Critical care after cardiac surgery

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Abstract - For several decades, the medical care of the cardiac surgical patient in the perioperative setting consisted of high-dose opioid stress-free anaesthesia and prolonged mechanical ventilation in the ICU. In recent years, the concepts of fast-track cardiac anaesthesia and short-stay intensive care have become the backbone of modern perioperative care. This review will focus on the safety and efficacy of early extubation and short-stay intensive care and will highlight some of the pitfalls associated with the implementation of a clinical pathway protocol for these patients.

Keywords - fast track cardiac anaesthesia, short-stay intensive care after CABG, early extubation

Introduction
The high-dose opioid anaesthetic technique was applied in cardiac anaesthesia for more than two decades. This technique provided stable haemodynamics, only mild cardiac depression and hypotension, and some hypnosis. The respiratory depression associated with the use of high doses of opioids resulted in prolonged respiratory depression which mandated mechanical ventilation for up to 12 -18 hours postoperatively[1,2]. Fortunately, at that time prolonged mechanical ventilation was considered beneficial for the cardiac surgical patient for several reasons [3-5]. It was thought to reduce respiratory complications in the early postoperative period, and to reduce the effort of breathing which was assumed to represent an extra burden to the jeopardized myocardium immediately after surgery. A major concern in coronary artery surgery was, and still is, the development of postoperative myocardial ischaemia and/or infarction, since this contributes to postoperative morbidity and mortality [6]. In a prospective randomized clinical study, Mangano and co-workers concluded that the severity of ischaemic episodes can be diminished by the use of prolonged postoperative intensive analgesia[7]. The scientific evidence that postoperative myocardial ischaemia was related to bad outcome and could be prevented by prolonged mechanical ventilation under deep analgo-sedation supported the use of high-dose opioid-based mono-anaesthetic technique in cardiac anaesthesia. This resulted in the worldwide acceptance of the high-dose opioid-based technique as the technique of choice in cardiac anaesthesia.

In the nineteen-eighties and nineties routine surgery was performed under moderate hypothermia and most patients were cooled to a core temperature of approximately 28 degrees Celsius [8,9]. Although patients were rewarmed with the heart-lung machine after the surgical intervention, a serious afterdrop in temperature was usually observed postoperatively and warming devices in the ICU were not as effective as nowadays. To prevent the deleterious effects of shivering and thermal discomfort, patients were sedated and ventilated at least until rewarmin was complete which was often many hours.

Certainly, the moderate to severe inflammatory response that these days is associated with the application of extracorporeal circulation, was associated with the dysfunction of several organs in the early postoperative period [10]. Oxygenation problems or patients’ agitation often mandated the prolonged use of sedatives and mechanical ventilatory support.

The peri-operative management of cardiac surgical patients has changed dramatically over the past two decades. New insights concerning the occurrence of peri-operative myocardial ischaemic complications in coronary artery surgery no longer supported the concept of beneficial prolonged mechanical ventilation under deep analgo-sedation [11,12]. Indeed, less than 40% of postoperative myocardial ischaemic events appeared to be related to myocardial oxygen/supply imbalances. Postoperative haemodynamic stability, although still important, was no longer considered the most imperative factor in the prevention of postoperative myocardial ischaemia. It also became evident that continuation of certain preoperative drugs (beta-blockers, lipid-lowering agents) into the perioperative period was beneficial for the patient [13,14]. Vascular endothelial function, reperfusion injury, the systemic inflammatory response syndrome, coagulation abnormalities and vasomotor effects were all found to be critically important to cardiac outcome.

Accordingly, the use of high-dose opioid anaesthetic techniques to provide maximum haemodynamic stability was questioned. Furthermore, the problem of awareness during high-dose opioid anaesthesia without the use of hypnotics, became apparent. The development of new short-acting sedative-hypnotic drugs (midazolam, propofol), newer short-acting opioids (sufentanil, alfentanil, remifentanil), new infusion devices...
allows rapid extubation after surgery [32]. In the literature, early authors define it as a type of anaesthetic management which is no uniform definition of fast-track cardiac anaesthesia, most short-stay intensive care after cardiac surgery? Although there are forced to contain costs and resources. In other words, the shoulders of the medical care providers and their governments [31]. In order to control indefinite medical care costs, governments are forced to contain costs and resources. In other words, the medical profession is being asked to do more and better with less.

**Fast-track cardiac anaesthesia and short-stay intensive care after cardiac surgery**

How can we best define fast-track cardiac anaesthesia and short-stay intensive care after cardiac surgery? Although there is no uniform definition of fast-track cardiac anaesthesia, most authors define it as a type of anaesthetic management which allows rapid extubation after surgery [32]. In the literature, early extubation varies between 1 and 10 hours after arrival in the ICU. Ultra fast-tracking refers to extubation of the patient in the operating room at the end of surgery. Short-stay intensive care after cardiac surgery is also not well-defined. However, it implies discharge from ICU to a ‘step-down’ unit as soon as the patient is extubated and all vital parameters are considered stable. This means that often only a few hours have to be spent in the ICU after cardiac surgery, in contrast to overnight treatment in the ICU which was standard care for some decades.

**Efficacy and safety of fast-track cardiac anaesthesia and short-stay intensive care after cardiac surgery**

The routine use of prolonged mechanical ventilation and its supposed beneficial effects was being questioned as early as the late seventies, especially in patients after uncomplicated cardiac surgery. The justifications for the practice of prolonged ventilation were: (1) the presumed beneficial effect of high-dose opioid anaesthesia which delayed weaning from artificial ventilation; (2) frequent respiratory complications in the postoperative phase; (3) the increased work of breathing in spontaneously breathing patients would represent an added burden on the myocardium at a time when cardiac function may still be compromised; (4) physiological stress may induce myocardial ischaemia; (5) continuous intense postoperative analgo-sedation in combination with mechanical ventilation decreases myocardial ischaemic episodes in the early postoperative phase [33-35].

Early extubation was performed as early as three hours after chest closure by Prakash and co-workers in the Netherlands in 1977, and by Quasha and colleagues in 1980 [36,37]. They found no differences in cardiopulmonary morbidity, haemodynamic performance, patient stress, drug utilization, or rate of recovery in the intensive care unit. Both authors concluded that compared with the standard care of overnight ventilation at that time, early extubation was safe and did not increase postoperative cardiac or pulmonary complications. Clinical practice was ahead of clinical research and demonstrated that early extubation was applicable in practice and apparently safe.

There is now mounting evidence that early extubation and a shortened length of stay in the ICU is safe. In a study on morbidity in fast-track cardiac surgery, Cheng and co-workers found no increase in perioperative cardiac, respiratory, haemodynamic or sympathoadrenal morbidity [38]. In this study, fast postoperative recovery resulted in reduced length of stay in the ICU and in hospital: extubation time 4.1 versus 18.9 hours, ICU discharge 17.3 versus 25.6 hours, hospital discharge 5.7 versus 6.6 days. Reyes, studying low and moderate-risk cardiac surgical patients, did not report increases in clinically important respiratory, cardiac, neurological, renal and infectious complications or an increase in number of re-operations or postoperative death [39]. It was found that most low- and moderate risk patients (60%), in whom cardiac operations with cardiopulmonary bypass were performed under opioid anaesthesia, could be extubated between 7 and 11 hours after operation and had an ICU length-of-stay of 27 hrs versus 44 hrs in the control group. Silbert and colleagues concluded from a prospective randomized trial in 1998, that early extubation is safe for primary outcome variables, incidence of reintubation, time in the ICU, length of...
hospital stay and CK and CK-MB concentrations [40]. In two large retrospective studies, comparing fast-track and non-fast-track patients, no differences were found in mediastinal or sternal infection, leg wound infection, operative mortality, late 1 to 24 month mortality and 30-day hospital re-admission [41,42]. A study comparing the effects of early versus late extubation on postoperative myocardial ischaemia and length of ICU and hospital stay did not find significant differences between the two groups [43]. Dumas and co-workers investigated the effect of timing of extubation on cognitive function at days 3 and 5, and at 8 weeks postoperatively. They found no differences between early and late extubation [44]. These data were confirmed by Michalopoulos and colleagues who showed that fast track is safe compared with routine extubation with no differences in postoperative complications, re-intubations, re-admissions or mortality [45]. In 2002 Nicholson and co-workers focused their research on pulmonary function after early extubation and did not find an increase in respiratory complications [46]. Interestingly, Dowd and colleagues reported a very low incidence of awareness of 0.3% when low doses of opioids with short acting anaesthetics were used to facilitate early extubation in fast-track anaesthesia [47]. In 1996, Weintrab and co-workers reported a retrospective analysis of 12,266 patients operated on between 1988 and 1996 [48]. Mortality rates decreased from 4.7% to 2.7%, Q-wave infarction fell from 4.1% to 1.3%, mean hospital costs decreased and length of stay after surgery decreased from 9.2 to 5.9 days. Meade and Hawkes reported that early extubation was associated with less time spent in ICU and in hospital, with no difference in mortality in the intensive care, in 30-day mortality, in myocardial ischaemia or in re-intubation rates on comparison with conventionally extubated patients [49,50]. Time spent in ICU and in hospital was significantly shorter. In 2003, a meta-analysis by Myles and co-workers on the safety and effectiveness of fast-track cardiac anaesthesia did not find evidence for increased mortality or morbidity [32].

The discussion on the pros and cons of early extubation following cardiac surgery has now settled in favour of early extubation [33,51]. It is now generally accepted that the respiratory system benefits from early extubation with respect to lesions of the vocal cords, mucus transport, coughing, auto-PEEP, atelectasis formation and overall pulmonary morbidity [46]. One of the key factors to adequate postoperative respiratory function is adequate analgesia in the postoperative period.

On the other hand, the debate regarding the optimal extubation time - the window of opportunity - is still ongoing [34]. There are several studies on outcome after extubation in the operating room which show that it is feasible with good results [52,53]. However, the nadir of ventricular function occurs about four hours following cardiopulmonary bypass. Also, the first few hours after cardiac surgery are characterized by periods of haemodynamic instability, temperature dysregulation, increased mediastinal blood loss and other homeostatic disturbances. Patients can rapidly deteriorate in this early postoperative phase and we believe that instabilities can be best anticipated and treated in an ICU setting in sedated and ventilated patients. The window of opportunity for extubation after uneventful cardiac surgery is therefore between two and six hours postoperatively.

Risk management in the cardiac surgical patient

Evidently, not every cardiac surgical patient is eligible for fast-tracking. How can patients who are suitable for this type of management be identified preoperatively?

Constantinides and colleagues defined preoperative risk factors which should exclude patients from a fast-track protocol: impaired left ventricular function, acute coronary syndrome within 90 days of surgery, reoperaion, peripheral vascular disease, preoperative intra-aortic balloon pump, raised serum creatinine, operative urgency and complex surgery [54]. Other authors also found age and female gender to be preoperative predictors of delayed extubation. Another study on preoperative clinical characteristics showed that age, sex, body mass index, obesity, diabetes, hypertension, obstructive pulmonary disease, exercise tolerance, and unstable angina were not significantly associated with the time spent in the ICU [55]. There is ongoing discussion concerning the preoperative risk factors that should be included in risk evaluation systems.

A risk stratification system such as the Euro-SCORE predicts risk-adjusted outcome and is used as a tool for informed consent, clinical decision making and quality monitoring [56,57]. However, risk stratification scoring systems have their own limits. A problem concerning risk stratification systems is how outcome is defined. For the clinician, medical related outcome measures such as mortality, morbidity are important. For the patient, functional status, quality of life and perceptions of the non-technical aspects of care are also important. For example risk stratification scoring systems in general can predict the percentage of predicted mortality for the average patient in a group of patients but are unable to predict the probability for mortality with respect to the individual patient. Nevertheless, the Euro-score is, at least in Europe, the best available tool to help us select low-risk surgery patients.

Of course, intraoperative- and postoperative factors which make fast-tracking not feasible cannot be predicted and only become apparent during the perioperative course [58-60]. Intraoperative factors include the quality of the grafts, the bypass time, the amount of blood transfusion, and the use of inotropic agents. Postoperative risk factors include respiratory problems, ongoing mediastinal blood loss, ischaemia, and rhythm disturbances [61-63]. These problems with patient selection in the clinical setting are usually bypassed by managing all pre-operatively eligible patients in the operating room with a fast-track anaesthetic technique. Upon arrival in ICU, it is then decided, according to the intraoperative course, whether or not to proceed with a short-stay ICU protocol. This strategy requires optimal communication between the intraoperative medical team and the postoperative ICU team.

Another problem with patient selection is the growing number of elderly patients with a significant number of co-morbidities. At the beginning of this century, several reports showed that the trend in coronary surgery over time had been towards
operating upon older patients with more co-morbidities and increased predicted operative risk. Paone and colleagues, in a retrospective study comparing patients older than 70 years with younger patients using a five-day postoperative pathway, found a mortality rate of 5.5 % versus 1.0 % and a length of hospital stay of 7.9 versus 6.4 days in the older group compared with the younger group [64]. Cheng and co-workers found in their study that being over 70 years of age was associated with a longer time to extubation and ICU discharge and length of hospital stay [65]. It appears logical that for older and sicker patients, perioperative care should be modified according to the specific needs of this patient population.

The literature on fast-tracking cardiac surgical programmes mainly investigated selected low-risk patient populations. Studies addressing the same issues in high-risk groups are rare. Alhan and co-workers found in a high-risk group of patients a significant later extubation time, a prolonged ICU length-of-stay, increased pulmonary and renal complications, increased red blood cell transfusion, higher ICU re-admission rate and increased mortality [66]. However, it is generally accepted that elderly and sicker patients are also better off with rapid extubation, with a shorter ICU stay and early mobilization. There is clearly a trend towards fast-tracking the higher-risk population and this is considered safe and efficient [67].

The postoperative intensive care unit

The advent of fast-track cardiac anaesthesia and short-stay intensive care after cardiac surgery also started the discussion whether or not these patients should be treated in a conventional ICU setting. Can adequate and safe postoperative care be given to these patients in “special care units” such as a dedicated Cardiac Care or a Recovery or PACU?

If a hospital has a highly-equipped special care unit with competent and qualified ICU doctors on the unit, an adequate nurse-patient ratio and immediate access to ICU and OR facilities, then special care may be feasible. Several institutions have reported safe and adequate care in these special units [68,69]. However, in the early postoperative phase the clinical condition of the patient may deteriorate extremely rapidly. Therefore, continuous adequate monitoring and maximum acute treatment or intervention should always be readily available to these patients in the early postoperative period. We believe that currently in most hospitals, the ICU setting is the safest and best place to recover from cardiac surgery. Discharge to a step-down unit as soon as possible after extubation and stabilization of vital parameters should be strived for after every single patient.

Cost-effectiveness

Several studies have shown that FTCA and SSIC are cost-effective concerning resource utilization, use of medication, use of laboratory facilities, number of medical investigations, staffing including nurse-to-patient ratio, and length-of-stay in ICU and hospital [32,48,65,70]. Comparison of costs between hospitals is difficult, especially between different countries, as calculation of costs and reimbursement systems differ significantly. Also, the shifting of medical costs from in-hospital to the post-hospital settings has not been studied thoroughly [71].

Teamwork

The success of FTCA and SSIC mainly depends on teamwork. The organization and orchestration of a clinical pathway in a hospital is not easy and also needs the active support of the non-medical management of a hospital. Cardiovascular surgery involves many different medical disciplines with their own medical specialty and autonomy who are not used to working as a team; cardiac surgeons, cardiologists, perfusionists, anaesthesiologists, intensivists, physical therapists, nutritionists and ICU- and ward nurses. The individual medical specialties should facilitate standardizing a number of aspects of the medical care process into a common clinical pathway protocol for the selected patient population [72]. In order for the programme to become successful and remain so, a continuous quality improvement team should be instituted to continuously motivate all health workers involved and to give the medical - and nursing staff ongoing information, feedback and education. There is a special and pivotal role for the cardiac anaesthesiologist since he/she is the doctor involved in the pre-, per- and postoperative care process of these patients [73].

Failed early ICU discharge

In a prospective controlled randomized clinical trial (n=404) on FTCA, Reyes and colleagues, reported a success rate of 60% of patients successfully extubated within 7-11 hours after surgery [39]. Early extubation failure was caused by: residual anaesthesia 44%, haemodynamic instability 33%, and hypoxaemia 13%. Cheng and co-workers were able to extubate 85 % of their patients successfully within 1 to 6 hours after surgery [38]. Reasons for extubation failure given in this study were: resternotomy for bleeding, IABP or low cardiac output syndrome, inadequate arterial blood gas, reintubation for pulmonary problems, CVA and death. In a retrospective cohort study (n=698) by Lee and co-investigators, the success rate of early extubation was 59% in a group of patients younger than 70 years of age and 48% in a group of patients older than 70 years of age [42]. In a recent study by Ender and colleagues, comparing their fast-track programme (n=421) with a matched historic control group (n=421), reported a percentage of successfully discharged patients from the PACU to the intermediate care of 86% [69]. Sixty-one fast-track (14%) had to be transferred from the PACU to the ICU for several reasons: 25 patients for logistical reasons concerning the availability of beds, 11 patients required non-invasive ventilation, 13 patients had problems with oxygenation, 2 patients had focal neurological problems, 6 patients had a decreased level of consciousness, 3 patients showed haemodynamic instability, and one patient had ongoing postoperative blood loss.

In the literature, intensive care re-admission rates after successful initial rapid discharge vary from 0.34 % to 14 % [66, 69, 74]. At our institution, in a prospective randomized clinical trial we compared safety and cost-effectiveness in 600 patients
undergoing either short-stay intensive care (8 hours intensive care treatment) or control treatment (care as usual, ‘overnight’ intensive-care treatment) after coronary artery bypass surgery [75]. A TIVA anaesthetic protocol of propofol and a short-acting opioid was used. The primary outcome measures were intensive care re-admissions and total hospital stay. The secondary outcome measures were total hospital costs, quality of life, postoperative morbidity, and mortality. Of the 300 patients selected for the SSIC program, 163 patients (54%) were successfully discharged to a step-down level within 8 hours after arrival in the ICU. The discharge criteria are shown below in the table. The difference in intensive care re-admission between the two groups was very small and not significantly different (short-stay group 2.68% versus control group 1.34%). The total hospital stay, short-stay group mean 8.5, median 6.7 days versus control group mean 8.1, median 6.7 days was comparable in the two groups. Postoperative morbidity and mortality were comparable in the two groups for the parameters investigated; re-exploration for bleeding, re-exploration for occlusion of graft, tamponade, postoperative myocardial infarction, atrial arrhythmias, pleural/pericardial effusion, superficial sternal wound infection, deep sternal wound infection, other infections, stroke, increased creatinine, dialysis and 30-day mortality. In the SSIC groups, quality of life improved more than in the control groups. Total hospital costs for SSIC were significantly lower than those for the control group, with a mean difference of 816 Euro (95% CI – 1.581 to –174 Euro).

ICU discharge criteria

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<tr>
<th>Pulmonary</th>
<th>Extubation &gt; 30 minutes</th>
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<tr>
<td></td>
<td>Oxygen &lt; 5 L min⁻¹ nasally</td>
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<td></td>
<td>Respiratory rate &gt; 10 min and &lt; 25 min</td>
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<td></td>
<td>PaO₂ &gt; 9 kPa and PCO₂ &lt; 6.5 kPa</td>
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<tr>
<td>Cardiac</td>
<td>No myocardial ischaemia or ongoing infarction</td>
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<td>No haemodynamically significant dysrhythmia</td>
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<td>Fluid balance</td>
<td>Chest tube drainage &lt; 100 mL hr⁻¹</td>
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<td></td>
<td>Diuresis &gt; 0.5 mL kg⁻¹ hr⁻¹</td>
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<tr>
<td>Neurological</td>
<td>No signs/symptoms of major neurological complications</td>
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<td>Haemodynamic</td>
<td>No IV vasoactive drugs</td>
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<td>except dopamine 2 and/or nitroglycerine 0.5 μg kg⁻¹ min⁻¹</td>
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<td>No IABP</td>
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<td>Cardiac Index &gt; 2 L min⁻¹ m⁻²</td>
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Reasons for failed early discharge from ICU

Reasons for failed early discharge from the ICU in 137 patients were analyzed retrospectively and in depth by a team of independent specialists (cardiac anaesthesiologist, cardiac intensivist, cardiac surgeon, ICU nurse) [76]. As shown below, due to intraoperative and/or postoperative problems, no weaning was initiated in 39% of these patients as they were no longer considered to be suitable for fast-tracking. In 14% of the patients, patients could not be discharged early because of logistical problems. In 47% of the patients weaning from the ventilator was initiated in time but rapid weaning failed.

<table>
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<th>I. No weaning initiated (39%)</th>
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<tr>
<td>1. Cardiovascular ischaemia</td>
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<td>low cardiac output</td>
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<td>hypertension</td>
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<td>hypotension</td>
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<td>major dysrhythmia</td>
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<th>II. Logistics (14%)</th>
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<td>18 patients</td>
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<th>III. Failed rapid weaning (47%)</th>
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<tr>
<td>1. Pulmonary factors</td>
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<td>2. Decreased arousal</td>
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<td>3. Restless agitation</td>
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It was concluded by the investigators that in the failed rapid weaning group (47% of the failed patients), several patients were kept too long on ICU due to unintended protocol violations: 4 in the ischaemic group, 3 in the hypertension group, 2 in the hypotension group, 5 in the bleeding group, and 10 in the pulmonary factors group. In summary, taking into account these unintended protocol violations, the number of successful discharges would increase from 163 patients (54%) to 201 patients (67%). This reported failure rate should be seen in the light of a strict research protocol and it seems appropriate to assume that a CPP allowing for more clinical judgement by the clinician can reduce the failure rate even more.

The authors concluded that FTCA and SSIC is a safe and cost-effective approach and that SSIC can be considered as an alternative to conventional postoperative intensive care treatment for low-risk coronary artery bypass graft patients. Other benefits include improved patient comfort, earlier mobilization, and more efficient resource utilization.

Conclusions

Fast track cardiac anaesthesia and short-stay Intensive Care after cardiac surgery are here to stay and are safe with regard to postoperative morbidity and mortality. Fast tracking and SSIC programs reduce costs and improve resource utilization.

Every hospital performing cardiac surgery should develop a clinical pathway protocol for the routine cardiac surgical patient. This multidisciplinary protocol should define the best clinical practice for these patients, based on the principles of evidence-based medicine and taking into account economic aspects. The medical care according to the CPP should include early postoperative extubation, rapid discharge within 8 hours from ICU to a step-down unit and early hospital discharge.
References


