Multivessel Awake Off-Pump Coronary Bypass Grafting Using Median Approach

Technical Considerations

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Objective: Several reports of awake off-pump coronary artery bypass grafting (AOCAB) under high thoracic epidural anesthesia (TEA) for single-vessel grafts have been published, but few have described its application in multiple bypass procedures. We report the procedures and safety of AOCAB for multivessel disease.

Methods: Fifty-five multivessel AOCAB (52 men, 3 women; aged 68 ± 9.5 years) were performed at our hospital between 2003 and 2010. A medium sternotomy was made after TEA was established. During coronary artery anastomosis, a stabilizer and an apical suction device were used, and a coronary artery active perfusion system was used to maintain flow distal to the anastomosis. Pneumothorax due to pleural opening, when occurred, was repaired using Neoveil sheet and drainage tube.

Results: There was no operative death and no cerebral ischemia, cardiac arrhythmia, and chronic obstructive pulmonary disease. Operating time was 177 ± 35 minutes. Left internal thoracic artery was used in 55 anastomoses, right internal thoracic artery in 7, gastroepiploic artery in 17, radial artery in 48, and saphenous vein in 24. Time of anastomosis was 4.93 ± 0.92 minutes for left anterior descending coronary artery, 4.75 ± 1.21 minutes for circumflex artery, and 4.98 ± 1.02 minutes for right coronary artery. Intraprocedural pneumothorax occurred in 17 cases; 14 were repaired and nonintubated AOCAB was accomplished, 1 was intubated, and 2 had temporary assisted ventilation and laryngeal mask. Time to discharge was 15.5 ± 8.4 days.

Conclusions: Multivessel AOCAB under TEA is not only feasible but also safe. Multiple grafts can be harvested under TEA, and complete vascularization is possible under constant monitoring of blood pressure and consciousness.

Key Words: Awake surgery, Off-pump CABG, High-epidural anesthesia.

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The use of off-pump coronary artery bypass grafting (CABG) procedures in Japan continues to increase and now accounts for >50% of all bypass procedures.[1] With complete revascularization becoming possible, off-pump CABG has gained widespread popularity, and operative mortality as well as postoperative complications have decreased. Gradually, the indication of off-pump CABG has been expanded to patients with preoperative cerebral or pulmonary comorbidities, whose conditions may deteriorate from general anesthesia, and those at risk for irreversible cerebral events due to intraoperative blood pressure decrease. The procedure is now also used in patients with arteriosclerosis obliterans and malignant tumors and those on hemodialysis. In addition, there are increasing needs for rapid discharge and rapid return to work, from both social and economic points of view.

Awake off-pump CABG (AOCAB) using high thoracic epidural anesthesia (TEA) was first reported by Karagoz et al[2] as a procedure that facilitates rapid discharge, decreases respiratory complications, and allows CABG to be performed when general anesthesia is contraindicated. The recovery period is extremely short, and this method has received much attention as a potential day surgery procedure. However, most reports have described single-vessel bypasses, and only very few small series reported its use in multiple-vessel bypass procedures.[3,4] This may be due to several reasons. First, the rate of potential occurrence of pneumothorax increases, which may lead to conversion to general anesthesia. Second, because of the longer time of operation, additional doses of local anesthetics increase the risk of anesthetic toxicity. Third, because multiple-vessel harvesting is necessary, additional anesthesia may be required. In this study, we sought to determine whether AOCAB for multiple-vessel grafts using median sternotomy is a safe and effective procedure.

METHODS

Patient Selection

We performed AOCAB for multiple-vessel disease in 55 patients (52 men and 3 women, average age 68.0 ± 9.5 years) between May 2003 and Jan 2010. This number constituted 4.4% of a total of 1260 CABG procedures performed during the same period in our hospital. The preoperative patient characteristics are shown in Table 1. Patient selection criteria were as follows: (1) patients with cerebrovascular impairment, either symptom-

TABLE 1. Preoperative Patient Characteristics

Age (yr)	68 ± 9.5
Sex (M/F)	52/3
Left ventricular ejection fraction (%)	61 ± 14
Preoperative comorbidities	
Cerebrovascular event (including recent cerebral hemorrhage)	35
Chronic obstructive lung disease	16
Arteriosclerosis obliterans	8
Chronic renal failure	3

atic or preoperative single photon emission computed tomography findings showing ischemia and/or transient ischemic attack or stenosis in unilateral carotid artery, who are at risk for cerebral ischemia due to blood pressure decrease during surgery; (2) patients with chronic pulmonary diseases who may not tolerate general anesthesia, specifically patients on home oxygen therapy and those with preoperative lung function test showing forced expiratory volume in 1 second <1000 mL or diffusing capacity for carbon monoxide (DLco%) ≤40% or SaO_2 ≤95%; (3) patients who request rapid discharge and return to normal daily life; (4) patients for whom the procedure is predicted to be completed within 3 hours. AOCAB was indicated for patients who fulfilled at least one of the first three criteria and also the fourth criterion.

Anesthesia

TEA was used in all the patients. A catheter was placed epidurally between T1 and T2 one day before the operation, and the position of the catheter tip was confirmed by contrast imaging. At the time of operation, a mixture of 2% lidocaine and 5 mg fentanyl citrate was infused via the epidural catheter at a speed of 20 mL/h to accomplish a neurologic block from C6 to C8. Surgery was conducted under constant monitoring of pain sensation. By avoiding general anesthesia, the patients remained conscious, and the procedure was performed without endotracheal intubation.

Operative Approach

A median sternotomy approach was used in our patients. Referring to the chest computed tomographic scan, we performed median sternotomy without perforating the pleura. From an incision made below the xyphoid process, we inserted a finger to reach behind the sternum and manually displaced the pleura to the left. We then used a sternotomy saw to open the sternum.

Graft Harvesting Technique

The internal thoracic artery (ITA) was harvested using an electrical scalpel for skeletonization, preserving the internal thoracic vein and harvesting only the ITA. This method minimizes the risk of pneumothorax and allows harvesting of a sufficiently long graft. In patients in whom pneumothorax resulted from perforation of the parietal pleura, we used a drain tube when the perforation was clearly identified. Under a continuous pressure of −10 cm of H_2O, the ruptured pleura was covered with a polyglycolic acid (PGA) nonwoven fabric sheet (Neoveil, Gunze, Kyoto, Japan) and another layer of fibrin glue was added to close the defect.[5]

The gastroepiploic artery (GEA) graft was harvested with minimum incision of the diaphragm using the skeletonization technique. In particular, we extended the skin incision inferiorly by 4 to 5 cm, for which we added TEA from Th5 to Th6.

Harvesting of the radial artery (RA) was performed under only TEA. RA harvesting was possible when TEA was effective up to the C5 region. When anesthesia was insufficient, an additional axillary block was performed under ultrasound guidance through the anterior arm.

Coronary Artery Anastomosis

A suction type stabilizer was usually used to stabilize the coronary artery. When anastomosing large coronary arteries such as the lower anterior descending branch and/or circumflex artery (CX), a narrow gauge tube was inserted through the coronary artery incision to perform coronary active perfusion (CAP) through a CAP system,[6] to prevent myocardial ischemia. Anastomosis was generally performed with 8-0 or 7-0 polypropylene suture. Figure 1 shows the intraoperative scene of AOCAB via a median sternotomy.

Exposure of CX and Right Coronary System

The conventional deep pericardial traction suture was not used because this would penetrate the pericardium and cause pneumothorax. The method of cardiac rotation by right thoracotomy was also not used for the same reason of avoiding pneumothorax. Instead, cardiac rotation was performed using an apical suction device to expose the circumflex branch. Anastomosis was performed as swiftly as possible to reduce the period of intraoperative hypotension.

FIGURE 1. During the awake OPCAB surgery, the patient is completely conscious and maintains spontaneous respiration.

TABLE 2. Operative Details

Grafts used	
Left internal thoracic artery	55
Right internal thoracic artery	7
Right gastroepiploic artery	17
Radial artery	38
Y composite	18
I composite	11
Aorta	9
Saphenous vein graft	24
Target vessels	
Left anterior descending coronary artery	54
Diagonal branch	22
Circumflex artery	33
Right coronary artery	39

Number of anastomoses per patient, 2.9 ± 0.8.

Prevention of Hypotension

Because AOCAB was performed with the patient conscious, it was relatively easy to perform the procedure without paying too much attention to hypotension, if the conditions of consciousness and blood pressure were normal. However, in the case that systolic pressure fell below 50 mm Hg, vasoconstrictive agents were added while the consciousness level was monitored. Particularly in patients with severe stenosis or occlusion of the internal carotid artery or patients with preoperative cerebral ischemia, we took the following measures to prevent hypotension: maintaining mean blood pressure above 50 mm Hg and continuously checking consciousness of the patient, and using the Trendelenburg or right decubitus position to increase preload volume.

Statistical Analyses

The values are expressed as mean ± standard deviation in text and tables. Statistical analysis was performed using the χ^2 test. A P value <0.05 was considered to indicate a significant difference.

RESULTS

There were no operative deaths and no postoperative respiratory complications, cerebral infarction, and postoperative bleeding. The average amount of bleeding was 470 ± 206 mL, and the average time of the procedure ranged from 96 to 240 minutes (177 ± 35 minutes). The arterial grafts used were the left ITA in 55 anastomoses, right ITA in 7, GEA in 17, and RA in 38. The target coronary arteries were the left anterior descending coronary artery in 54 anastomoses, diagonal branch (D_1) in 22, CX in 33, and right coronary artery (RCA) in 39. The mean number of anastomoses was 2.9 ± 0.8 per patient (Table 2). Axillary block was required in 10 cases for harvesting the RA.

TABLE 3. Incidence of Pneumothorax During AOCAB and Outcome

Pneumothorax	17 (right 2, left 14, bilateral 1)/55 (31%)
Recovery from pneumothorax	14/17
Convert to general anesthesia	1/17
Support with laryngeal mask	2/17
Accomplish AOCAB	52/55 (95%)

AOCAB, indicates awake off-pump coronary artery bypass grafting.

TABLE 4. Operative Parameters

Procedure time (min)	174 ± 35
Bleeding amount (mL)	470 ± 206
Internal thoracic artery harvest time (min)	12.5 ± 3.4
Anastomosis time (min)	
Left anterior descending coronary artery	4.93 ± 0.92
Circumflex artery	4.75 ± 1.21
Right coronary artery	4.98 ± 1.02
Left internal thoracic artery flow (mL/min)	42 ± 20

The average time for harvesting the ITA was 12.5 ± 3.4 minutes. In 17 patients (31%), pneumothorax occurred during ITA ablation or median sternotomy. The pneumothorax was on the left in 14 patients, on the right in 2, and bilateral in 1. In the single case of bilateral pneumothorax, the procedure was converted to general anesthesia. In two cases of right pneumothorax, respiratory function was impaired, and a laryngeal mask together with temporary positive pressure ventilation were used. In the remaining 52 of the 55 patients (95%), AOCAB was completed under spontaneous respiration (Table 3).

To manage pneumothorax, the PGA fabric sheet and fibrin glue layer technique were used to close the opening in the pleura. This method was used in all except the first three cases of pneumothorax in this series (14 of 17 cases). In all 14 cases treated by the PGA fabric sheet, pneumothorax was controlled and AOCAB was accomplished.

In the 52 cases in which spontaneous breathing was maintained, the average blood CO_2 was 47 ± 5.2 Torr, and the average bispectral index monitor level, which indicates cerebral activity, was 81.8 ± 12.6.[7]

The average times required for anastomosis of the left anterior descending coronary artery, CX, and RCA were 4.93 ± 0.92 minutes, 4.75 ± 1.21 minutes, and 4.98 ± 1.02 minutes, respectively (Table 4). By using the Trendelenburg position and the apical suction device, there was almost no change in blood pressure during exposure of the CX and anastomosis of RCA. The hemodynamic condition was extremely stable. During anastomosis of the circumflex branch, the pressure of the pulmonary artery was 29 ± 4.0 mm Hg systolic and 15 ± 3.1 mm Hg diastolic and the cardiac index was 2.9 ± 0.4 L/min/m^2 (Table 5). During the procedure, the patients showed no symptoms and remained conscious.

DISCUSSION

Our study showed that multivessel AOCAB via a median sternotomy under TEA is a safe procedure. There was no incidence of significant adverse respiratory or cerebrovascular complications. This procedure can be performed at the same level of safety as conventional off-pump CABG.

Off-pump CABG has now become almost a standard procedure in Japan, and the database of the Japanese Association for Thoracic Surgery has shown a decrease in the relative numbers of not only operative fatalities but also complications.[1] Together with the increasing popularity of catheter interventions, the number of serious cases in which CABG is indicated

TABLE 5. Intraoperative Hemodynamics

Systolic BP (mm Hg)	
Preoperative	89 ± 17
During anastomosis of CX	73 ± 14
During anastomosis of RCA	80 ± 14
Systolic PAP (mm Hg)	
During anastomosis of CX and RCA	29 ± 4
Cardiac index	
During anastomosis of CX and RCA (L/min/m^2)	2.9 ± 0.4
PaO_2 (Torr)	47 ± 5.2
BIS monitor	82 ± 13

BP indicates blood pressure; CX, circumflex artery; RCA, right coronary artery; PAP, pulmonary artery pressure; BIS, bispectral index monitor.

has increased, and there is an increasing demand for a minimally invasive procedure that allows rapid return to normal daily life. We have performed off-pump CABG under combined general anesthesia and TEA and have been able to reduce the amount of intraoperative anesthesia dosage and also shorten the time to discharge.[8] In 2000, Karagoz et al[9] reported the first CABG procedure performed under TEA alone. This introduced the possibility of AOCAB without tracheal intubation. The advantages of the awake procedure include the fact that tracheal positive pressure ventilation is not necessary, thus decreasing the number of pulmonary-related complications. Even in patients at higher risk of critical stenosis of cerebral vessels, AOCAB allows real-time monitoring for any change in consciousness and prompt response appropriate to the situation.[10] In addition, this procedure makes fast tracking possible and has the advantage of maintaining a high level of cerebral function in elderly patients.[11]

TEA enhances the safety of the procedure by decreasing the tonus of the sympathetic nervous system, decreasing heart rate, and dilating the coronary artery.[12] Making use of these advantages, AOCAB was first used in patients with severe chronic obstructive lung disease, in whom general anesthesia cannot be conducted,[13] and the indication was gradually extended to patients with cerebral infarction and other serious conditions.

In our previous study comparing off-pump CABG conducted under general anesthesia only and AOCAB conducted under TEA, better operative results were obtained in the TEA group.[12] Our quality of life questionnaires also indicated more rapid resolution of postoperative pain. The above results indicate that AOCAB is the least invasive CABG procedure.[12]

Avoidance of Pneumothorax

In the present series, pneumothorax occurred in 17 cases due to perforation in the mediastinal pleura during ITA harvesting via a median sternotomy. During ITA harvesting, the internal thoracic vein was preserved. By skeletonizing only the ITA, we were able to reduce the frequency of pneumothorax. Even in cases in which pneumothorax did occur, repair of the perforated pleura was possible by the biomaterial neopleura technique using PGA nonwoven fabric and fibrin glue, a method that was established experimentally by our group.[5] When this method was evaluated by a thorax model, the positive pressure-induced burst pressure was 355.9 ± 55.8 mm Hg. In a swine model, repair was easily achieved regardless of the defect size or location, and air leakage was not seen after repair. This method was found to achieve a strong closure with sufficient durability.[5] Karagoz et al[2]stated that when pneumothorax occurs, it is better to leave the pleura open. On the contrary, our experience suggests that it is better to close the puncture.

Graft Harvest

Kirali et al[3] reported seven cases of multiple bypass procedures using bilateral ITA grafts. For non-ITA grafts using GEA and RA, additional local anesthesia is necessary. Therefore, it is important to have the cooperation of the anesthesiologist. To harvest the RA, a low dose of additional local anesthesia and axillary block is sufficient, and it is generally possible to harvest the RA artery within a short time. For both of these procedures, an invasive neuroplexus mapping is necessary.

Effects of TEA and Usefulness of Off-pump CABG

The application of TEA in coronary artery disease has had a long history. Dilatation of the coronary artery by TEA was demonstrated experimentally,[14] and TEA has been reported to be useful clinically.[15] The heart rate decreases to ~80% of the normal rate and the occurrence of arrhythmia decreases, and there are almost no cases of decreased blood pressure, which improves the dilation of the coronary artery and the ITA.[16,17] From this point of view, TEA combined with off-pump CABG provides an ideal operative environment. CABG performed under combined general anesthesia and TEA has been reported.[18,19] We also conducted CABG under general anesthesia alone or combined with TEA and showed that surgery could be conducted safely in the elderly aged older than 80 years.[20] From our experience, TEA significantly reduced intraoperative arrhythmia compared with when only general anesthesia was used, and no patient required administration of inotropic agents and the hemodynamic status was extremely stable. TEA causes dilation of the coronary vessels and reduction in heart rate, which results in reduction of the double product, minimizing myocardial ischemia at the distal site of the blocked coronary artery.[14] If myocardial ischemia is minimized, the procedure becomes safer because the difference in speed of anisotropic transmission is decreased. Thus the ischemia arrhythmia action potential due to micro reentry is increased, permitting safer anastomosis.[21] A reduction in blood pressure is associated with vascular dilation due to TEA, because high TEA has minimal effect on the abdominal vasculature.

In the present series, there was not a single case of intraoperative arrhythmia or circulatory deterioration, and all procedures were performed under safe conditions. Concerning anastomosis, we used the coronary active perfusion system for active coronary perfusion, and because the peripheral myocardium was perfused,[6] this contributed to the zero incidence of ischemia and arrhythmia. However, the most important point is to keep the ischemic time as short as possible. In our system using a very smooth and reliable technique for anastomosis of coronary arteries, all anastomoses took <5 minutes.

Exposure of Right and Circumflex Coronary Artery

Cardiac rotation and management of blood pressure during CX and RCA exposure and anastomosis are not a problem, but particular attention has to be paid to the possibility of

cerebral ischemia due to decreased blood pressure, especially in patients with diseases involving the RCA or CX. Awake CABG is very effective in patients with hypotension accompanying cerebral ischemia, because any change in consciousness can be recognized immediately and any decrease in blood pressure or decrease in consciousness can be treated in real time. To prevent decrease in blood pressure, we use either a Trendelenburg or right supine position to increase the venous return and maintain a sufficient minimum level of blood pressure. Because a deep pericardial retraction suture[22] or right thoracotomy cannot be used, as they would cause pneumothorax, an apical suction device is used for cardiac rotation, and it is possible to completely revascularize the left ventricle using this method.

The procedure described here requires excellent cooperation between experienced cardiovascular surgeons and anesthesiologists. Because of the risk of lidocaine intoxication with prolonged local anesthesia, we consider that AOCAB is indicated only for procedures that can be completed in 3 hours. Because almost all OPCAB procedures can be performed in 3 hours, AOCAB can be used in most cases.

CONCLUSIONS

Our report shows that AOCAB using TEA can be performed safely even in patients with preoperative comorbidities such as obstructive pulmonary disease or cerebrovascular disease. We are able to perform this procedure even in patients with a history of critical cerebral vascular accident and in patients with chronic obstructive pulmonary disease, without any significant negative outcome. Complete revascularization of the CX or RCA is possible with this technique, and the ultrafast-track procedure allows early discharge and early return to normal daily life. AOCAB may be a major area of development of least invasive cardiovascular surgery.

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CLINICAL PERSPECTIVE

This is an interesting report from Dr. Watanabe and his group at Kanazawa University describing 55 patients who underwent multi-vessel off-pump coronary bypass grafting while awake through a median sternotomy. High thoracic epidural anesthesia was used. This is one of the largest reported series in the literature of patients having multi-vessel bypass grafting using this technique. There were no operative deaths and no strokes in this small series that was performed over a 7-year period. The authors had mean anastomotic times of less than 5 minutes. There was only one patient who required general anesthesia due to bilateral pneumothoraces. While this small series shows that awake off-pump coronary bypass grafting is feasible, it does not adequately address safety or efficacy. In a procedure that already has relatively low complication rates, a safety study would require hundreds of patients. Moreover, efficacy would best be addressed in a randomized fashion using graft angiography as an end point. While this technique has some attractive features, its benefits remain poorly defined. The authors claimed that it facilitates rapid discharge yet the mean time to discharge in this small series was over 15 days. While this may reflect socioeconomic conditions in Japan, it still is a long hospital length of stay. Moreover, this group has significant expertise in off-pump coronary artery bypass grafting (OPCAB) with short anastomotic times, whether such results could be obtained by groups less skilled in OPCAB is unknown. At present, the utility of this approach would be in the rare patient in whom general anesthesia is contraindicated. However, this pioneering group is to be congratulated for a careful analysis of their early results and a continued exploration of this innovative approach.