total graft patency was 99% (202/204 branches) (LITA 100%, RA 99%, SV 98%, GEA 100%). There was no hospital death, and there were a postoperative (day 5) stroke and ahypoxemia (on a ventilator for 6 days), but no other serious perioperative complications. Two patients underwent an additional percutaneous coronary intervention (PCI) (1 year and 5 years after surgery, respectively), but there were no other cardiac events. **Conclusion:** Our technique of using the second Universal Arm applied to the fulcrums for lifting and traction of the fixed tubes of Tentacleswas considered useful for performing OPCAB.

Keywords

Coronary Artery Bypass Grafting (CABG), Off-Pump Coronary Artery Bypass (OPCAB), Universal Arm, Tentacles, Minimally Invasive Cardiac Surgery (MICS)

1. Introduction

With recent medical advances, minimally invasive cardiac surgery (MICS), which does not require the use of cardio-pulmonary bypass (CPB) or a complete sternal incision, is now being performed. Cardiac surgery that uses CPB to circulate blood throughout the body has some problems such as surgical invasiveness and post-operative complications. In contrast to on-pump surgery using CPB, off-pump surgery, which is performed under cardiac pulsation without CPB, is mainly applied to coronary artery bypass grafting (CABG), so called off-pump coronary artery bypass (OPCAB). The CABG can be performed by off-pump, on-pump beating, or on-pump under cardiac arrest, depending on the conditions of patient and the policies of each institution. The advantages of minimally invasive OPCAB are considered to be significant for elderly patients with complications [1]-[3] or renal dysfunction [4] [5], as the quality of the bypass can be assured. We believe that our original OPCAB technique using Universal Arm (OpInstruments, BRD), a flexible stainless steel product that can be attached anywhere on a standard sternal retractor, is useful for performing high quality OPCAB, and we present the technique in this report.

2. Method

2.1. Patients

Of the 94 CABG patients (all through a median sternotomy/under cardiac pulsation) performed by the first author in our department between April 2019 and August 2024, 72 OPCAB patients (77% of off-pump rate) are included in this study. Three concomitant procedures were performed: OPCAB of 2 branches and mitral valve plasty (MVP), OPCAB of 3 branches and MVP, OPCAB of 3 branches and MVP and tricuspid valve annuloplasty (TAP), and these additional procedures were performed after completion of OPCAB.

The patient demographic data shown in Table 1. The demographics were age, gender, number of bypass branches, Canadian Cardiovascular Society (CCS) functional classification, New York Heart Association (NYHA) classification, Japan score, left ventricular ejection fraction (LVEF), serum creatinine (Cr) level, albumin(Alb) level, unstable angina pectoris (UAP), acute myocardial infarction (AMI), urgent surgery within 48 hours, hyper tension (HT), diabetes mellitus (DM), hyperlipidemia (HL), chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), hemodialysis (HD), history of percutaneous coronary intervention (PCI), preoperative intra-aortic balloon pumping (IABP). The informed consent and handling of personal information regarding this study were obtained from each subject patient when undergoing surgical treatment.

Table 1. Patient demographics.

	Variables, mean ± SD or %
Age, year	69.4 ± 8.1
Gender, male %	82.0

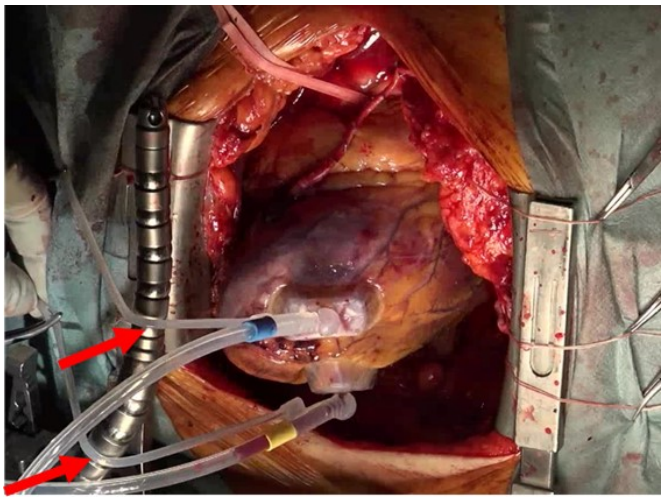
Continued

Number of bypass branches	2.9 ± 0.6
CCS functional classification	2.7 ± 1.1
NYHA classification	2.2 ± 1.0
Japan score	3.3 ± 3.4
LVEF (%)	52.9 ± 14.8
Creatinine (mg/dl)	1.22 ± 0.94
Albumin (g/dl)	4.0 ± 0.5
UAP (%)	56.9
AMI (%)	5.6
Urgent surgery (%)	4.2
Hypertension (%)	90.3
Diabetes mellitus (%)	50.0
Hyperlipidemia (%)	73.6
COPD (%)	18.1
CKD (%)	43.1
Hemodialysis (%)	4.2
History of PCI (%)	16.7
Preoperative IABP (%)	6.9

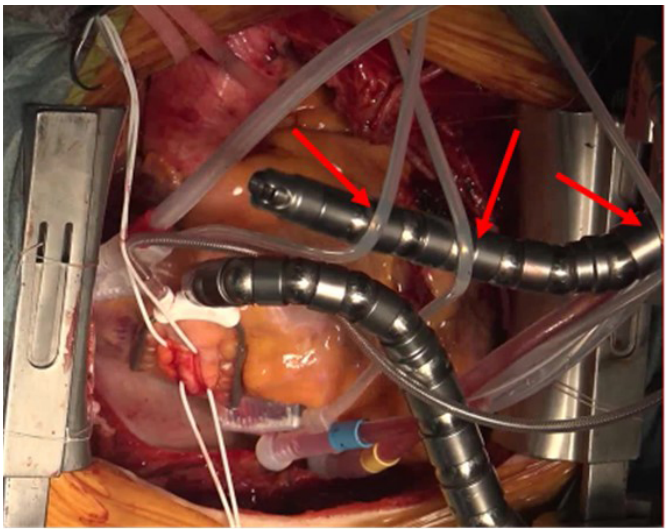
2.2. Operative Management and Surgical Procedure

The surgical techniques and perioperative management of CABG performed in our hospital are within the view of the current international standard techniques and optimal management of CABG. All eligible patients were operated with median full-sternotomy. Two Universal Arms were used, one in combination with a stabilizer as usual, and the other as fulcrums for lifting and traction of the fixed tubes of Tentacles (SB-KAWASUMI LABORATORIES, INC., Japan), which is a suction heart positioner for cardiac decompression (**Figure 1**). Universal Arms can be attached to any parts of sternal retractor by the use of retractor adapter. The anastomoses of bypass grafts to the coronary arteries were performed with 60 cm long, 7-0 or 8-0 monofilament sutures using the internal shunt. The CABG to the left anterior descending artery (LAD) was performed with the double parachute technique, and the those to other areas were performed with the simple continuous sutures of one knot. As grafts for CABG, generally the left internal thoracic artery (LITA) was used alone for the LAD, the radial artery (RA) for the circumflex region, and the great saphenous vein (SV) for the right coronary artery (RCA), using a sequential anastomosis, as appropriate. In the patients whose anastomoses of bypass grafts to the ascending aorta were not suitable, we anastomosed the grafts to the diagonal and/or circumflex branches using right internal thoracic artery (RITA)-RA composite graft, and performed the bypass grafting by utilizing the right gastroepiploic artery (GEA) in situ to the right coronary artery (RCA). We have not established specific criteria prior to surgery for determining whether to perform CABG using OPCAB or ONCAB; instead, we decide the surgical approach based on the intraoperative judgment described below. The CPB system with cannulation was on standby before the anastomotic procedures in all patients undergoing CABG, and the on-pump coronary artery bypass (ONCAB) was indi-

cated for patients who did not maintain systolic blood pressure of 80 mmHg or higher, proper cardiac output, mixed venous oxygen saturation and cardiac wall motion on transesophageal echocardiography by medication, adjustment of infusions, and/or correction of heart position. The patients of ONCAB were excluded from this study. The intraoperative evaluation of graft flow was performed using the ultrasound doppler echocardiography to confirm the diastolic predominant blood flow and the mean graft blood flow of 30 ml/min or greater. The patency of the bypass grafts was evaluated by coronary computed tomography angiography (CCTA) evaluation prior to discharge. The CCTA examinations were generally performed 1 to 2 weeks after surgery.



(a)



(b)

Figure 1. (Upper part of image is head side) (a) Universal Arm is used as fulcrums (red arrows) for lifting and traction of two fixed tubes of Tentacles, and left circumflex area is showing. (b) Two Universal Arms are used, one in combination with a stabilizer as usual, the stabilizer is fixed to segment 3 of right coronary artery, and the other as fulcrums (red arrows) for lifting and traction of three fixed tubes of Tentacles.

2.3. Follow-Up and Statistics

Follow-up was basically obtained by regular outpatient contact. Patients who underwent surgery were generally required to attend outpatient visits every three to six months for complete blood counts, chest radiograph, and electrocardiograms to confirm the absence of significant chest symptoms. Patients with suspicious findings of myocardial ischemia underwent CCTA or coronary angiography as appropriate. Continuous variables are expressed as the mean ± standard deviation. Survival analysis was performed by Kaplan-Meier curve with survival probabilities reported at multiple follow-up intervals. All eligible patients were successfully followed up during each postoperative observation period. All statistical analyses were performed using R software (version 4.5.1; R Foundation for Statistical Computing, Vienna, Austria).

3. Results

The operation time was 330 ± 63 min. The mean number of bypass branches was 2.9 (1 - 5), and the used grafts were 70 LITA + 2 composite (72/72 patients: 100%), 8 RITA composite (8/72 patients: 11%), 79 RA branches (54/72 patients: 75%), 57 SV branches (44/72 patients: 61%), and 1 GEA branch (1/72 patients: 1%). The early postoperative (CCTA-confirmed) total graft patency rate was 99% (202/204 branches) (L-/R-ITA: 100%, RA: 99%, SV: 98%, GEA: 100%).

The perioperative factors (postoperative intubation time, red blood cell (RBC) transfusion, intensive/high care unit (ICU/HCU) stay, postoperative hospital stay), the postoperative complications (paroxysmal atrial fibrillation (PAF), re-operation for bleeding, sepsis, deep wound infection, cerebral infarction), and the operative and hospital mortality are showed in Table 2. There were no operative and hospital deaths, 1 of postoperative (5th day) cerebral infarction and 1 of hypoxemia (on ventilation for 6 days), but no other serious perioperative complications. Additional percutaneous coronary interventions (PCIs) for newly arising stenotic lesions of native coronary arteries were performed for two patients at 1 year and 5 years after the surgery respectively, and there were no other cardiac-related events. Figure 2 shows a postoperative survival curve of the subject patients. The mean follow-up period was 36 ± 19 months. Mortality rate during the postoperative follow-up was 2.8% (2/72 patients). The two patients died of pneumonia in other hospitals after they discharged from our hospital in health. All other patients are alive and well to this day. The survival rate of the patients was 97% within the observation period.

Table 2. Perioperative and postoperative data.

	Variables, mean ± SD or %
Intubation time (h)	18 ± 71
Median intubation time (h) (IQR)	15 (14 - 17)
Transfusion (unit)	3.7 ± 5.8
ICU/HCU stay (day)	4.7 ± 3.4

Continued

Hospital stay (day)	23 ± 11
Paroxysmal AF (%)	6.9
Reoperation for bleeding (%)	0
Sepsis (%)	0
Deep wound infection (%)	1.4
Cerebral infarction (%)	1.4
Perioperative death (%)	0
Hospital death (%)	0

IQR, interquartile range; I CU/HCU, intensive and high care unit; AF, atrial fibrillation.

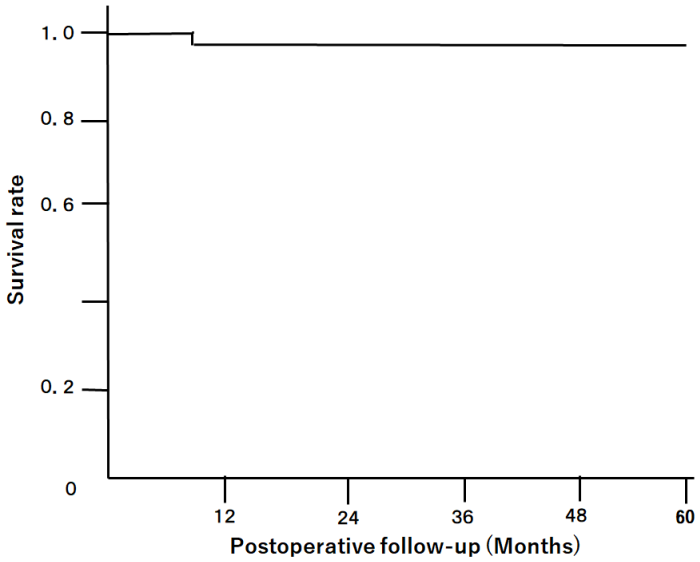


Figure 2. Postoperative survival curve. Survival rate is 97% within observation period.

4. Discussion

When we perform a median sternotomy, we dissect the intertrochanteric ligament, and make a longitudinal incision in the middle of the linea alba to divide it into left and right sides and then fully dissect the back of the rectus abdominis muscle. These maneuvers allow the sternum through the median incision to be opened wide to left and right, and as a result, a good field of surgical view is obtained. On the other hand, the sternal fractures are infrequent, and the postoperative pain is often not difficult to control. The wide opening of the sternum to left and right through a median incision is useful in preventing impaired venous return and ensuring a good field of view in the area of hard-to-see branches during CABG manipulation. As a result, our method may contribute to the completion of OPCAB procedure.

OPCAB is considered a good indication for patients who have a risk of complications associated with CPB, such as cerebral embolism [1]-[3], and pulmonary and renal damage [4] [5]. There are some reports that OPCAB procedure is technically challenging and has inferior mid- and long-term results [6] [7], however the outcomes of OPCAB performed by experienced surgeons have been reported

to be equivalent to those of CABG performed using CPB [8]-[11]. SV grafts are widely used, but a recent research paper [12] demonstrates a high occlusion rate of 25% at one year. And on a 10-year follow-up study, the patency rate for radial artery grafts was 91.6%, and the complete patency rate (no luminal abnormalities) was 88%, compared to 97.5% and 96.3%, respectively, for ITA grafts. The early postoperative graft patency rate and the mid-term results of our study are good, and the long-term results are awaited. It may be possible that our surgical technique has a positive influence.

Although the optimal location for anastomosis can be estimated based on preoperative CCTA findings, an intraoperative evaluation is necessary to determine the final location. Therefore, the role of the cardiac positioner used to develop the field of view in coronary artery bypass operations is important. Standard techniques for using cardiac positioning devices for OPCAB have been demonstrated in recent papers [13]-[15]. A common suction-type heart positioner tends to have a single attachment to the apex of heart. Tentacles with three suction portions can have each suction portion attached to up to three locations on the flat part of the heart, therefore it does not apply the local suction load when lifting up the heart. In addition, the device may be useful in developing the field of view of an anastomosis by attaching it to the left and right sides of the anastomosis. When we anastomose a bypass graft to a diagonal or a circumflex branch, Tentacles may have the effect of suppressing intraoperative low cardiac output (low output syndrome: LOS) and hypotension, which are associated with reduction of the venous return to right atrium and the blood flow of right ventricular outflow tract due to traction and rotation of the heart. The same can also be said for upward traction during the anastomosis to right coronary artery. Furthermore, when anastomosing the right coronary artery, segment 2 to 3, the suction portion of the Tentacles can be attached to the right ventricular surface to provide leftward traction. The main issue in using Tentacles is how to lift the heart in front of the patient without interfering with the anastomosis procedure, so as not to cause circulatory disturbance. Our method of using Universal arm as a fulcrum for lifting and traction of Tentacles fixation tube solves this problem.

Intraoperative graft evaluation is recommended to evaluate blood flow by transit-time flowmeter [16] [17] and fluorescence imaging [18], but since both devices are expensive, we used ultrasound doppler echocardiography [19] [20]. The recommended blood flow of bypass graft is reported as a mean flow of cutoff value of 15 - 20 ml/min [21]-[24], but we evaluated by the mean value of 30 ml/min or higher and the diastolic predominant coronary blood flow in principle. In two cases of bypass occlusion (one, RA and the other, SV) on postoperative CCTA findings, there were no problems in the intraoperative graft evaluation, but in the one case, the native flow was superior to the sequential bypass flow of RA graft, and in the other case, the SV was anastomosed to the RCA, small posterior descending artery, which had a well-developed collateral blood flow from the LAD with an anastomosis of LITA. These patients were followed up with good wall

motion of left ventricle in postoperative echocardiography. As a result, all other coronary artery bypass grafts showed good patency on postoperative CCTA.

The Society of Thoracic Surgeons (STS) reported a CABG operative mortality rate of 2.2% and an OPCAB rate of 13% in 2018 [25], and the Japan Adult Cardiovascular Surgery Database (JACVSD) reported the operative mortality rate of 3.0% (2.0% in elective CABG, 1.1% in elective OPCAB) and an OPCAB rate of 55% [26] [27]. In this study of OPCAB cases in our department, the OPCAB rate was 77% and the operative mortality rate was 0%. However, two patents of ONCAB performed during the same period died, resulting in the CABG surgical mortality rate of 2.1%. There were no intraoperative problems in 22 ONCAB cases, including the two deaths. One of the death patients with a preoperative acute myocardial infarction (AMI), low LVEF, CKD undergoing hemodialysis and severe lower extremity arteriosclerosis with foot necrosis died of an acute worsening of heart failure on postoperative day 15. An another death patient, who had an unstable postinfarction angina with low LVEF and some psychotropic medications before the surgery, died of a severe malignant syndrome on postoperative day 8.

In addition, although poor surgical outcomes have been reported in cases of conversion from OPCAB to pump CABG, our method of keeping extracorporeal circulation on standby and immediately initiating this system before critical condition such as a shock dispels the aforementioned concerns.

5. Conclusion

Universal Arm has excellent flexibility and fixity of the arm part, and cost-effectiveness for reusable equipment. A stabilizer attachment, which is combined with Universal Arm, offers effective mobility. Our technique of using the second Universal Arm applied to the fulcrums for lifting and traction of the fixed tubes of Tentacles was considered useful for performing OPCAB. The surgical outcome of OPCAB in this study was good, as the intraoperative stable circulation was maintained and the quality of bypass was ensured.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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