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Mixed venous oxygen saturation predicts short and long-term outcome after CABG surgery

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SUMMARY

Background: Complications to inadequate haemodynamic state is a leading cause of morbidity and mortality after cardiac surgery. Unfortunately commonly used methods to assess haemodynamic state are not well documented with regard to outcome. The aim of this study was to investigate SvO₂ as a prognostic marker for short and long-term outcome in a large unselected CABG cohort and in subgroups with or without treatment for intraoperative heart failure.

Methods: 2755 consecutive CABG patients and subgroups consisting of 344 patients with and 2411 patients without history of intraoperative heart failure respectively were investigated. SvO₂ was routinely measured on admission to the intensive care unit (ICU). Follow-up averaged 10.2±1.5 years.

Results: The best cut off for 30-day mortality related to heart failure based on ROC analysis was SvO₂ 60.1%. Patients with SvO₂ <60% had higher 30-day mortality (5.4% v 1.0%; p<0.0001) and lower 5-year survival (81.4% v 90.5%;p<0.0001). Incidence of perioperative myocardial infarction, renal failure and stroke was also significantly higher rendering longer ICU-stay. Similar prognostic information was obtained in the subgroups that were admitted to ICU with or without treatment for intraoperative heart failure. In patients admitted to ICU without treatment for intraoperative heart failure and SvO₂ ≥60% 30-day mortality was 0.5% and 5-year survival 92.1%.

Conclusion: Measurement of SvO₂ on admission to ICU estimates a haemodynamic state that is predictive of short and long-term outcome after CABG regardless if the patients are admitted to ICU with or without treatment for intraoperative heart failure.

Key words: Assessment, patient outcomes; coronary artery bypass; patient monitoring; postoperative complications; survival

Complications to postoperative heart failure is the leading cause for adverse outcome after cardiac surgery^{1,2}. Adequate monitoring of haemodynamic state is therefore essential in this setting.

Unfortunately commonly used methods to assess haemodynamic state are not well documented with regard to outcome^{3,4}. Uncertainty regarding how to use haemodynamic data obtained for decision-making could partially explain reports of worse outcome or lack of benefit associated with the use of pulmonary artery catheters in critically ill patients and in cardiac surgery^{5,6}.

Heart failure, in physiological terms, reflects a cardiac output insufficient to meet the systemic requirements⁷. Evidences of such mismatch between supply and demand are low mixed venous oxygen saturation (SvO₂) and inadequate organ function. In a small CABG cohort it has previously been demonstrated that SvO₂ correlates with short-term outcome⁸. These patients were managed according to a metabolic strategy implying that inotropic drugs to a large extent were replaced by metabolic support^{8,9}. Due to the highly selected cohort it can be argued that the results were not representative for CABG surgery in general. Furthermore that the additional value of SvO₂ measurements remains obscure given that many patients admitted to ICU already have treatment for known intraoperative heart failure.

In the light of this we wanted to test the hypothesis that SvO₂ has predictive value in an unselected cohort of CABG patients with regard to short-term outcome. Furthermore, we wanted to study the predictive value of SvO₂ in patients admitted to ICU with or without intraoperative treatment for heart failure. As postoperative complications remain an important determinant of long-term outcome we also wanted to study SvO₂ with regard to long-term survival.

MATERIAL AND METHODS

Patients

The University Hospital in Linköping is the only referral center in the southeast region of Sweden, serving a population of approximately one million. All patients at this department undergoing isolated CABG between 1995 and 2000 were included in the study. During this period a total of 2774 patients were operated with isolated CABG. In this cohort data on SvO₂ was lacking in 19 patients leaving 2755 patients to be followed in the study. Furthermore, these patients were divided into two subgroups of patients who did (n=344) or did not (n=2411) get treatment for heart failure intraoperatively before admission to ICU.

The study was performed according to the principles of the Helsinki Declaration of Human Rights and approved by the ethics committee for medical research at the Faculty of Health Sciences University Hospital of Linköping. Owing to the nature of the study, the ethics committee waived the need for written informed consent (2003-12-16; Dnr 03-596).

Demographic and periprocedural data were registered prospectively in a computerised database. All fields were defined in a data dictionary.

Cause of mortality within 30 days was analysed specifically from each patient chart and in most cases supported by autopsy. Cause of death was categorised in to death related to heart failure and other causes of death. Data on late mortality was retrieved from the Swedish Civil Registry. Eight patients emigrated during follow-up, four of them within five years of surgery. Average follow-up was 10.2 ± 1.5 years (range 0.9-12.7).

Clinical management

After an overnight's fast, and administration of their betablockers the patients were premedicated with 4-10 mg oxicone and 0.2- 0.5 mg scopolamine i.m. Anaesthesia was induced with thiopentone 1-2 mg/kg body weight and fentanyl 5-10 ug/kg body weight. Pancuronium bromide or rocuronium bromide were used for neuromuscular blockade. Anaesthesia was maintained with intermittent doses of fentanyl and isoflurane.

The patients underwent surgery using standard techniques with cardiopulmonary bypass (CPB) and aortic cross clamping using cold crystalloid cardioplegia¹⁰. SvO₂ was monitored on the venous line of the CPB circuit during and on weaning from CPB. Before weaning from CPB, an epidural catheter cut 5 cm from its tip (Perifix-Katheter, B.Braun Melsungen AG, Germany) was introduced by the surgeon through the outflow tract of the right ventricle 15 cm into the pulmonary artery for monitoring of pulmonary artery pressure and intermittent blood sampling. An epidural needle was used for puncture of the right ventricular wall and the abdominal wall. A 4-0 prolene purse string suture was gently tightened around the puncture site at the right ventricular outflow tract to minimize risk for bleeding at withdrawal, which usually was done the next morning before the withdrawal of the chest tubes.

From this catheter blood samples were drawn for measurement of SvO₂ after weaning from CPB, on admission to ICU, the first postoperative morning and whenever other clinical variables raised questions about haemodynamic adequacy. Only SvO₂ measurements obtained on admission to ICU were routinely recorded in the computerised institutional database.

Based on previous experience it was our practice to repeat sampling for SvO₂ in the ICU not only in patients with low SvO₂ but also in patients with a negative trend and whenever other clinical variables raised questions about haemodynamic adequacy. If benign causes such as hypovolaemia and shivering could be excluded more serious conditions such as tamponade or myocardial pump failure were considered. In this respect SvO₂ was used to identify patients that might benefit from echocardiography in the ICU and more meticulous haemodynamic monitoring. Swan-Ganz catheters were employed in 7.9% of the patients and mainly selected for patients with pronounced circulatory problems in need of pharmacological support.

Definitions

Definitions for variables presented in table 1 are given in the on-line Appendix.

Statistics

Receiver-operating-characteristics (ROC) analysis was carried out to calculate the area under the curve (AUC) and to evaluate prognostic performance of SvO₂ with regard to all-cause mortality and mortality related to cardiac failure. Chi-square test or Fisher's exact test was used when appropriate for comparison of dichotomous variables. Students t-test or Mann-Whitney U test was used when appropriate for comparison of continuous variables. Kaplan-Meier estimator and the log-rank test were used for assessment of long-term survival. As the analyses were exploratory no formal adjustment was made for multiple testing, however, a more conservative p-value of <0.01 was required for statistical significance. Results are given as percentages or mean \pm standard deviation. Statistical analyses were performed with Statistica 8.0, StatSoft Inc.,Tulsa, OK and SPSS 17.0 (SPSS Inc.).

RESULTS

Demographics

The mean age in the whole unselected cohort was 65 ± 9 years and 22% were females. Average Higgins score¹¹ was 2.3 ± 2.5 . Overall 30 day mortality was 1.9% and 5 year survival 88.9 %. SvO₂ on arrival to ICU averaged $66.3 \pm 7.0\%$. The distribution of SvO₂ values are given in 5% intervals in the online-Appendix (figure 4), with the majority in the range between 60-75%. Figure 1 displays 30-day mortality related to these SvO₂ intervals.

There were no complications recorded that were related to catheterisation of the pulmonary artery.

The best cut off for 30-day mortality related to heart failure based on ROC analysis was SvO₂ 60.1% with an area under the curve of 0.74, sensitivity 59.3% and specificity of 82.4% (figure 2). The negative predictive value was 99.5%.

Based on the ROC-analysis the patients were divided into two groups with higher ($\geq 60\%$) and lower ($< 60\%$) SvO₂. 2309 patients (84%) had SvO₂ $\geq 60\%$ and 446 patients (16%) had SvO₂ $< 60\%$.

Patients with $SvO_2 < 60\%$ had significantly higher Higgins score, higher age, higher proportion of female gender, diabetes, hypertension, recent myocardial infarction and poor left ventricular function (Table 1).

Short-term outcome

30-day mortality was 1.0% (n=24) in patients with $SvO_2 \geq 60\%$ and 5.4% (n=24) in patients with $SvO_2 < 60\%$ ($p < 0.0001$) yielding a relative risk of 5.2 (95% Confidence Interval 3.0-9.0) for the patients with $SvO_2 < 60\%$ compared to those with $SvO_2 \geq 60\%$ ($p < 0.0001$).

30-day mortality related to heart failure was 0.6% (n=13) in patients with $SvO_2 \geq 60\%$ and 3.1% (n=14) in patients with $SvO_2 < 60\%$ ($p < 0.0001$) yielding a relative risk of 5.6 (95% Confidence Interval 2.6-11.8) for the patients with $SvO_2 < 60\%$ compared to those with $SvO_2 \geq 60\%$ ($p < 0.0001$).

Postoperative morbidity was also significantly higher in patients with $SvO_2 < 60\%$ including higher incidence of perioperative myocardial infarction, renal failure, stroke and reoperation for bleeding. ICU stay and ventilator treatment was prolonged in patients with $SvO_2 < 60\%$. Patients with $SvO_2 < 60\%$ received inotropic drugs more frequently both intraoperatively and in the ICU.

Long-term follow up

5-year survival was 90.5% ($SvO_2 \geq 60\%$) and 81.4% ($SvO_2 < 60\%$) respectively ($p < 0.0001$).

Survival up to 12 years related to different levels of SvO_2 according to Kaplan-Meier is presented in figure 3.

SUBGROUP ANALYSES

PATIENTS WITHOUT INTRAOPERATIVE TREATMENT FOR HEART FAILURE

From the total cohort of 2755 patients, 2411 were admitted to ICU without treatment for heart failure intraoperatively. In this subgroup mean age was 65 ± 9.4 years and 21% were females. SvO_2 on

arrival to ICU averaged $66.5 \pm 6.8\%$. Average Higgins score was 1.9 ± 2.1 . Overall 30-day mortality was 0.9% and 5-year survival 91.0%.

2049 patients (85%) had $\text{SvO}_2 \geq 60\%$ and 362 patients (15%) had $\text{SvO}_2 < 60\%$. Patients with $\text{SvO}_2 < 60\%$ had significantly higher Higgins score, higher age, higher proportion of female gender, diabetes, hypertension, recent myocardial infarction and poor left ventricular function (Appendix, Table2).

Short-term outcome

30-day mortality was 0.5% (n=10) in patients with $\text{SvO}_2 \geq 60\%$ and 3.2% (n=12) in patients with $\text{SvO}_2 < 60\%$ ($p < 0.0001$) yielding a relative risk of 6.8 (95% Confidence Interval 3.0-15.6) for the patients with $\text{SvO}_2 < 60\%$ compared to those with $\text{SvO}_2 \geq 60\%$ ($p < 0.0001$).

30-day mortality related to heart failure was 0.1% (n=3) in patients with $\text{SvO}_2 \geq 60\%$ and 1.4% (n=5) in patients with $\text{SvO}_2 < 60\%$ ($p = 0.0002$) yielding a relative risk of 9.5 (95% Confidence Interval 2.3-39.4) for the patients with $\text{SvO}_2 < 60\%$ compared to those with $\text{SvO}_2 \geq 60\%$ ($p = 0.002$).

30-day mortality related to SvO_2 interval is given in figure 5 (Appendix).

Postoperative morbidity was also significantly higher in patients with $\text{SvO}_2 < 60\%$ including higher incidence of perioperative myocardial infarction, renal failure, and reoperation for bleeding. ICU stay and ventilator treatment was prolonged in patients with $\text{SvO}_2 < 60\%$ (Appendix, Table2).

Long-term follow up

5-year survival was 92.1% ($\text{SvO}_2 \geq 60\%$) and 84.5% ($\text{SvO}_2 < 60\%$) respectively ($p < 0.0001$).

PATIENTS WITH INTRAOPERATIVE TREATMENT FOR HEART FAILURE

From the total cohort of 2755 patients, 344 patients were admitted to ICU with treatment for heart failure intraoperatively. These patients were treated with either inotropic support, glucose-insulin potassium (GIK) or both. In this subgroup mean age was 67 ± 9 years and 28% were females. SvO₂ on arrival to ICU averaged $64.9 \pm 8.3\%$. Average Higgins score was 4.7 ± 3.5 . Overall 30-day mortality was 7.6% (n=26) yielding a relative risk of 8.3 (95% Confidence Interval 4.7-14.4) for these patients compared to those admitted to ICU without intraoperative treatment for heart failure (p<0.0001). Five-year survival was 74.1%.

260 patients (76%) had SvO₂ $\geq 60\%$ and 84 patients (24%) had SvO₂ < 60%. Preoperative characteristics are given in the Appendix (Table 3).

Short term outcome

30-day mortality was 5.4% (n=14) in patients with SvO₂ $\geq 60\%$ and 14.3% (n=12) in patients with SvO₂ <60% (p=0.007) yielding a relative risk of 2.7 (95% Confidence Interval 1.3-5.5) for the patients with SvO₂ < 60% compared to those with SvO₂ $\geq 60\%$ (p=0.009).

30-day mortality related to heart failure was 3.8% (n=10) in patients with SvO₂ $\geq 60\%$ and 10.7% (n=9) in patients with SvO₂ <60% (p=0.02) yielding a relative risk of 2.8 (95% Confidence Interval 1.2-6.6) for the patients with SvO₂ < 60% compared to those with SvO₂ $\geq 60\%$ (p=0.02).

30-day mortality related to SvO₂ interval is presented in the Appendix (figure 5).

Postoperative morbidity was also significantly higher in patients with $SvO_2 < 60\%$ with a higher incidence of perioperative myocardial infarction and stroke. ICU stay and ventilator treatment was prolonged in patients with $SvO_2 < 60\%$.

Long-term follow up

5-year survival was 77.7% ($SvO_2 \geq 60\%$) and 63.1% ($SvO_2 < 60\%$) respectively ($p=0.008$).

DISCUSSION

The major finding of this study was that SvO_2 on admission to ICU in a large unselected cohort of CABG patients estimated a haemodynamic state that predicted short-term and long-term outcome.

In cardiac surgery early postoperatively the heart is in a vulnerable state recovering from ischaemia. Inotropic agents should be used judiciously particularly after CABG since these drugs can aggravate the consequences of ischaemia and it has been demonstrated that ischaemia and evolving myocardial infarction account for a large proportion of patients with postoperative heart failure^{4, 10, 12, 13}. In this situation a goal orientated strategy of SvO_2 levels might lead to an overuse of inotropic support and increased workload, which could be harmful to the heart. On the other hand a more conservative approach with acceptance of lower SvO_2 might lead to inadequate systemic perfusion jeopardizing perfusion of vital organs. Based on this reasoning it would be desirable with appropriate guidelines to assess the adequacy of circulation in individual patients. In the absence of studies providing generally accepted criteria for institution of inotropic treatment, observational data such as ours may provide some guidance. The high negative predictive value found in our study suggests that it may be reasonably safe to withhold inotropic treatment if SvO_2 exceeds 60% if other clinical, haemodynamic, and laboratory data do not suggest otherwise.

Although used for assessment of haemodynamic state and even for goal directed therapy there is little data in the literature regarding adequate SvO_2 values during the first postoperative hours after cardiac

surgery¹⁴. In a highly selected small cohort of patients treated according to a metabolic strategy markedly increased morbidity and mortality was reported if patients were admitted to ICU after CABG with SvO₂ below 55%⁸. In a relatively small cohort of patients undergoing surgery for aortic stenosis ROC analysis suggested a cut off SvO₂ of 53.7%¹⁵. The present study is considerably larger and includes all patients undergoing CABG in south east Sweden during a five-year period. Basically our results confirm the previous observations but suggest that the level of SvO₂ that should lead to increased attention after CABG is approximately 60% rather than 55%.

Outcome after cardiac surgery is to a large extent determined by the preoperative status of the patient. However, the outcome is also influenced by events during surgery and anaesthesia and the patient's prognosis at arrival to ICU may differ markedly from the preoperative evaluation. Early reevaluation on admission to ICU is desirable for a proactive management plan, identification of patients that may benefit from further diagnostic and therapeutic measures, estimation of the need for ICU resources and for better prediction of the prognosis for individual patients¹⁶. Our results suggest that SvO₂ data can be used not only to identify patients in need of more meticulous surveillance but also those that can be passed on according to fast track protocols. With the simple and inexpensive method to measure SvO₂ employed in our practice SvO₂ data can be safely obtained in virtually all patients despite a restrictive use of Swan-Ganz catheters. It remains to be documented if information of similar value can be obtained by sampling from central venous catheters^{17, 18}.

It can be argued that in most patients a poor haemodynamic state is known on admission to ICU even without SvO₂ measurements. In this study we found that SvO₂ provided information of prognostic value even in patients admitted to ICU without known heart failure. Thus, patients with SvO₂ below 60% had significantly higher postoperative mortality and morbidity. On the other hand, if patients were admitted to ICU without intraoperative treatment for heart failure and SvO₂ \geq 60% the risk of

death within 30 days related to heart failure was 0.1%. Furthermore, these patients comprising approximately three fourths of the CABG-cohort had a 92.1% five-year survival.

In patients operated for aortic stenosis SvO₂ below 55% was associated not only with increased postoperative mortality but also markedly impaired long-term survival¹⁵. The present study confirms the long-term prognostic value of SvO₂ on admission to ICU. In addition to a significantly reduced long-term survival in the subgroup with SvO₂ below 60% we found a relationship between different levels of SvO₂ on admission to ICU and long-term survival (fig 3). This implies that SvO₂ on admission to ICU reflects the haemodynamic state adequately taking into account preoperative risk factors for heart failure, intraoperative events leading to heart failure and recovery occurring before admission to ICU.

The limitations of this study are its retrospective nature and that only SvO₂ data obtained on admission to ICU were available in our database. The latter prevented interpretations regarding therapeutic interventions to raise SvO₂. The data comes from a cohort operated more than ten years ago. On balance, this may not be negative as it provided the opportunity to study long-term outcome. Furthermore, circulation physiology remains unchanged although shifts in patient profile and clinical management have occurred.

To conclude the main finding of this study in a large unselected cohort of CABG patients is that measurement of SvO₂ on admission to ICU estimates a haemodynamic state that predicts short and long-term outcome after CABG. This was valid regardless if patients are admitted to ICU with or without treatment for intraoperative heart failure.

Declaration of interests: None of the authors have any conflicts of interest to declare.

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Table 1. Perioperative characteristics in all patients with SvO₂ ≥ 60% and SvO₂ < 60%.

Characteristics	SvO ₂ ≥ 60 % n = 2309	SvO ₂ < 60 % n = 446	p-value
Age (years)	65 ± 9	68 ± 9	< 0.0001*
Female gender	20.0 %	31.4 %	< 0.0001*
BMI kg/m ²	26.7 ± 3.7	26.9 ± 3.6	0.35
Diabetes mellitus	18.5 %	24.7 %	0.003*
Hypertension	39.3 %	46.4 %	0.005*
Preoperative CVI	6.2 %	8.3 %	0.10
COPD	5.9 %	4.1 %	0.13
NYHA class III/IV	76.4 %	80.6 %	0.06
Myocardial infarction < 1 week	4.8 %	9.4 %	0.002*
LVEF ≤ 0.30	4.4 %	10.4 %	0.0002*
Higgins Score	2.1 ± 2.4	3.2 ± 3.0	< 0.0001
Urgent surgery	45.8 %	52.5 %	0.01
Emergency surgery	4.7 %	10.6 %	< 0.0001*
Redo procedure	2.7 %	6.7%	<0.0001*
Unstable angina	46.7%	57.7 %	< 0.0001*
Aortic Cross Clamp-time (min)	43 ± 18	48 ± 20	< 0.0001*

CPB time (min)	80 ± 28	94 ± 38	< 0.0001*
Peripheral anastomoses	3.6 ± 1.2	3.8 ± 1.1	0.0008*
Left internal mammary artery	94.5 %	93.9 %	0.67
Inotropic drugs started intraoperatively	4.1 %	7.2 %	0.005*
GIK started intraoperatively	9.0 %	15.9 %	< 0.0001*
Inotropic drugs and/or GIK started intraoperatively	11.3 %	18.4 %	< 0.0001*
Inotropic drugs started in ICU	5.6 %	18.6 %	< 0.0001*
Mechanical assist (IABP/LVAD)	1.1 %	4.9 %	< 0.0001*
SvO ₂ ICU %	68.5 ± 5.0	55.0 ± 4.3	< 0.0001*
Reoperation for bleeding < 24 hours	2.5 %	5.6 %	0.0005*
Perioperative stroke	1.4 %	3.4 %	0.004*
Perioperative myocardial infarction	5.0 %	13.0 %	< 0.0001*
Renal failure	1.9 %	5.3%	< 0.0001*

Postoperative Dialysis	0.3 %	0.9 %	0.04
MOF	0.5 %	1.1 %	0.14
Time in ICU (days)	1.5 ± 2.0	2.3 ± 3.2	< 0.0001*
Time on ventilator (hours)	13 ± 40	27 ± 67	< 0.0001*
Mortality 30 days (total)	1.0 %	5.4 %	< 0.0001*
Mortality 30 days (heart failure)	0.6 %	3.1 %	< 0.0001*
5-year survival	90.5 %	81.4 %	< 0.0001*

Table 1. Perioperative characteristics in all patients with $SvO_2 \geq 60\%$ and $SvO_2 < 60\%$. BMI = body mass index. CVI = cerebrovascular injury. COPD = chronic obstructive pulmonary disease. LVEF = left ventricular ejection fraction. CPB= cardiopulmonary bypass. GIK = glucose-insulin-potassium. ICU = intensive care unit. IABP = intra-aortic balloon pump. LVAD = left ventricular assist device. MOF= multi organ failure. * Indicates statistically significant difference between groups.

FIGURE LEGENDS

Figure 1. Incidence of postoperative 30-day mortality related to different levels of SvO₂ on admission to ICU.

Figure 2. Receiver operating characteristics (ROC) to evaluate the prognostic performance of SvO₂ on admission to ICU with regard to mortality related to heart failure within 30 days of surgery. AUC = area under the curve; CI=confidence interval. The best cut off for mortality related to heart failure was SvO₂ 60.1%, with a sensitivity of 59.3% and a specificity of 82.4%. The negative predictive value was 99.5%.

Figure 3. Cumulative long-term survival according to Kaplan-Meier related to SvO₂ level on admission to ICU.

Figure 1. 30-day mortality related to SvO₂ on admission to ICU

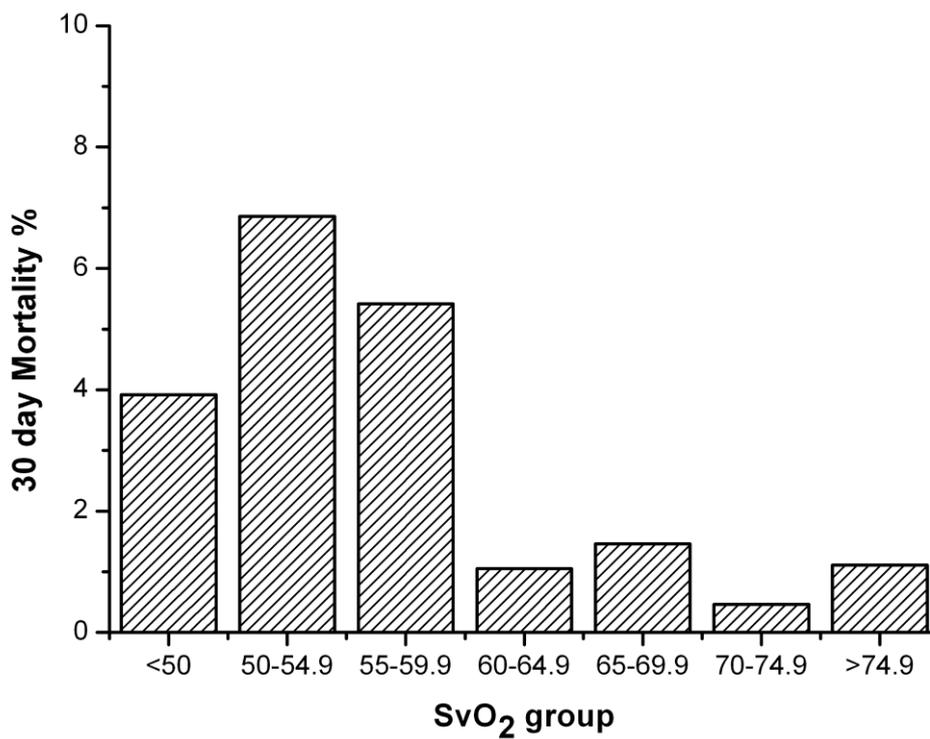


Figure 2. SVO2 and 30-day mortality related to heart failure

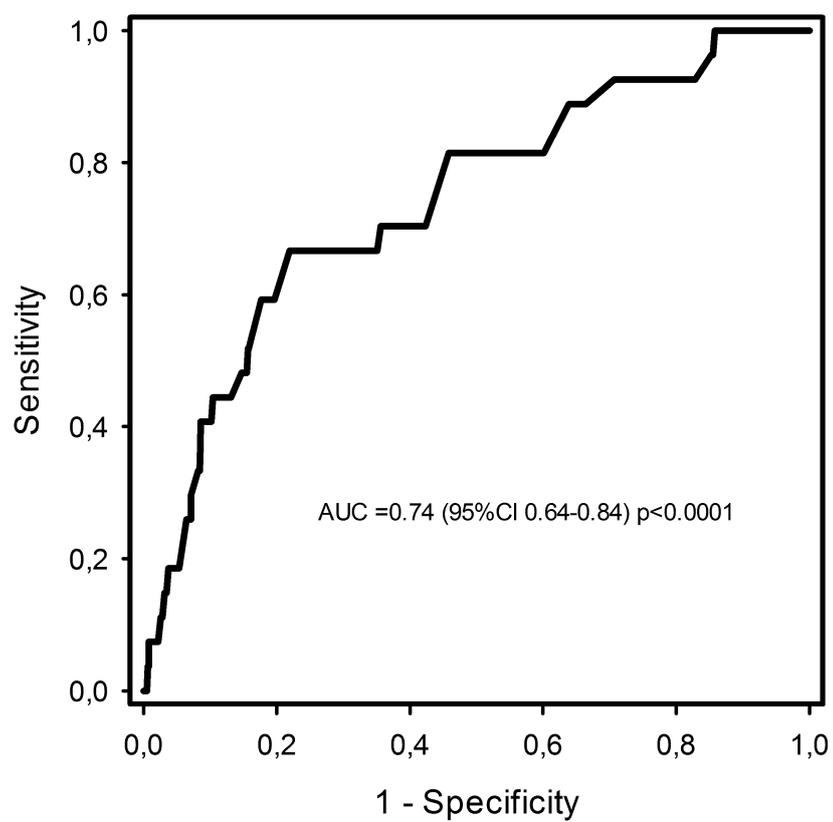
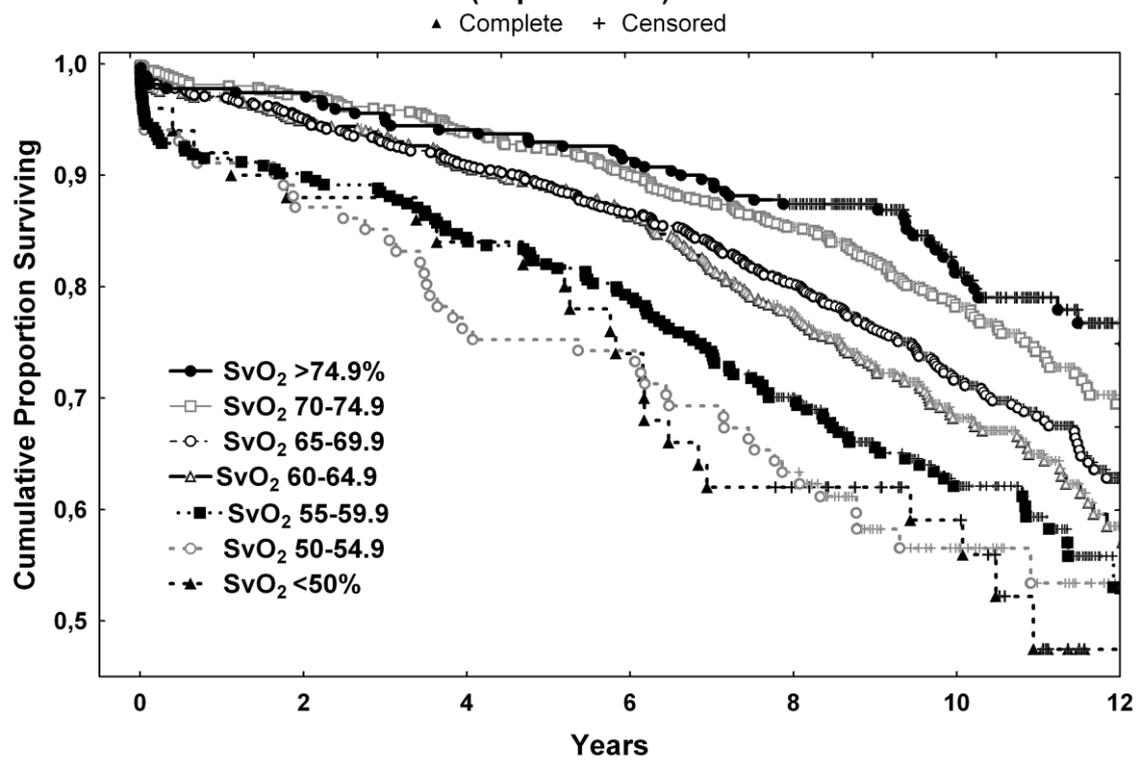


Figure 3. Cumulative Survival related to SvO₂ level
(Kaplan-Meier)



ON-LINE SUPPLEMENTARY APPENDIX

Table 2. Perioperative characteristics in patients admitted to ICU without treatment for heart failure intraoperatively divided in groups by $SvO_2 \geq 60\%$ and $SvO_2 < 60\%$.

Characteristics	$SvO_2 \geq 60\%$ n = 2049	$SvO_2 < 60\%$ n = 362	p-value
Age (years)	65 ± 9	68 ± 9	< 0.0001*
Female gender	19.1 %	31.2 %	< 0.0001*
BMI kg/m^2	26.6 ± 3.6	27.0 ± 3.7	0.49
Diabetes mellitus	17.1 %	23.8 %	0.002*
Hypertension	38.6 %	46.0 %	0.008*
Cerebral vascular insult	5.7 %	7.6 %	0.16
COPD	5.6 %	3.3 %	0.07
NYHA class III/IV	74.9 %	78.1 %	0.20
Myocardial infarction < 1 week	3.9 %	8.1 %	0.0007
LVEF ≤ 0.30	2.8 %	6.4 %	0.0099*
Higgins Score	1.8 ± 2.0	2.7 ± 2.6	< 0.0001*
Unstable angina	44.0 %	54.4 %	0.0002*
Urgent Surgery	45.2 %	52.2 %	0.01

Emergency Surgery	2.9 %	8.3 %	< 0.0001*
Redo procedure	1.8 %	4.4 %	0.002*
Aortic Cross Clamp-time (min)	42 ± 17	47 ± 17	< 0.0001*
CPB time (min)	76 ± 23	86 ± 29	< 0.0001*
Peripheral anastomoses	3.5 ± 1.2	3.8 ± 1.1	0.0006*
Left internal mammary artery	95.2 %	95.9 %	0.60
Inotropic drugs started in ICU	4.2 %	16.0 %	< 0.0001*
SvO ₂ ICU %	68.5 ± 4.9	55.3 ± 4.1	< 0.0001*
Reoperation for bleeding < 24 hours	2.3 %	5.5 %	0.0007*
Perioperative stroke	1.1 %	1.4 %	0.67
Perioperative myocardial infarction	3.6 %	7.2 %	0.001*
Postoperative renal failure	1.1 %	3.9 %	0.00005*
Postoperative Dialysis	0.1 %	0.6 %	0.049
MOF	0.2 %	0.8 %	0.08

Time in ICU (days)	1.3 ± 1.6	1.6 ± 2.3	< 0.0001*
Time on ventilator (hours)	10 ± 32	16 ± 46	< 0.0001*
Mortality 30 days (total)	0.5 %	3.3 %	< 0.0001*
Mortality 30 days (heart failure)	0.1 %	1.4 %	0.0002*
5-year survival	92.1 %	84.5 %	< 0.0001*

Table 2. Perioperative characteristics in patients admitted to ICU without treatment for heart failure intraoperatively divided in groups by $SvO_2 \geq 60\%$ and $SvO_2 < 60\%$. BMI = body mass index. CVI = cerebrovascular injury. COPD = chronic obstructive pulmonary disease. LVEF = left ventricular ejection fraction. CPB= cardiopulmonary bypass. ICU = intensive care unit. IABP = intra-aortic balloon pump. LVAD = left ventricular assist device. MOF= multi organ failure. * Indicates statistically significant difference between groups.

Table 3. Perioperative characteristics in patients admitted to ICU with treatment for heart failure intraoperatively divided in groups by $SvO_2 \geq 60\%$ and $SvO_2 < 60\%$.

Characteristics	$SvO_2 \geq 60\%$ n = 260	$SvO_2 < 60\%$ n = 84	p-value
Age (years)	67 ± 9	69 ± 8	0.02
Female gender	27.3 %	32.1 %	0.39
BMI kg/m ²	27.4 ± 4.1	26.6 ± 3.4	0.10
Diabetes mellitus	30.0 %	28.6 %	0.80
Hypertension	44.4 %	48.2 %	0.55
Preoperative CVI	10.2 %	11.4 %	0.76
COPD	7.7 %	7.2 %	0.88
NYHA class III/IV	88.0 %	91.5 %	0.38
Myocardial infarction < 1 week	11.8 %	15.0 %	0.46
LVEF ≤ 0.30	15.7 %	27.3 %	0.08
Higgins Score	4.6 ± 3.3	5.3 ± 3.9	0.12
Urgent surgery	50.8 %	53.6 %	0.66
Emergency surgery	18.5 %	20.2 %	0.72
Redo procedure	9.6 %	16.7 %	0.08
Unstable angina	67.6 %	72.0 %	0.46

Aortic Cross Clamp-time (min)	50 ± 23	55 ± 28	0.10
CPB time (min)	105 ± 42	128 ± 50	<0.0001*
Peripheral anastomoses	3.8 ± 1.3	3.8 ± 1.1	0.97
Left internal mammary artery	88.5 %	85.7 %	0.50
Inotropic drugs started intraoperatively	36.5 %	38.1 %	0.80
GIK started intraoperatively	79.4 %	84.5 %	0.32
Inotropic drugs and/or GIK started intraoperatively	100 %	100 %	
Inotropic drugs started in ICU	16.3 %	29.8 %	0.007*
Mechanical assist (IABP/LVAD)	7.7 %	16.7 %	0.02
SvO ₂ ICU %	68.6 ± 5.4	53.6 ± 4.7	< 0.0001*
Reoperation for bleeding < 24 hours	3.8 %	6.0 %	0.41
Perioperative stroke	3.8 %	11.9 %	0.006*
Perioperative myocardial	16.0 %	38.1 %	< 0.0001*

infarction

Postoperative renal failure	8.8 %	13.1 %	0.26
Postoperative Dialysis	1.5 %	2.4 %	0.61
MOF	2.7 %	2.4 %	0.87
Time in ICU (days)	3.0 ± 3.5	4.8 ± 5.0	0.00007*
Time on ventilator (hours)	37 ± 72	72 ± 110	0.00005*
Mortality 30 days (total)	5.4 %	14.3 %	0.007*
Mortality 30 days (heart failure)	3.8 %	10.7 %	0.02
5-year survival	77.7 %	63.1 %	0.008*

Table 3. Perioperative characteristics in patients admitted to ICU with treatment for heart failure with inotropic drugs and/or GIK intraoperatively divided in groups by $SvO_2 \geq 60\%$ and $SvO_2 < 60\%$. BMI = body mass index. CVI = cerebrovascular injury. COPD = chronic obstructive pulmonary disease. LVEF = left ventricular ejection fraction. CPB= cardiopulmonary bypass. GIK = glucose-insulin-potassium. ICU = intensive care unit. IABP = intra-aortic balloon pump. LVAD = left ventricular assist device. MOF= multi organ failure.

* Indicates statistically significant difference between groups.

FIGURE LEGENDS

Figure 4. Distribution of SvO₂ in the study population on admission to ICU.

Figure 5. Incidence of postoperative 30-day mortality related to different levels of SvO₂ on admission to ICU in patients with or without intraoperative treatment for heart failure.

Definitions

Emergency operation was defined as a procedure usually performed immediately but not later than 24 hours from acceptance. Urgent operations were defined as scheduled procedures within one week on patients unable to leave the hospital because of clinical condition.

Severe systolic left ventricular dysfunction corresponds to an ejection fraction ≤ 0.30 .

Patients were classified as diabetics only if they had an established diagnosis of diabetes mellitus according to medical records that could be confirmed by the patient. Registration in the database also required active treatment on admission ranging from diet to insulin.

Chronic obstructive pulmonary disease (COPD) was registered when patient had medical treatment or spirometric evaluation showing signs of COPD.

Inotropic treatment was recorded in our database if patients received a continuous infusion of inotropic agents lasting for more than 30 minutes regardless of dosage or a bolus with or without infusion of a phosphodiesterase inhibitor.

Complications presented refer to in-hospital events occurring at our institution. Perioperative myocardial infarction was diagnosed by biochemical markers of myocardial injury or by findings at

autopsy¹. Aspartate aminotransferase (ASAT) > 3.0 μ kat/L with alanine aminotransferase less than half of ASAT, supported by Creatinine Kinase-MB > 70 μ g/L on the first postoperative morning or by a sustained elevation of troponin-T > 2.0 μ g/L on the 4th postoperative day was considered diagnostic for myocardial infarction.

Reoperation for bleeding was defined by the indication for reoperation, regardless of the amount of blood lost in chest tubes. The decision to re-explore was at the discretion of the individual surgeon.

Postoperative renal failure was defined as plasma creatinine exceeding 170 μ mol/l regardless of preoperative value. Postoperative dialysis refers to need of dialysis that was not present preoperatively.

Stroke was defined as focal neurological deficit persisting for more than 24 hours or depression of consciousness or confusion if associated with signs of cerebral injury on CT-scan. The majority of patients with suspected neurological injury were examined by a neurologist and by CT-scan. Cognitive dysfunction was not assessed.

Multiorgan failure was defined as failure of three or more vital organs.

Cause of death related to heart failure was defined as death caused by heart failure or complications initiated by heart failure.

Higgins score

Higgins score was developed at Cleveland Clinic and published in 1992¹. It was based on a retrospective analysis of preoperative risk factors in 5051 patients who underwent CABG followed by a prospective validation in 4069 patients undergoing CABG at Cleveland Clinic.

Emergency procedure*	6
Age >64 but <75	1
Age >74 (years)	2

Redo-procedure	3	
Severe LV-dysfunction	3	LVEF < 0.35
Mitral regurgitation	3	MR requiring surgery
Aortic stenosis	1	AS requiring surgery
Previous vascular surgery	2	
Cerebrovascular disease	1	TIA or Stroke
COPD	2	COPD requiring treatment
Diabetes	1	Diabetes requiring oral drugs or insulin
Anaemia	2	Hb ≤ 110 g/L
S-Creatinine >140 but < 168	1	
S-Creatinine > 167 (µmol/L)	4	
Body weight ≤ 65 kg	1	

* Patient admitted to operating room directly from ICU, coronary care unit or cath lab because of unstable angina or unstable haemodynamic state despite pharmacological or mechanical circulatory support.

1. Higgins TL, Estafanous FG, Loop FD, et al. ICU admission score for predicting morbidity and mortality risk after coronary artery bypass grafting. *Ann Thorac Surg* 1997; **64**:1050-8.

1. Vanky F, Hakanson E, Maros T, Svedjeholm R. Different characteristics of postoperative heart failure after surgery for aortic stenosis and coronary disease. *Scand Cardiovasc J* 2004; **38**:152-8

Figure 4.

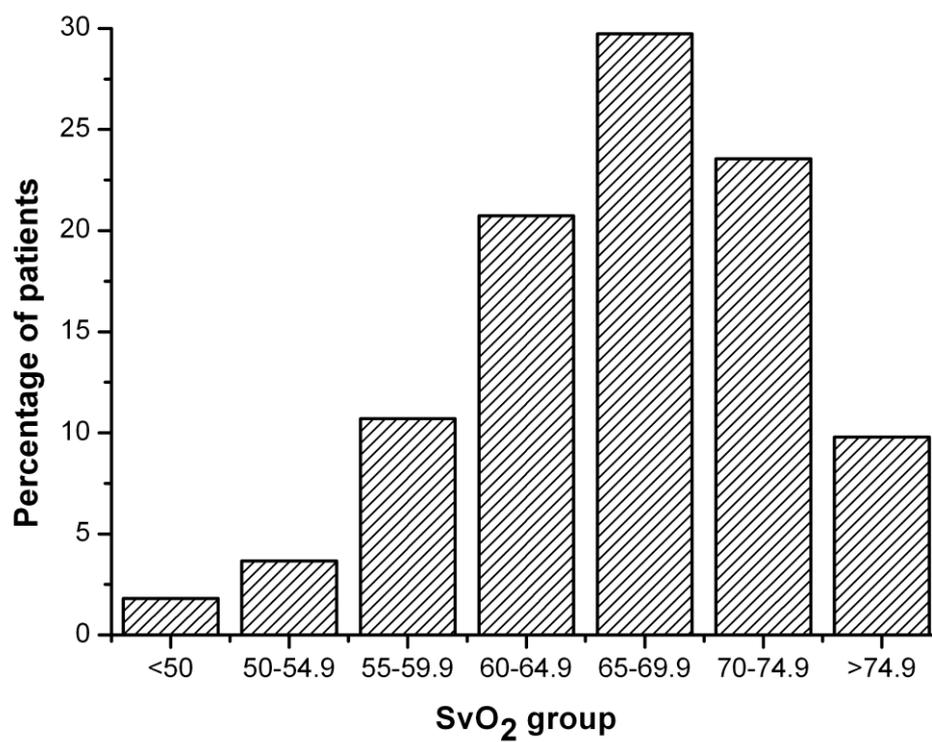


Figure 5.

