Low preoperative cerebral oxygen saturation is associated with longer
time to extubation during fast-track cardiac anaesthesia

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Abstract

OBJECTIVES: Fast-track cardiac anaesthesia programs aiming at early tracheal extubation have not only been linked to a decrease in intensive care unit and hospital length of stay but also to a decrease in morbidity and mortality as well as a containment of rising medical costs. General recommendations for the inclusion criteria concerning fast-track programs are not available.

METHODS: The present study determined the factors influencing the time to extubation in patients undergoing a newly implemented fast-track protocol. Seventy-nine patients were retrospectively studied. Successful fast track was defined as time to extubation within 75 min after admission to ICU.

RESULTS: Sixty patients fulfilled the successful fast-track criteria with a mean time to extubation of 43.9 min (range 15–75 min). Nineteen patients needed more than 75 min to be weaned from the respirator with a mean time to extubation of 135 min (range 90–320 min). Analysis of pre- and intraoperative factors revealed that these groups differed only with respect to preoperative cerebral oxygen saturation levels: 67.7 ± 5.2 versus 60.8 ± 7.4%.

CONCLUSIONS: Cerebral oxygen saturation assessment prior to cardiac surgery is significantly related to time to extubation and may thus be used to stratify candidates in fast-track programs.

Keywords: Near-infrared spectroscopy • Cerebral oxygen saturation • Cardiac surgery • Fast-track cardiac anaesthesia

INTRODUCTION

Fast-track cardiac anaesthesia (FTCA) programs—employing short acting hypnotic and opioid medications with the goal of early tracheal extubation—have not only been linked to a decrease in intensive care unit (ICU) and hospital length of stay [1–4], but also to a decrease in morbidity and mortality [1] as well as a containment of rising medical costs [1–3]. With an increasing number of cardiac procedures being performed on co morbid elderly patients [3, 5, 6], the postoperative management of these patients in the ICU may further benefit from FTCA. However, generally recommendations for the inclusion criteria concerning FTCA programs are not available. Cerebral oximetry determined via near-infrared spectroscopy (NIRS) offers the possibility of measuring the oxygen supply/demand ratio in the frontal brain tissue non-invasively [7]. We have recently shown that preoperative cerebral oxygen saturation (ScO2) is related to objective measures of cardiopulmonary function and that low preoperative ScO2 concentrations are associated with an adverse perioperative course. Preoperative ScO2 levels equal to or less than 50% are an independent predictor of mortality and postoperative delirium in patients undergoing on-pump cardiac surgery and might serve as a refined marker for preoperative risk stratification in cardiac surgery patients [8, 9]. The present study was designed to determine the factors influencing the time to extubation in patients included in a newly implemented fast-track protocol for on-pump cardiac surgery.

MATERIALS AND METHODS

Demographic and clinical data—prospectively gathered for quality improvement—were used for this retrospective analysis after the ethical committee of the University of Luebeck had waived the need to obtain formal informed consent. Data from 80 consecutive patients undergoing elective on-pump cardiac surgery at the University of Luebeck from August 29 to 31 October 2011 were analysed. One patient underwent re-exploration because of severe bleeding after cardiac surgery and was excluded from this study, leaving 79 patients for a final analysis.
Patients were selected for the fast-track protocol if they met the following criteria: elective on-pump cardiac surgery, age between 18 and 85 years, no preoperative vasoactive support and no preoperative support by intra-aortic balloon pump (IABP). Due to the limitations of personnel resources, a maximum of three patients per day could be included in this fast-track protocol. All patients included in our protocol were managed by a dedicated anaesthesiologist who was only involved in the care of these FTCA patients and had no other obligations.

In accordance with our institutional standard practice, ScO2 sensors for the determination of ScCO2 with an (INVOS® 5100 monitor Somanetics, Troy, MI, USA) were applied bihemispherically before induction of anaesthesia. The baseline ScO2 values were recorded when no further increase in ScO2 was observed with patients breathing oxygen-enriched air. Inter-hemispheric differences of maximally 5% were observed in ScO2.

Anaesthesia following our institutional fast-track protocol

Oral premedication was administered in accordance with institutional standards with dipotassium clorazepate 10–20 mg p.o. the evening before surgery and midazolam 3.75–7.5 mg, Baken p.o. on call to the operating room. Anaesthesia was induced with sufentanil [0.5–1 µg/kg body weight (BW)] and propofol (1–2 mg/kg BW). Muscle relaxation was achieved with vecuronium-bromide (0.6 mg/kg BW). Thereafter, anaesthesia was maintained with sevoflurane (0.8–1.0 minimum alveolar concentration) and remifentanil (0.2–0.3 µg/kg/min) with the goal of early postoperative extubation. At the end of the surgery, sevoflurane was stopped and a continuous infusion of propofol (3–5 mg/kg/min) was administered. Intraoperatively, all patients were ventilated in a volume-controlled mode with a tidal volume of 6 ml/kg predicted body weight (PBW), and the respiratory rate adjusted to achieve normocapnia. The depth of anaesthesia was guided by the bispectral index (BIS) with anaesthetics modified to achieve a BIS between 40 and 50. Fluid therapy was performed by balanced cristalloid (Sterofundin; BBraun; Melsungen, Germany) and colloidal (Volutyte®, Fresenius, Germany; Gelafundin®, BBraun, Melsungen, Germany) fluids.

Cardiopulmonary bypass management

Before cardiopulmonary bypass (CPB), all patients received 400 IU/kg of heparin. Surgery was performed in moderate hypothermia (core temperature: 32°C) using antegrade blood cardioplegia. Blood flow during CPB was adjusted to achieve a mean arterial blood pressure (MAP) between 50 and 70 mmHg, a mixed venous oxygen saturation—measured at the inflow of the CPB circuit—higher than 70%, and relative ScO2 concentrations higher than 80% of the preoperative baseline. To achieve this goal, norepinephrine and nitroglycerin were applied as a bolus or continuous infusion. Haematocrit was adjusted between 26 and 29%. Acid-base balance was performed after [alpha]-stat blood gas principles. After weaning from CPB, protamine was applied accordingly.

After CPB, all patients were rewarmed and a body temperature between 36.0 and 37.0°C was maintained by heating blankets.

Before skin closure, each patient received 1 g metamizole sodium for early postoperative analgesia and 2 mg granisetron to reduce the frequency of postoperative nausea and vomiting. Upon admission to the ICU, patients were positioned at 30–45° head-up tilt to prevent regurgitation. Continuous infusions of propofol and remifentanil were stopped if the patients were haemodynamic stable and normothermic (core temperature >36°C). Postoperative analgesia was initiated with a bolus of piritramide (0.1 mg/kg BW). Haemodynamic stability was defined as a MAP of 60–90 mmHg, a heart rate between 60 and 90 bpm, a central venous pressure between 10 and 15 mmHg, a central venous oxygen saturation (ScvO2) >70% and requirement of ≥0.15 µg/kg/min norepinephrine and ≥6 µg/kg/min dobutamine. Thereafter, weaning from the ventilator was begun as soon as possible in accordance with the institutional respiratory weaning protocol.

Respiratory weaning protocol

Upon admission to the ICU, all patients were mechanically ventilated with biphasic airway pressure ventilation. Pressures were adjusted to deliver a tidal volume of 6–8 ml/kg PBW and positive end-expiratory pressure (PEEP) was set to 7 mbar and FiO2 to 0.6. An arterial blood gas analysis was performed 10 min after admission.

Ventilator settings and FiO2 were adjusted to maintain a PaCO2 between 35 and 45 mmHg and an arterial oxygen saturation (SaO2) of 95% or more. If SaO2 was below 90% with a FiO2 of 0.6, PEEP was increased to 10 mbar. Each modification was controlled 5 min thereafter with an arterial blood gas analysis. As soon as patients showed spontaneously triggered breaths, the ventilation mode was switched to continuous positive airway pressure/ pressure support ventilation (CPAP/PSV) using the former lower pressure limit as the CPAP value and the upper pressure limit as augmentation. If blood gas analysis was satisfactory, the pressure support was gradually withdrawn to 5 mbar. If the patient then achieved extubation criteria as summarized in Table 1, extubation was accomplished. After successful extubation, 2–4 l/min supplemental oxygen was applied via a facemask for the next 6 h to maintain a transcutaneous oxygen >95%. Non-invasive pressure support ventilation by a facemask was considered if SpO2 values declined below 90%. The following criteria were defined as extubation failure: respiratory frequency >35 breath per min, SaO2 lower than 90% or PaO2 lower than 60 mmHg (despite non-invasive positive pressure ventilation), clinical signs suggestive of respiratory failure or severe haemodynamic instability.

Statistical analysis

Statistical analyses were performed by MedCalc 11.3.3 statistical software package (MedCalc Software bvba, Mariakerke, Belgium) and PASW Statistics 18 (formerly SPSS) for Windows (SPSS, Inc., Chicago, IL, USA). After analysis by the Kolmogorov–Smirnov test, data were analysed by either the Student t-test for independent samples or the Mann–Whitney U-test, as appropriate. Being aware that using the Kolmogorov–Smirnov test in small sample sizes is critical, the main results were confirmed with the non-parametrical test (Mann–Whitney U-test). Nominal data were analysed by the $\chi^2$-test, the Fisher’s exact test (in the 2 × 2
RESULTS

All patients were graded ASA III status. All patients underwent elective cardiac surgery with CPB. The surgical procedures comprised: coronary artery bypass grafting (CABG): n = 40, CABG with aortic or mitral valve replacement: n = 16, mitral valve reconstruction: n = 8, mitral valve replacement: n = 2, aortic valve replacement: n = 8, aortic valve replacement with ascending aortic surgery: n = 2, right atrial thrombectomy: n = 1, and Ross procedure: n = 2.

In all except one patient, surgery could be performed without major complications. Based on data from the Leipzig fast-track protocol [1], successful fast track was defined as time to extubation within 75 min after admission to ICU. It was successfully accomplished in 60 cardiac surgery patients, with a mean time to extubation of 43.9 min (range 15–75 min). In the remaining 19 patients, time to extubation was 135 min (range 90–320 min) (Fig. 1), and was therefore graded as non-successful. None of these patients required non-invasive ventilation.

Pre- and also intraoperative parameters were compared between patients from successful and non-successful fast-track protocols (Table 2). No significant differences in patient demographics (sex, age), preoperative data (cerebrovascular disease, diabetes, chronic renal insufficiency, chronic obstructive pulmonary disease, atrial fibrillation, hypertension, hyperlipidemia, left ventricular ejection fraction, additive EuroSCORE), surgery-related data (type of surgery, duration of surgery, CPB time, aortic cross-clamp time), transfusion of packed red cells and dose of catecholamines were found (Table 2). Patients successfully extubated in <75 min showed significantly higher preoperative baseline ScO2 levels compared with those with a time to extubation >75 min (P < 0.001).

ROC analysis of preoperative ScO2 readings and time to extubation revealed an AUC of 0.83 (95% CI, 0.79–0.91; P < 0.001) (Fig. 2). The cut-off value to discriminate successful from non-successful fast-track procedures was ScO2 ≥66% (sensitivity 94.7%, specificity 63.3%).

A univariate binary logistic regression for relevant factors possibly influencing the success of the fast-track protocol was performed (Table 3). Only the preoperative regional cerebral oxygen saturation showed a significant impact on the success of the fast track. Consequently, no multivariate analysis could be performed.

On further exploration, a correlation analysis between ScO2 and time to extubation revealed an inverse correlation of rho = −0.603 (95% CI, −0.727 to −0.440; P < 0.001) (Fig. 3).

DISCUSSION

Increasing evidence suggests that modern FTCA pathways including early extubation following cardiac surgery result in a decrease in ICU and overall hospital length of stay as well as in a decreased resource utilization [1–4]. To optimize patient stratification for FTCA programs, it appears important to determine which preoperative factors influence time to extubation. The present retrospective observational pilot study was designed to determine the factors influencing the time to extubation in patients undergoing a newly implemented FTCA protocol following the on-pump cardiac surgery. The present study reveals a close association between preoperative ScO2 levels and time to extubation following cardiac surgery and thereby suggests that ScO2 may be used to stratify patients to be enrolled in an FTCA pathway. To the best of our knowledge, no prior data are available on the relation between preoperative ScO2 levels and successful fast-track procedure.

Data comparing preoperative risk factors and time to extubation in patients undergoing FTCA programs are conflicting [4, 10, 11].
Our results are in accordance with prior studies concluding that early extubation in cardiac surgery patients is feasible regardless of the preoperative risk status and that the anaesthetic management is probably the most important variable associated with the time to extubation after cardiac surgery [4, 12]. Reis et al. [4] reported a significantly shorter ventilation time in 76 cardiac surgery patients undergoing fast-track extubation compared with 188 patients undergoing conventional anaesthetic protocol. Preoperative risk factors, demographics and surgery-related data were all similar between the two groups. Plümer et al. [12] did not find any differences in time to extubation between 55 risk and 173 control cardiac surgery patients and concluded that the necessity for prolonged ventilation is primarily caused by intra- or perioperative events. In contrast to these findings and the results of the present study, Suematsu et al. observed that a combination of increased age, duration of surgery, occurrence of perioperative heart failure, glucose level during the CPB, postoperative transfusion volume and PaO2/FiO2 ratio was an independent factor for delayed extubation in 167 patients undergoing CABG procedure [13]. However, in their study, cut-off values of >24 h for delayed extubation were used; and patients requiring temporary preoperative IABP support as well as emergency patients were not excluded from their analysis. This may, at least in part, explain the differing findings.

NIRS is increasingly used for monitoring the adequacy of cerebral oxygen delivery. Interestingly, intraoperative cerebral desaturation has not only been linked to postoperative cerebral complications after cardiac surgery but also to worse general clinical outcome [14]. Casati et al. [15] demonstrated a shorter hospital and recovery room stay when perioperative cerebral saturations were maintained at 75% of baseline in patients undergoing non-cardiac surgery. A recent large observational trial showed that preoperative SCr levels equal or less than 50% are an independent predictor of mortality in patients undergoing on-pump cardiac surgery and might serve as a refined marker for preoperative risk stratification in these patients. Additionally,
preoperative ScO2 was related to objective measures of cardiopulmonary function [left ventricular ejection fraction (LVEF), N-terminal B-type natriuretic peptide] and low preoperative ScO2 concentrations were associated with an adverse perioperative course [8, 9].

Based on our previous findings [8], the results of the present study may be interpreted as follows: patients needing a longer time to be weaned off the respirator had a poorer cardiopulmonary function. It is of note that we did not observe a significant relationship between successful fast-track and LVEF in the present study. This may be most likely explained by intraobserver variability (i.e. that it is rather difficult to get a precise information on the ‘true’ LVEF) [16] and that when using a grading system, a correlation will only be detectable if large populations including a representative number of patients with rather low LVEF levels are analysed; both were not the case in the present study.

Limitations

This study has several limitations:

(i) The retrospective nature and the small sample size are clear limitations of the study. The small and unequal sample size might have concealed differences in patient characteristics. Larger observations and prospective interventional trials are needed to determine the relationship between ScO2 and time to extubation.

(ii) In comparison with other studies, we used the mean of the bihemispheric measurements for the calculation of ScO2. In case of large inter-hemispheric differences, this might have introduced a systematic error. However, since the differences between both hemispheres were small, the potential for error induced by this practice is rather low.

(iii) The cut-off value of 66% derived from the present study needs to be interpreted with caution since this specific number is derived from a relatively small population, a rather hard endpoint for the definition of extubation failure (>75 min), and has been determined by one specific cerebral oximeter. Recent data show that the commercially available ScO2 monitors from various manufacturers differ in the degree of the contribution of extracranial tissue to the ScO2 signal [17]. Thus, it cannot be ruled out that a different cut-off level may arise using other cerebral oximeters or monitoring a different population.

In conclusion, the present findings suggest that preoperative ScO2 is associated with time to extubation in patients undergoing elective on-pump cardiac surgery during fast-track cardiac anaesthesia following surgery. Thus, the determination of preoperative cerebral oxygen saturation levels may serve as an independent marker for identifying ideal fast-track candidates.

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REFERENCES


