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ORIGINAL ARTICLE

Postoperative outcome in awake, on-pump, cardiac surgery patients

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Abstract
Purpose Thoracic epidural anesthesia (TEA) alone or combined with general anesthesia (TEA-GA) has been assumed to improve early postoperative outcome in cardiac surgery. The aim of our study was to investigate data of early and late postoperative outcome results of awake TEA patients undergoing cardiac surgery with comparison to patients under combined and general anesthesia (GA).
Methods Forty-seven patients undergoing elective on-pump cardiac surgery were assigned to receive either epidural (group TEA, $n = 17$), combined (group TEA-GA, $n = 15$), or general (group GA, $n = 15$) anesthesia. Early and late postoperative outcome data, including hospital and 3-year mortality rates, were recorded and compared among the study groups.
Results There was no major difference in early or late postoperative outcome data across all study groups, except for lower incidence of atrial fibrillation in the TEA group compared with the GA group (23.5% vs. 66.7%, respectively, $P < 0.05$). Also, TEA and TEA-GA groups compared with the GA group had lower pain visual analogue scale scores at 24 h postoperatively (4 ± 7, 6 ± 7, 14.7 ± 11, respectively, $P < 0.05$) and morphine requirements during the first 24 h after surgery (30 ± 6, 30 ± 6, 250 ± 140 μg/kg, respectively, $P < 0.05$).
Conclusions Based on our data, all three anesthetic methods were equivalent in terms of major determinants of postoperative outcome, except for lower incidence of atrial fibrillation in awake patients compared with patients under general anesthesia. Methods using postoperative epidural analgesia provided superior pain relief.

Keywords Cardiac surgery · Thoracic epidural anesthesia · Cardiopulmonary bypass · Postoperative outcome · Mortality

Introduction

Awake cardiac surgery (AWCS) technique with the use of sole thoracic epidural anesthesia (TEA) was recently introduced as an alternative to general anesthesia (GA) following the introduction of minimally invasive cardiac surgical procedures. Awake TEA has been successfully used in low-risk AWCS off-pump [1, 2] and on-pump [3] procedures, as well as in high-risk on-pump procedures [4]. TEA offers several advantages in comparison with GA, including thoracic sympathicolysis, attenuated stress response, and myocardial blood-flow redistribution [5], and has been used as combined TEA-GA anesthesia. Moreover, TEA likely decreases the incidence of postoperative myocardial infarction [6] and arrhythmias [5, 7] and improves postoperative pain control [5] and pulmonary outcome [7, 8]. Additionally, awake TEA patients may benefit from spontaneous ventilation, which is likely to be a significant advantage in comparison with tracheal intubation and

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mechanical ventilation in GA [9]. However, contrary to combined anesthesia, there is only limited data on detailed postoperative outcome results in AWCS patients [1–4]. Moreover, only one study reporting postoperative outcome in AWCS patients used a controlled study design [2]. On the other hand, postoperative outcome data published so far show promising results of overall uncomplicated postoperative course with rapid recovery and early hospital discharge in AWCS patients [1–4]. Limited data also exist on early in-hospital [1–4] and late mortality rates [4] of awake AWCS patients.

Our hypothesis was that the AWCS technique with TEA reduces postoperative complications because of sympathetic blockade and avoidance of tracheal intubation with mechanical ventilation. In our study, we recorded major parameters of postoperative outcome, including early and late 3-year mortality rates of patients undergoing awake on-pump cardiac surgery and compared this data with patients undergoing cardiac surgery under combined and sole GA.

Materials and methods

The study included 47 consecutive patients undergoing cardiac surgery on cardiopulmonary bypass (CPB) referred for aortic valve replacement, coronary artery bypass grafting, or combined procedures after obtaining approval from the Local Ethics Committee and informed patient consent. Inclusion criteria were planned on-pump cardiac surgery, age >18 years. Exclusion criteria were severe peripheral vascular disease, left ventricular systolic dysfunction (ejection fraction <50%), and allergy to local anesthetics. Ethical and medical considerations did not allow a randomized study design. All advantages and disadvantages of each type of anesthesia were discussed in detail with every patient. Patients freely chose the most comfortable type of anesthesia for themselves. There were three study groups: (1) The TEA group comprised patients undergoing AWCS with only TEA supported by light sedation ($n = 17$); (2) the TEA-GA group consisted of patients undergoing combined TEA and GA ($n = 15$); (3) the GA group consisted of patients undergoing sole GA ($n = 15$).

Premedication, cannulation sites, and patient monitoring (all groups)

All patients received 7.5–15 mg of midazolam orally 1 h prior to arrival to the operating room. Before anesthesia induction, hemodynamic monitoring was established via radial artery catheter (Arteriofix art.-Kath.-Set 22G/80 mm, B. Braun, Melsungen, Germany). A central venous catheter (Central Venous Catheter Set with AMC THROMBOSHIELD, Edwards Lifesciences, CA, USA) was placed via the right internal jugular vein into the superior caval vein to measure central venous pressure (CVP). An epidural-space puncture was performed in the TEA and TEA-GA groups before anesthesia induction. During cannulation, patients were ventilated via face mask with fresh gas flow of 6 l/min. Monitoring included five-lead electrocardiography, intra-arterial blood pressure, CVP, pulse oximetry, capnography, diuresis, nasopharyngeal (not in TEA group), and rectal temperature.

Epidural puncture and thoracic epidural anesthesia (TEA and TEA-GA groups)

The epidural puncture was performed in the TEA and TEA-GA group at the level Th1/2–Th2/3 using an 18-gauge Tuohy epidural needle (Perican, B. Braun) under local anesthesia in the sitting or lateral decubital position. Coagulation profiles of all patients were normal before epidural puncture. The epidural space was identified using the hanging drop technique, and 7 ml of 0.5% bupivacaine + 10 μg (2 ml) of sufentanil were administered as a bolus into the space. Afterward, an epidural catheter (Perifix - Katheter, B. Braun) was inserted 2–4 cm into the epidural space. The level of anesthesia was determined by loss of pinprick sensation (Th1–Th10). Then, continuous epidural infusion using a mixture of 15 ml 0.5% bupivacaine + 50 μg sufentanil (10 ml) and 15 ml saline was applied with rate of 7–10 ml/h till the end of surgery.

Management of awake patients (TEA group)

In awake patients, after epidural puncture, slight sedation was used by administering dexmedetomidine starting with 1 μg/kg dose infused over 10 min and continuing with infusion of 0.2–0.4 μg/kg per hour. Richmond agitation and sedation score scale was used targeting −1 grade in all patients (not fully alert, but with sustained awakening for >10 s, with eye contact, to voice) [10]. To monitor patients' comfort and anesthesia sufficiency, patients were regularly questioned every 15 min about their status, and sedation was adjusted if needed. If pain of any intensity occured during the surgery, the patient would be intubated and GA commenced. Therefore, visual analog scale (VAS) scores were not recorded during the surgery. Additional local anesthesia with 0.5% bupivacaine was used in patients in whom saphenous vein graft harvesting was required.

General anesthesia (GA group)

General anesthesia was induced with an intravenous bolus of thiopental (0.3–0.5 mg/kg), sufentanil (0.5 μg/kg), and

rocuronium (0.4–0.6 mg/kg). GA was maintained using isoflurane of minimal alveolar concentration 0.7–1.0 in a gas mixture of oxygen and air. Total amount of sufentanil was 2.5–5 μg/kg according to the individual pain response. No other myorelaxation was needed throughout the procedure.

Combined thoracic epidural and general anesthesia (TEA-GA group)

In the combined anesthesia group, epidural puncture was performed as described above. GA was then induced and maintained using isoflurane in the same dosage as in GA group. Two patients required additional administration of sufentanil (they received 25 and 60 μg as a bolus, respectively).

Surgery and CPB management (all groups)

Median sternotomy was used in all patients. After administration of 300 IU/kg unfractionated heparin to achieve activated clotting time >480 s, cannulation of the aorta (24-F × 20 cm aortic perfusion cannula, Edwards Lifesciences) and right atrium (36-F to 46-F × 40 cm Thin-Flex™ Dual Stage Venous Drainage Cannula, Edwards Lifesciences) was performed and CPB commenced. The time interval between epidural puncture and heparin administration was between 60 and 90 min. The CPB circuit was primed by 1,500 ml Hartmann's solution and 200 ml of 20% mannitol. CPB blood flow rates were kept at 2.4 l/min/m^2. Mean arterial pressure was maintained between 45 and 70 mmHg with boluses (10 μg) or continuous infusion of norepinephrine. A Stockert roller pump CPB and hollow-fiber oxygenator (Medos Hilite 7000 heparin-coated, MEDOS Medizintechnik, AG, Germany) was used. Fresh gas flow was initially set to 2 l/min and inflow oxygen concentration to 60% and was subsequently adjusted to maintain blood gases in physiological ranges [partial pressure of oxygen in arterial blood (PaO_2) >100 mmHg, $PaCO_2$ 35–45 mmHg]. During CPB, all patients were kept normothermic and received blood cardioplegia. Transfusion trigger was set to 70 g/l of hemoglobin concentration. In the TEA-GA and GA groups, isoflurane concentrations were not changed, and no other intravenous anesthetics, including propofol, were used during CPB. The time interval between aortic cross-clamp release and CPB discontinuation was 30% of the total aortic cross-clamp time. Before weaning from CPB, epicardial stimulation was used when needed. The effects of heparin were reversed with 3 mg/kg of protamine after discontinuation of CPB. Chest closure was then performed, and patients were transferred to the postoperative intensive care unit (ICU). Pre- or post-CPB hypotension [mean arterial pressure (MAP) <65 mmHg] was managed with intravenously administered fluid boluses and norepinephrine boluses (10 μg). Persistent hypotension required continuous norepinephrine infusion.

Postoperative management (all groups)

After transfer to ICU, patients monitoring included hemodynamic parameters [heart rate (HR), MAP, and CVP], laboratory parameters (arterial and central venous acid base and blood-gas parameters, hemoglobin concentration, and glycemia in regular intervals), diuresis, and blood loss. Patients in the TEA group breathed via face mask using fresh gas flow of 4–12 l/min according to their arterial oxygen parameters. Triggers for any kind of ventilatory support were PaO_2 <60 mmHg and partial pressure of carbon dioxide in arterial blood ($PaCO_2$) >60 mmHg. Intubated patients (TEA-GA and GA groups) were weaned off the ventilator and extubated according to local extubation protocol. This included fully awake, cooperative patients with stable hemodynamic parameters without significant blood loss (<200 ml/2 h) and with acceptable arterial blood gas parameters (i.e., PaO_2 >60 mmHg and $PaCO_2$ <60 mmHg) on nonaggressive ventilation [pressure-support ventilation, positive end-expiratory pressure (PEEP) ≤5 cmH_2O, fractional inspiratory oxygen (FiO_2) ≤0.4, pressure support ≤6 cmH_2O, and respiration frequency ≥10/min]. In the GA group, postoperative pain management was conducted by a nurse-driven intravenously administered morphine protocol. Patients with VAS scores <50 received 1 mg morphine, and 2 mg of morphine were administered to patients with VAS scores >50. The minimal time interval between two morphine injections was 5 min and the maximal hourly dose was 10 mg. After 24 h, an analgesic therapy continued with oral morphine sulphate. Postoperative analgesia in the TEA and TEA-GA groups was provided by continuous infusion of local anesthetics to the epidural catheter (a mixture of 15 ml 0.5% bupivacaine + 50 μg sufentanil + 25 ml saline infused at 3–7 ml/h), which was removed on the fourth postoperative day. In case of insufficiency of epidural analgesia, opioids were administered in the same way as in the GA group. Criteria for ICU discharge were as follows: fully alert and cooperative patient without significant neurological impairment, hemodynamic stability without inotropic or vasopressor therapy, no hemodynamically significant arrhythmias, spontaneous breathing with arterial oxygen saturation >90% at FiO_2 ≤50% via a facemask, urine output >0.5 ml/kg/h, and chest-tube drainage <20 ml/h. Criteria for hospital discharge were hemodynamically stable patient with controlled arrhythmias, independent in ambulation and feeding, afebrile with no infections and clean wound, normal voiding and bowel

movements, full oral diet, and pain controlled on oral medication.

Study protocol (all groups)

We recorded and compared early postoperative outcome data including all major organ system outcomes parameters and early (ICU and hospital) mortality rates among groups. Analgesia quality was evaluated using VAS scoring recorded every 4 h and compared at 24 h postoperatively among groups. Additionally, morphine requirements during the first 24 h postoperatively were compared among groups.

Follow-up

Follow-up data for each patient were collected after a 3-year period via telephone interviews or correspondence and included an inquiry on overall satisfaction with perioperative course and anesthesia, mortality rate, and cause of death. The response rate was 100%.

Statistical analysis

Data are presented as mean ± standard deviation (SD). SPSS 13.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. A chi-square test was used for comparisons of pre- and postoperative qualitative parameters, followed by Fisher's exact test. Normal distribution was tested for all quantitative parameters. Kruskal–Wallis nonparametric analyses with Mann–Whitney tests were used for comparisons of quantitative parameters among groups. P values <0.05 were considered statistically significant.

Results

Forty-seven consecutive patients were enrolled from 2005 to 2008. Two patients in the TEA group had a conversion to GA during surgery: The first patient suffered from a severe embolic stroke after discontinuation of CPB, was intubated, and subsequently died on the third postoperative day due to cerebral edema. The second patient suffered from aortic dissection after decannulation of the aorta and was intubated. After surgical correction, he had an uneventful postoperative course. All other patients had uneventful perioperative courses, and there were no serious complications, including those related to epidural puncture and use of epidural catheter (epidural hematoma, abscess, spinal cord injury, accidental dural puncture, high spread of epidural anesthesia).

Demographic, preoperative, and perioperative data

There was no difference in demographic, preoperative, and perioperative data across all study groups, except for lower weight in the TEA group compared with the TEA-GA group (Table 1) and a mildly longer aortic cross-clamp time in TEA-GA group compared with the TEA and GA groups (Table 2). Only norepinephrine was injected; other inotropes, including dobutamine, dopamine, and epinephrine, were not needed during the procedures.

Postoperative outcome data

There was no difference in postoperative outcome data (Tables 3, 4, 5) except for higher pain VAS scores and higher morphine requirements in the GA group compared with the TEA and TEA-GA groups (Table 4). The incidence of atrial fibrillation was higher in the GA group compared with the TEA group (Table 4). Total norepinephrine dose and vasopressor support duration tended to be lower in the TEA group compared wtih the TEA-GA and GA groups but did not reach statistical significance (Table 4). The overall satisfaction with perioperative course and anesthesia type did not differ among groups (86%, 91%, 83%, respectively, $P = 0.864$). Patients who were satisfied on inquiry would choose the same type of anesthesia for the procedure again.

Length of hospital stay and early mortality rates

There was no difference in either ICU or hospital length of stay across the study groups (Table 3). Also, no difference in ICU, hospital, or early 30-day mortality rates was noted across study groups (Table 3).

Late mortality rate

The overall 3-year mortality rate did not differ among groups (Table 3). There was no difference in the incidence of deaths related to cardiovascular causes (myocardial infarction, heart failure, sudden cardiac death) in these patients (66.7%, 50%, and 66.7%, respectively, $P = 0.678$).

Discussion

Our data show that there was no major difference in early and late postoperative outcome data among the three study groups, except for a higher incidence of atrial fibrillation in the GA group compared with the TEA group. Also, pain relief was more efficient and analgesic requirements lower in the TEA and TEA-GA groups compared with the GA

Table 1 Demographic and preoperative data

	TEA ($n = 17$)	TEA-GA ($n = 15$)	GA ($n = 15$)	P value
Age (years)	67 ± 10	64 ± 11	67 ± 7	0.451
Weight (kg)	67 ± 7	82 ± 15*	79 ± 15	0.025
Height (cm)	174 ± 9	173 ± 11	173 ± 9	0.948
BMI (kg/m^2)	26 ± 5	28 ± 5	27 ± 4	0.454
BSA (m^2)	1.9 ± 0.2	2 ± 0.2	2 ± 0.2	0.702
Male (female)	9 (6)	10 (5)	10 (5)	0.908
CAD	6/17	8/15	7/15	0.765
Hypertension	12/15	11/15	12/15	0.879
LVEF (%)	63 ± 5	62 ± 7	58 ± 7	0.147
COPD	4/17	4/15	2/15	0.598
Diabetes mellitus	6/17	5/15	6/15	0.910
Stroke/TIA	1/17	1/15	0/15	0.593
NYHA (%)				
I	7	0	0	0.624
II	40	47	53	
III	40	40	47	
IV	13	13	0	
EUROSCORE ad.	4.7 ± 2.3	4.3 ± 1.5	4.4 ± 21	0.689
Serum creatinine (μmol/l)	95 ± 21	100 ± 26	99 ± 30	0.624
Type of surgery (%)				0.914
AVR	65	60	60	
CABG	24	33	27	
AVR + CABG	12	7	13	

TEA thoracic epidural anesthesia group, *TEA-GA* combined thoracic epidural anesthesia and general anesthesia group, *GA* general anesthesia group, *CAD* coronary artery disease, *LVEF* left ventricular ejection fraction, *COPD* chronic obstructive pulmonary disease, *TIA* transitory ischemic attack, *NYHA* New York Heart Association heart failure classification, *EUROSCORE ad.* European System for Cardiac Operative Risk Evaluation, additive score, *BMI* body mass index, *BSA* body surface area, *AVR* aortic valve replacement, *CABG* coronary artery bypass grafting

*$P < 0.05$ versus TEA, $P < 0.05$ versus TEA-GA

Table 2 Perioperative data

	TEA ($n = 17$)	TEA-GA ($n = 15$)	GA ($n = 15$)	P value
Duration of surgery (min)	280 ± 32	270 ± 42	263 ± 45	0.450
Duration of CPB (min)	92 ± 11	87 ± 15	86 ± 19	0.167
Aortic cross clamp time (min)	52 ± 10	61 ± 10*	51 ± 18**	0.048
Surgical revision due to ischemia	0	0	0	
Surgical revision due to bleeding	0	1	0	0.406
Perioperative blood loss (ml)	940 ± 200	1,050 ± 370	1,060 ± 240	0.408
Transfusion (PRBC units)	1.5 ± 1.4	2.3 ± 2.5	1.1 ± 1.8	0.248

TEA thoracic epidural anesthesia group, *TEA-GA* combined thoracic epidural anesthesia and general anesthesia group, *GA* general anesthesia group, *CPB* cardiopulmonary bypass, *PRBC* packed red blood cells

* $P < 0.05$ versus TEA, **$P < 0.05$ versus TEA-GA

group. It has been reported that TEA improves coronary blood flow distribution and was proposed to decrease the incidence of postoperative myocardial infarction [6]. However, this is not supported by the most recent meta-analysis [7]. There were no cases of perioperative myocardial ischemia, and no inotropic support except for norepinephrine was used in any of the study groups. Postoperative myocardial ischemia is a relatively common

complication after surgical coronary revascularization, with the incidence as high as 10–25%, significantly affecting postoperative morbidity and mortality [11]. In this study, myocardial revascularization procedures represented about 35–40% of operations in each group, which were relatively small. Thus, our results are certainly influenced by this limitation.

Atrial fibrillation is the most common arrhythmia after cardiac surgery that leads to increased risk for thromboembolism and excessive health-care resource use [12]. In our study, there was a lower incidence of atrial fibrillation in the TEA group, which corresponds to previously reported effects of TEA [7, 11]. This effect is most likely a consequence of sympathetic blockade and blunted stress response. Catecholamine response, reflected by epinephrine and norepinephrine release, is abolished or attenuated under TEA [5]. It is well known that the incidence of atrial fibrillation increases with procedure complexity in cardiac surgery [12]. Although our patients underwent various types of on-pump surgical procedures, their incidence did not differ among study groups (Table 1). Furthermore, the hypotensive effect of TEA with its possible consequences has been described in the literature [13]. However, our results show the opposite findings compared with published data (Table 4). There was a trend toward lower total norepinephrine dose and shorter vasopressor support time in the TEA and TEA-GA groups compared with the GA group, but the statistical significance was not reach in any of these parameters. The etiology of this remains unknown. It has been shown that atrial fibrillation represents a risk factor for hypotension and increased use of ionotropic medications after cardiac surgery [14]. Thus, we speculate that the higher incidence of atrial fibrillation in the GA group could prolong vasopressor support in these patients.

Although there is a considerable body of evidence that TEA may improve pulmonary outcome in patients undergoing cardiothoracic or abdominal surgery [7, 8], there was no difference in pulmonary outcome data among our study

Table 3 Length of intensive care unit/hospital stay and mortality rates

	TEA ($n = 17$)	TEA-GA ($n = 15$)	GA ($n = 15$)	P value
Length of stay (days)				
ICU	5 ± 2	5 ± 2	8 ± 12	0.516
Hospital	10 ± 5	12 ± 6	16 ± 15	0.339
Mortality				
ICU	1 (5.9%)	0	0	0.406
Hospital	1 (5.9%)	0	0	0.406
30-day	1 (5.9%)	0	0	0.406
3-year	3 (17.6%)	4 (26.7%)	3 (20%)	0.678

TEA thoracic epidural anesthesia group, *TEA-GA* combined thoracic epidural anesthesia and general anesthesia group, *GA* general anesthesia group, *ICU* intensive care unit

$P < 0.05$ versus TEA, $P < 0.05$ versus TEA-GA

Table 4 Pain management and pulmonary and cardiovascular outcome data

	TEA ($n = 17$)	TEA-GA ($n = 15$)	GA ($n = 15$)	P value
Pain VAS score at 24 h postoperatively	4 ± 7	6 ± 7	14.7 ± 11*, **	0.004
Morphine requirements first 24 h (μg/kg)	30 ± 6	30 ± 6	250 ± 140*, **	0.001
Pulmonary outcome				
Reintubation	0	0	1 (6.7%)	0.360
Time to extubation (h)	0.2 ± 1.2	7.3 ± 3.8*	6.7 ± 3.5*	0.001
Mechanical ventilation >48 h	1 (5.9%)	0	1 (6.7%)	0.609
Pneumonia	0	0	1 (6.7%)	0.406
Pneumothorax	0	0	0	
Atelectasis	0	0	0	
Cardiovascular outcome				
Myocardial infarction	0	0	0	
Ionotropic support	0	0	0	
Intra-aortic balloon pump	0	0	0	
Atrial fibrillation	4 (23.5%)	8 (53.3%)	10 (66.7%)*	0.028
Total norepinephrine dose (μg/kg)	36 ± 62	43 ± 85	69 ± 72	0.231
Norepinephrine support >48 h	1 (5.9%)	3 (20%)	4 (26.7%)	0.111

TEA thoracic epidural anesthesia group, *TEA-GA* combined thoracic epidural anesthesia and general anesthesia group, *GA* general anesthesia group, *VAS* visual analogue scale (0–100)

* $P < 0.05$ versus TEA, **$P < 0.05$ versus TEA-GA

Table 5 Neurological, renal, and infections outcome data

	TEA ($n = 17$)	TEA-GA ($n = 15$)	GA ($n = 15$)	P value
Neurological outcome				
ICU delirium	3 (17.6%)	4 (26.7%)	4 (26.7%)	0.887
Stroke/TIA	1 (5.9%)	1 (6.7%)	0	0.593
Renal outcome				
Peak postoperative serum creatinine (μmol/l)	124 ± 46	110 ± 33	102 ± 23	0.355
RIFLE risk	2 (11.8%)	2 (13.3%)	1 (6.7%)	0.799
RIFLE injury	0	0	0	
RIFLE failure	0	0	0	
CRRT	0	0	0	
Infection				
Catheter-related	0	2 (13.3%)	0	0.483
Sternum dehiscence	0	1 (6.7%)	3 (20%)	0.598
Urinary tract	1 (5.9%)	0	0	0.406

TEA thoracic epidural anesthesia group, *TEA-GA* combined thoracic epidural anesthesia and general anesthesia group, *GA* general anesthesia group, *ICU* intensive care unit, *TIA* transient ischemic attack, *RIFLE* risk, injury, failure, loss, end-stage renal disease (Acute Dialysis Quality Initiative workgroup classification system), *CRRT* continuous renal replacement therapy

$P < 0.05$ versus TEA, $P < 0.05$ versus TEA-GA

groups. The overall incidence of these complications was low in all groups (Table 4). It has been proposed that awake TEA may be more beneficial and safer than GA in patients with chronic obstructive pulmonary disease (COPD) [4, 15]. Patients with asthma or COPD have a high incidence of bronchial hyperreactivity [16]. Therefore, general anesthesia with tracheal intubation can induce bronchospasm, which, in some cases, can be life threatening in these patients [17]. Awake TEA providing superior analgesia, improved diaphragmatic function, and preservation of spontaneous ventilation without mechanical ventilation may contribute to improved pulmonary outcome in these patients [4, 9, 15, 18]. On the other hand, thoracic sympathicolysis may increase airway resistance, and motor blockade of intercostal muscles [19] could lead to respiratory insufficiency in COPD patients. However, published data support the safety of TEA in COPD patients when none of the above-mentioned risks has been proved to be of clinical significance [20, 21]. Severe COPD patients represent a high-risk surgical population with an extremely high percentage of postoperative pulmonary complications [21]. Thus, severe COPD patients have been frequently contraindicated for cardiac surgery. In our study, two patients suffered from severe COPD [forced expiratory volume in 1 s (FEV1) <30% of normal values]. Both patients preferred sole TEA and had uneventful perioperative courses. These data support the hypothesis that the TEA method could represent an alternative to the GA or conservative approach in COPD patients. However, other specifically designed studies are warranted to confirm this hypothesis.

Analgesia quality was evaluated using visual VAS scores. VAS scores and morphine requirements were significantly lower in patients with TEA (TEA and TEA-GA groups), which corresponds to previously reported results of TEA and represents the beneficial effect of TEA supported by the largest body of evidence compared with its other effects [5, 9]. Inadequate analgesia during the postoperative period may increase morbidity by causing adverse hemodynamic, metabolic, immunologic, and hemostatic alterations [22]. Thus, aggressive pain control could have the potential to improve outcomes in these patients [5]. Additionally, avoiding use of parenteral opioids in TEA patients reduces the incidence of opioid-related side effects [5].

There has been a trend toward more rapid recovery after cardiac surgery, with earlier extubation and shorter stays in ICU and in hospital (fast-track anesthesia) [23]. TEA represents one fast-track anesthesia method, and many studies report shorter length of hospital stay when using TEA [5]. In contrast, there was no difference in duration of ICU or hospital stay among our study groups. Nevertheless, length of hospital stay is also influenced by other factors unrelated to anesthetic method used. The local protocol of patient discharge represents the crucial factor. We simply were unable to influence surgeons' final decisions regarding discharge from hospital. On the whole, contrary to the combined anesthesia technique, there is still a lack of good-quality evidence on postoperative outcome in awake cardiac surgical patients. Studies published so far concentrate more on describing the awake technique and actual perioperative course, with sparse comments on postoperative

outcome [1, 3, 4]. Moreover, only one of these studies used a controlled design [2]. Our study examines for the first time the detailed postoperative outcome results of awake patients in controlled manner, although patients were not randomized. Our study failed to indicate improvement in any of the major morbidity outcome measures except for lower incidence of postoperative atrial fibrillation and better pain relief. This corresponds to results of the latest meta-analysis of postoperative outcome in combined TEA-GA patients [10]. However, we believe that in specific high-risk patients, especially those with COPD, avoiding tracheal intubation and mechanical ventilation could improve postoperative morbidity rates, as discussed above.

Also, only limited data exist on early in-hospital [1–4, 8] or late [4] mortality rates of awake TEA patients, which seems to be low (~4%) [4]. This corresponds to our early in-hospital mortality rate of 5.9%. There was only one study reporting 2-year mortality rates of awake TEA patients [4]. This is the first study to date reporting long-term outcome of awake TEA patients compared with other types of anesthesia. In our study, 3-year mortality rates and the incidence of deaths related to cardiovascular causes (myocardial infarction, heart failure, sudden cardiac death), which represents 50–66.7%, did not differ among the study groups. However, it is still a matter of debate as to whether early or late mortality rates are related to anesthesia type itself or surgical complications [4].

The risk of epidural hematoma formation related to the use of TEA still represents the major argument against the wide-spread use of the technique. New cases of epidural hematoma related to epidural anesthesia in cardiac surgery have recently been reported [24, 25]. Epidural hematoma formation may lead to catastrophic neurologic consequences. Prompt diagnosis and urgent decompressive laminectomy with hematoma evacuation are crucial in minimizing neurological damage [26]. However, the latest estimation of the risk of epidural hematoma formation in cardiac surgery was calculated to be 1:12,000 [27]. Such a risk is similar to the risk of epidural hematoma in nonobstetric surgery. On the other hand, this analysis contains data from on-pump as well as off-pump procedures. Therefore, the risk for solely on-pump procedures may be increased due to higher levels of heparinization. Although the overall risk is considered to be relatively low, all possible precautions must be undertaken to minimize it. Normal coagulation parameters and safe withdrawal intervals of antithrombotic drugs are mandatory [28]. The time interval between epidural catheter placement and full heparinization in on-pump cardiac surgery should be at least 1 h [5, 28]. We experienced none of the above-described inadvertent effects in our TEA patients. We also had no other previously described side effects of TEA, such as incomplete anesthesia, pneumothorax, phrenic nerve palsy, or severe hemodynamic instability requiring intubation [2]. Two of our awake TEA patients had to be switched to GA because of embolic stroke and aortic dissection, respectively. However, these two complications are not caused by the anesthetic technique but are typically related to the surgical procedure [29].

Awake cardiac surgery with TEA requires a patient's perfect understanding and collaboration. Close collaboration between anesthetist and surgeon is necessary. Moreover, this technique is demanding for a surgeon, who needs to be experienced and able to promptly manage potential complications. Awake cardiac surgery also bears a certain amount of psychic stress for the patients. Therefore, it should be restricted to selected patients who have excellent compliance to the technique. The final decision as to which method should be chosen should be made on an individual basis after careful evaluation of the procedure risks and advantages and disadvantages of each anesthetic technique with regard to the patient's personality and cooperation.

Our study has a few limitations. First, ethical and medical considerations did not allow a randomized study design. Therefore, after a thorough explanation of advantages and disadvantages of each anesthetic method, the patient chose the type of anesthesia. Second, there was a small number of patients in each group.

In conclusion, our data show that there was no major difference in early and late postoperative outcome data, including hospital and 3-year mortality rates, among the three study groups, except for the lower incidence of atrial fibrillation in awake TEA patients compared with patients under GA. Also, methods using postoperative epidural analgesia provided superior pain relief. Future studies are warranted to elucidate the potential profit of the awake technique in cardiac surgery in specific patient cohorts, such as high-risk patients with COPD.

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Conflict of interest None.

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