

# Coronary Artery Bypass Grafting Through Complete Sternotomy in Conscious Patients

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## ABSTRACT

**Background:** Complete sternotomy is the standard approach in cardiac surgery, and coronary artery bypass grafting (CABG) is the most common revascularization procedure to use this approach. A new technique has been developed that permits complete surgical revascularization with arterial grafts in awake patients. This technique, which we refer to as awake coronary artery bypass grafting, avoids general anesthesia, mechanical ventilation, and extracorporeal circulation, thereby creating the least invasive method for heart operations yet described.

**Methods:** A thoracic epidural catheter was placed at T2-T3 level one day before surgery. In 12 patients, single ( $n = 6$ ), double ( $n = 5$ ), or triple ( $n = 1$ ) vessel coronary artery bypass grafting was performed without general anesthesia. In six patients, this procedure was performed after complete median sternotomy.

**Results:** Ten patients remained awake throughout the whole procedure. Two patients required secondary intubation due to incomplete analgesia in one case and pneumothorax in the other. Procedural time was  $98.2 \pm 19.8$  minutes. Intermediate care stay was  $4.9 \pm 0.6$  hours. There were no perioperative complications, and early angiographic results before discharge were excellent in all patients.

**Conclusions:** The data presented show the feasibility and safety of complete surgical revascularization via median sternotomy using arterial grafts without general anesthesia. This approach shortens recovery time and increases patient comfort, suggesting that outpatient cardiac surgery may eventually be possible.

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## INTRODUCTION

For many decades the standard approach to access in cardiac surgery has been complete median sternotomy. Over one million heart operations are performed worldwide every year by this approach, which permits a broad spectrum of cardiac procedures. Surgeons have not changed the standard access for over four decades because it offers many advantages, such as free access not only to the heart itself but also to the thoracic vessels.

A recent trend in cardiac surgery has been to minimize surgical trauma by limiting surgical incisions or avoiding extracorporeal circulation [Calafiore 1998, Diegeler 1999, Falk 1999] in order to perform operations on the beating heart. Although these attempts have been pursued for over five years, no major advance has been achieved, and these minimally invasive heart operations have never exceeded 5 to 10% of the total number of procedures. The postulated benefits of minimally invasive cardiac surgery, such as reduced pain, faster postoperative mobilization and recovery, increased patient comfort, and reduced cost have not been proven so far, with the exception of improved cosmetic results of limited access surgery [Mark 1994, Mack 1997, Falk 1999, Jegaden 2001].

A new strategy to reduce the invasiveness of cardiac surgery has recently been described by H. Karagöz, who performed the world's first single bypass operation via limited surgical access on an awake patient [Karagöz 2000]. The present report describes our performance of the first multivessel revascularization via complete median sternotomy in an awake patient. Our procedure also achieved all of the above-mentioned benefits of the standard median sternotomy.

## PATIENTS AND METHODS

### Generally

This study was approved by the Ethics Committee of the university, and written informed consent was obtained from all participants. Between March and May of 2001, 12 coronary artery bypass grafting (CABG) procedures in awake patients were performed at Johann Wolfgang Goethe University, in Frankfurt, Germany. Prior to these 12 procedures we pursued a stepwise approach to introduce awake coronary

Table 1. Patients' demographics and perioperative data (n = 12), values are mean  $\pm$  SEM (NYHA = New York Heart Association, IMC = intermediate care, BSA = body surface area)

Patient Demographics	
Age (years)	65 $\pm$ 4.7
Sex ratio (M:F)	10:2
Weight (kg)	80.1 $\pm$ 2.8
Height (cm)	167.4 $\pm$ 2.1
BSA (m <sup>2</sup> )	1.89 $\pm$ 0.03
NYHA preoperative (mean)	2.8 $\pm$ 0.2
Left ventricle ejection fraction (%)	61 $\pm$ 3.4
Previous myocardial infarction (n)	4
Chronic obstructive lung disease (n)	6
Renal disease (n)	4
Peripheral vascular disease (n)	3
Operative data	
Procedure time (min)	98.2 $\pm$ 19.8
Time for anastomosis (min)	6.9 $\pm$ 1.4
Number of anastomosis	1.6 $\pm$ 0.3
Chest tube drainage (ml)	158 $\pm$ 29
IMC stay (hours)	4.9 $\pm$ 0.6
Hospital stay (day)	7.8 $\pm$ 0.5

artery bypass grafting (ACAB) in our hospital. In the first step, patients with multivessel coronary artery disease were anesthetized conventionally, and a thoracic epidural catheter was inserted as an adjunct to general anesthesia. The second step, intubation and general anesthesia, was delayed until sternotomy and internal thoracic artery takedown were completed. The 12 most recent procedures were performed completely without general anesthesia while the patient was awake and spontaneously breathing.

Demographic data and preoperative status of patients are described in Table 1. Seven patients of this cohort had significant comorbidity, such as severe obstructive lung disease, peripheral vascular disease, renal insufficiency, or diabetes.

All data were reviewed prospectively. Statistical tests were done using the Stat View statistical software package (Abacus Concepts, Inc., Cary, NC). Data are expressed as mean  $\pm$  standard deviation.

### Anesthesia for ACAB

One day before elective surgery a thoracic epidural catheter was inserted at T2-T3 level (Figure 1, ). On the day of surgery the patients were premedicated with 7.5 mg of midazolam p.o. In the operating room an infusion of ropivacaine 0.5% with sufentanil 2  $\mu$ g/ml was started. Sensory level was tested every five minutes until sensory block was achieved between the neck and the abdomen, including both arms. Patients breathed 5 l/min. of oxygen via a face mask. Monitoring included arterial and central venous blood pressure, ECG (II, aVF, V<sub>5</sub>), pulse oximetry, and endtidal CO<sub>2</sub>. The thoracic epidural catheter was used for both intraoperative and postoperative pain management.

### Operative Technique for ACAB

The chest was opened through complete sternotomy for double or triple vessel bypass grafting and through partial lower sternotomy for single vessel bypass grafting. Careful dissection of the internal thoracic artery was necessary to avoid pneumothorax in the spontaneously breathing patient. For multivessel CABG, an additional radial artery graft was dissected with the adjunct of local anesthesia. After creating a pericardial cradle, the surgeon exposed the target vessels with the aid of mechanical stabilization. Anastomoses were performed with standard beating heart bypass technique using proximal control of the target vessel and a blower mister to clear the anastomosis site. In six patients the left internal thoracic artery (LITA) was anastomosed to the left anterior descending artery (LAD), in three to the diagonal branch and LAD, and in two to the LAD and the left radial artery to the right coronary artery (RCA). In one case, we performed triple revascularization with the LITA to the LAD and to the diagonal branch and with the radial artery to the RCA.

### RESULTS

In 12 patients, single (n = 6), double (n = 5), or triple (n = 1) vessel CABG was performed without general anesthesia. Two patients in this series required secondary intubation after completion of internal thoracic artery harvesting due to incomplete analgesia of the upper chest in one patient and pneumothorax with consecutive coughing and chest discomfort in the other. Both patients were extubated after the procedure in the operating room. Operative time in the whole cohort was 98.2  $\pm$  19.8 minutes. Intraoperative hemodynamic parameters are shown in Figure 2. The postoperative monitoring phase in the intermediate care unit amounted to 4.9  $\pm$  0.6 hours. The analysis of postoperative cardiac enzyme levels was unremarkable, and there was no perioperative myocardial infarction. Furthermore, there was no wound healing problem or any other complication in this cohort. Early angiographic results before discharge were excellent in all patients, and all patients recovered well but remained hospitalized for 7.8  $\pm$  0.5 days due to local reimbursement regulations.

### DISCUSSION

Awake coronary artery bypass grafting (ACAB) via complete sternotomy is an alternative method for coronary artery revascularization that extends the spectrum of minimally invasive cardiac surgery techniques. Common philosophies in conventional minimally invasive CABG surgery either focus on avoiding cardiopulmonary bypass [Kirklin 1983] or limited surgical access [Mack 1997, Calafiore 1998, Ribakove 1998, Karagöz 1999, Diegeler 1999, Falk 1999] to improve outcome. Avoidance of general anesthesia and positive pressure ventilation for CABG via complete sternotomy has not been described as an adjunct to minimally invasive cardiac surgery. Complete sternotomy provides ideal access to all regions of the heart and neighboring structures, which enables the surgeon to perform complete revascularization. In our series of patients, double or triple bypass grafting was performed using

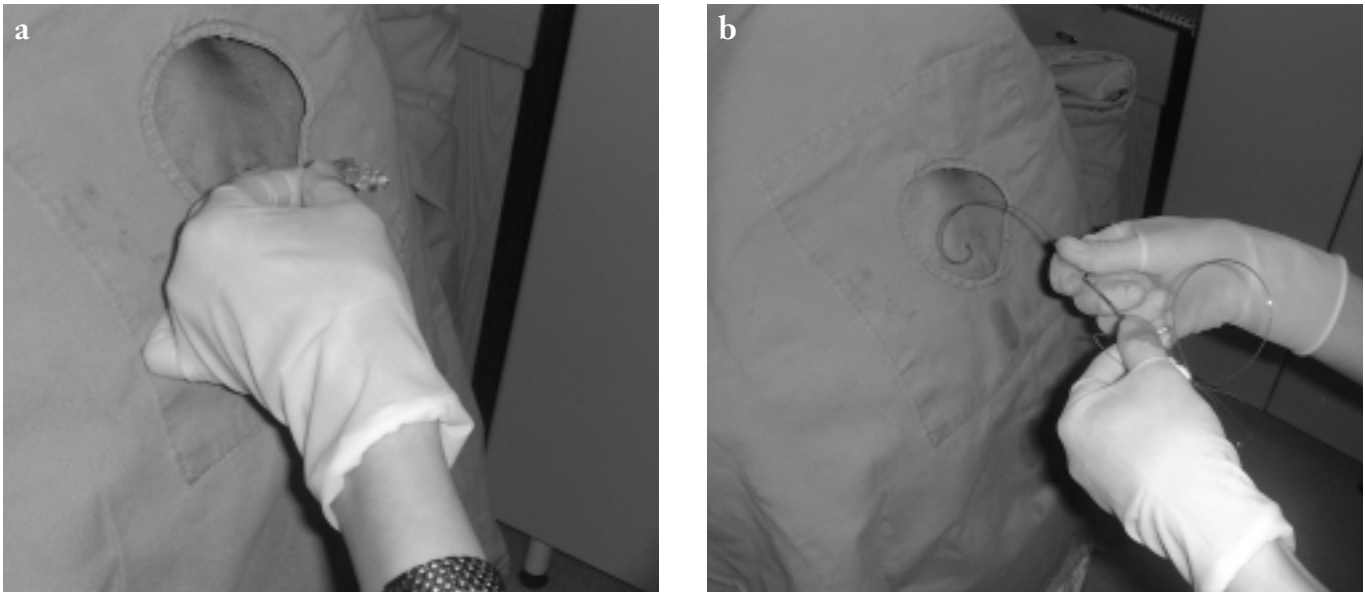


Figure 1a, b. Placement of the epidural catheter at T2-T3 level.

arterial grafts while the patients were conscious, and a better long-term prognosis was achieved. With the anesthetic technique described, other types of cardiac or thoracic procedures beyond coronary surgery may be possible.

Patients with certain risk profiles, including chronic obstructive pulmonary disease (COPD), coagulation disorders, and neurologic conditions seemed to benefit most from operations without cardiopulmonary bypass [Jegaden 2001]. However, significant complications following CABG surgery are often associated with preexisting pulmonary disease or reduced general health status. This often requires prolonged postoperative ventilatory support and prolonged intensive care unit stay. With ACAB, the risk of postoperative pulmonary failure and the complications of long-term ventilation may be reduced.

The risks of thoracic epidural anesthesia (TEA) are infection and hematoma, although reports show that these com-

plications are rare, with a rate of peridural hematoma or infection of 1/50,000 to 1/100,000 [Steneth 1994, Fawcett 1997, Horlocker 1999, Tenling 2000]. The potential risks of endotracheal intubation, such as trauma to teeth or vocal cords, or peri-intubational hypoxia, are absent. Some patients suffer hemodynamic compromise when narcotic medication is administered before intubation. This poses the risk of preoperative myocardial ischemia or infarction in patients with severe coronary artery disease, a risk that TEA avoids. Thoracic epidural anesthesia provides excellent conditions for off-pump coronary artery bypass surgery by dilating the coronary arteries and the internal thoracic artery, and by reducing heart rate and arrhythmias during manipulation of the heart [BARI Investigators 1996, Tenling 2000]. In our initial experience, native coronary arteries as well as thoracic artery grafts were well dilated, thus facilitating the anastomoses.

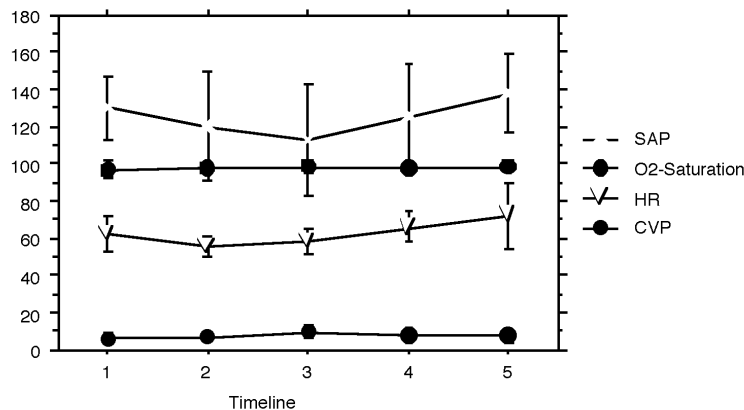


Figure 2. Perioperative hemodynamic parameters: 1: before induction of the epidural anesthesia, 2: sternotomy, 3: anastomosis, 4: sternal closure, 5: one hour postoperative. (CVP = central vein pressure, HR = heart rate, O<sub>2</sub> = oxygen, SAP = systemic arterial blood pressure).

Partial lower sternotomy or complete sternotomy was performed in standard fashion. Dissection of the internal thoracic artery was carried out carefully to avoid pneumothorax because irritation or injury to the pleural cavity induces coughing and extreme respiratory excursions that, in turn, render the operative field unstable. Furthermore, the anesthesiologist stays in close contact with the patient during critical steps of the procedure to avoid movement of the body.

In the last decade, the results of catheter-based coronary interventions have improved tremendously despite higher restenosis and reintervention rates [BARI Investigators 1996, Kurbaan 1998] than those of surgical arterial revascularization. The risk of repeat revascularization can rise to more than 50% within three years after angioplasty, as compared to 2% for patients undergoing conventional CABG [BARI Investigators 1996, Kurbaan 1998]. The driving force behind catheter-based procedures is their low invasiveness and superior procedural patient comfort. These procedures are performed without general anesthesia, without endotracheal intubation, with minimal pain, and with a very short hospital stay and faster return to normal activities and work [Kurbaan 1998]. Conventional beating heart procedures have now achieved good mid-term patency rates and very low hospital complications. However, although such procedures are considered minimally invasive surgical techniques, they require general anesthesia, which implies that procedural pain reception by the patient is unchanged [Walther 1999].

It is our impression that patient comfort is improved substantially by avoiding general anesthesia and mechanical ventilation. In our experience, there was no need to keep bypass surgery patients in the intensive care unit. Rapid postoperative mobilization and faster recovery due to continuous application of pain medication through the thoracic epidural catheter shortens hospitalization time, which may eventually lead to outpatient CABG surgery for single vessel and multi-vessel coronary artery disease. However, local reimbursement regulations in Germany currently require a minimum hospital stay in order to obtain a flat fee for coronary bypass grafting. From a medical point of view, all ACAB patients could have been discharged within three days after surgery.

## CONCLUSION

This early report shows the feasibility and safety of ACAB in a small patient group. ACAB is acceptable to many patients because it avoids general anesthesia and allows effective pain management. With further refinement of the procedure, outpatient coronary artery bypass surgery may become feasible and eventually compete with interventional catheter-based techniques.

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## REVIEW AND COMMENTARY

### 1. Editorial Board Member LO23 writes:

- a) The authors should comment on why no circumflex territory vessels were grafted and what the patient inclusion criteria were for this procedure.
- b) In addition, it would be of interest to know how many patients in total were approached to have this procedure, and how many refused.

**Authors' Response by Tayfun Aybek, MD:**

- a) Revascularization of the circumflex territory is in most cases due to difficult hemodynamic impairment associated with exposing the vessel. In our earlier report we initially selected patients with two-vessel disease (LAD, RCA) to avoid possible complications. After gaining further experience with the technique, we expect to perform RCX revascularization soon.
- b) Of the 14 patients we approached for the procedure, 12 accepted and only two refused.

**2. Editorial Board Member JZ29 writes:**

I would like to see more data on patient comorbidities, such as chronic obstructive pulmonary disease (COPD), hypertension (HTN), diabetes mellitus (DM), and arteriosclerotic peripheral vascular disease (ASPVD). I would also like to know how the surgeons sewed between breaths, coughs, or other disturbances? Did they have complications because of this?

**Authors' Response by Tayfun Aybek, MD:**

As to comorbidities, two out of four patients with chronic renal disease suffered terminal renal disease and needed regular dialysis for more than four years. In the other two patients, creatinine levels were 1.8 and 2.4 mg/dl. Three patients suffered from arteriosclerotic peripheral vessel disease, with Fontaine classification between II and IIIa. Four patients had diabetes mellitus and two of them required insulin substitution.

None of the six COPD patients had FEV<sub>1</sub> < 50%. Arterial blood PaO<sub>2</sub> levels in this COPD subgroup ranged between 52 and 70 mmHg without oxygen supplementation. As long as no pneumothorax occurred, the chest was completely stable. The patients were breathing spontaneously, supported only by the diaphragm muscles, due to complete anesthesia of the intercostal muscles. In one patient, pneumothorax and pleural irritation was the cause of unstable operating situs and coughing, which finally required endotracheal intubation.

**3. Editorial Board Member SG14 writes:**

- a) The authors claim that ACAB is probably most helpful for patients with COPD, but only half of the patients belonged in this group. In the Discussion section, it is claimed that the described procedure has an excellent patient acceptance, and the authors have the impression that the patient's comfort approaches that experienced with catheter intervention, yet no supporting data are supplied. Studies have shown that when patients claim to be more comfortable with CABG than PTCA, it is precisely because they are awake. It is surprising that a cardiac surgeon would be willing to ignore safety standards by performing CABG on an awake patient. What about exposure and stabilization?
- b) The authors describe the anesthetic drug concentration without mentioning the total amount of applied drugs. The planned peridural narcosis is explained, but not the level reached.

- c) In performing such an anesthesia on an awake patient, sympicolysis is of great importance following hemodynamic dysregulation.
- d) In case the IMA is not suitable for any reason (hypoplasia, iatrogenic trauma), conversion would again probably be obligatory.

**Authors' Response by Tayfun Aybek, MD:**

- a) In our clinic the ACAB procedure is used not only for high-risk patients but also for average-risk patient cohorts. Due to avoidance of cardiopulmonary bypass and ventilation as well as general anesthesia, it is obvious that the high-risk patient group gains higher benefit from the coronary revascularization. In the low-risk patient group, ACAB is performed to increase patient comfort through effective perioperative pain management and the absence of general anesthesia and ventilation. We believe that ACAB is the least invasive procedure currently available. For that reason, we described ACAB as a procedure that comes close to PTCA in regard to patient comfort. However, we chose not to compare the risk profiles of ACAB and PTCA. In our opinion, 5-7 minutes of coronary occlusion is totally acceptable for chronic ischemic heart. That means the procedure does not carry any additional risk due to awake technique.
- b) The anesthetic drug application was guided by the sensory effect on the spinal segments reached by the catheter. The initial dose was given as a bolus injection and a continuous infusion was maintained according to the clinical effect. Most patients required 3-4 ml/hour of the drug concentration described in the Patients and Methods section of our article. The sensory level was tested prior to skin incision.
- c) The positive effects of epidural anesthesia were described in the Discussion section of our article. Our observation of hemodynamic stabilization is supported by the literature cited.
- d) In case of IMA injury, we would prefer to harvest a radial artery graft with local anesthesia. A fallback to saphenous vein harvesting with general anesthesia was not necessary in our series.

**4. Editorial Board Member AN153 writes:**

The criteria for selection and mental preparation of patients to ensure cooperation are not adequately described. Was adequate truncal relaxation obtained in patients who had a median sternotomy? The patients' reasons for acceptance of awake surgery should also be mentioned.

**Authors' Response by Tayfun Aybek, MD:**

When the ACAB technique was offered to patients, it was described in conjunction with standard alternative techniques. It was pointed out that the respiratory weaning period, with the discomfort of the endotracheal tube, is effectively bypassed by this technique. Only two patients, for psychological reasons, refused to have awake surgery. One patient specifically emphasized that he was more afraid of general anesthesia than the procedure itself.