Cerebral oxygen saturation monitoring in on-pump cardiac surgery – A 1 year experience

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Abstract

Objective: To determine the usefulness of cerebral oxygen saturation monitoring in a heterogeneous population of patients undergoing on-pump cardiac surgery and the relationship between minimal perioperative cerebral oxygen saturation (rSO2) levels and clinically relevant outcome parameters.
Setting: Cardiac anesthesia unit of a University Hospital
Design: Retrospective analysis
Participants: n=274 patients monitored bi-hemispherically with an INVOS 5100 cerebral oxymeter and n=526 matched patients without cerebral oxygenation monitoring. The decision to monitor a patient was based on individual co-morbidities associated with an increased risk of stroke (cerebral and/or peripheral artery disease, history of stroke) at the discretion of the attending anesthetist.
Interventions: None prespecified.
Measurements and main results: In a first analysis, all patients that had been monitored by cerebral oximetry in 2006 were determined by analysis of the anesthesia charts and the institutional cardiac surgery database and compared with a control group matched for Euroscore, age, and type of surgery. This analysis revealed that monitored patients had more preoperative risk factors, had a longer duration of surgery, cardiopulmonary bypass and aortic crossclamp, and needed longer high dependency unit care (all $p<0.05$) than the control patients. However, major postoperative complications were not different between both groups.
In a second analytical step, monitored patients showing intraoperative minimal rSO2 levels of less than 50% or rSO2 levels greater than 50% were compared. This analysis revealed a higher incidence of postoperative organ dysfunction and hospital length of stay in patients with low rSO2 levels. However, groups were not comparable with respect to the preoperative risk profile.
To adjust for these differences, in a third analytical step, patients were stratified according to the median Euroscore. This analysis revealed, that patients with an Euroscore ≤ 8 and intraoperative rSO2 levels <50% had more postoperative organ complications and longer high dependency unit and hospital stay in comparison to patients not showing intraoperative cerebral hypoperfusion. Such effects were not detectable in patients with a Euroscore > 8.
Conclusions: These data suggests that patients with a higher risk profile for cerebral vascular accidents and renal dysfunction undergoing on-pump cardiac surgery may benefit from cerebral oxygenation monitoring and that rSO2 levels < 50% are associated with an unfavourable clinical course. However, the association between low cerebral oxygen saturation and worse outcome seems to be limited to patients with a low to moderate risk profile (Euroscore ≤ 8).

Background

Cerebral oximetry by near infrared spectroscopy has been suggested to be a non-invasive tool to detect cerebral hypoperfusion in patients undergoing cardiac surgery (1). Maintaining cerebral regional oxygen saturation (rSO2) higher than 50% has been shown to reduce postoperative neurological dysfunction and leads to improved clinical outcomes in patients undergoing isolated coronary artery bypass grafting (CABG) (2).

In 2006 we adopted the technology of cerebral oximetry to our cardiac anesthesia unit and monitored an increasing number of patients with a high risk of neurological and general postoperative complications. The present study was designed to determine the usefulness of cerebral oxygen monitoring with regard to clinically relevant outcome parameters in a heterogeneous population of patients undergoing on-pump cardiac surgery in comparison with a control group of patients not being monitored and if perioperative rSO2 levels below 50% are associated with a unfavorable clinical outcome.

Materials and methods

Following approval by the local ethical committee the anesthesia charts and the institutional cardiac surgery database for 2006 were analyzed to determine the intraoperative course of absolute rSO2 values as well as:

- *preoperative demographic and clinical data* (biometric data, left ventricular ejection fraction, Euroscore, previous cardiac surgery, peripheral artery disease, carotid artery disease, previous cerebrovascular accident, presence of chronic kidney disease, preoperative renal replacement therapy, preoperative intraaortic balloon counterpulsation, preoperative treatment with inotropes, preoperative intubation, preoperative infection, cardiopulmonary resuscitation immediately before surgery).
- *perioperative and surgical data* (duration of surgery and cardiopulmonary bypass, aortic cross-clamp time, intraoperative use of cardiac assist devices or IABP, time to extubation, ICU and hospital length of stay, transfusion of packed red cells or fresh frozen plasma).
- *postoperative morbidity* (The major postoperative complications: need for reintubation, need for renal replacement therapy, postoperative low cardiac output syndrome (LCOS) and perioperative stroke were combined to a "Major complication score (MaCS)").
- *30 and 180 day mortality*.

All patients had received general anesthesia according to our institutional standard. Induction of anesthesia was induced using etomidate and sufentanil and maintained with sufentanil and sevoflurane before and after cardiopulmonary bypass (CPB) and sufentanil with propofol during cardiopulmonary bypass (CPB). Patients were equipped with a radial arterial line and a central venous catheter. A pulmonary artery catheter for continuous determination of mixed venous oxygen saturation (SvO2) and CI was used, if appropriate. Surgical procedures were performed with CPB in moderate hypothermia using antegrade blood cardioplegia. All patients received a bolus of 500 mg of methylprednisolone before CPB and 4MU of aprotinine throughout the surgical procedure.

1421 patients underwent cardiac surgery in our institution in 2006. 330 of these patients were monitored with cerebral oximetry at the discretion of the attending anesthetist. 51 patients undergoing deep hypothermic cardiac arrest and 5 with off-pump procedures were excluded in this analysis. The results of these analyses have been presented elsewhere (3).

Analysis 1: A control group of patients that had not been subjected to rSO2 monitoring was matched by Euroscore, type of surgery and age. The intention to include as many patients as possible to the control-group was limited by the differences in type of surgery. Consequently matching resulted in n=274 monitored (MON) patients and 526 controls (CON). It is of note that the investigator performing this matching was blinded to rSO2 levels and outcome data.

The control group consisted of 320 patients receiving CABG only, 102 patients subjected to aortic or mitral valve repair or replacement, 15 patients undergoing aortic and mitral valve repair/replacement, and 89 patients treated with CABG combined with valve repair or replacement. The monitored group consisted of 164 patients undergoing CABG, 51 patients with aortic or mitral valve replacement, 7 patients with combined aortic and mitral valve repair/replacement, and 52 patients with CABG combined with aortic or mitral valve repair/replacement.

Analysis 2 and 3: With respect to significant differences in important clinical risk factors in comparison between the monitored and the control group, further

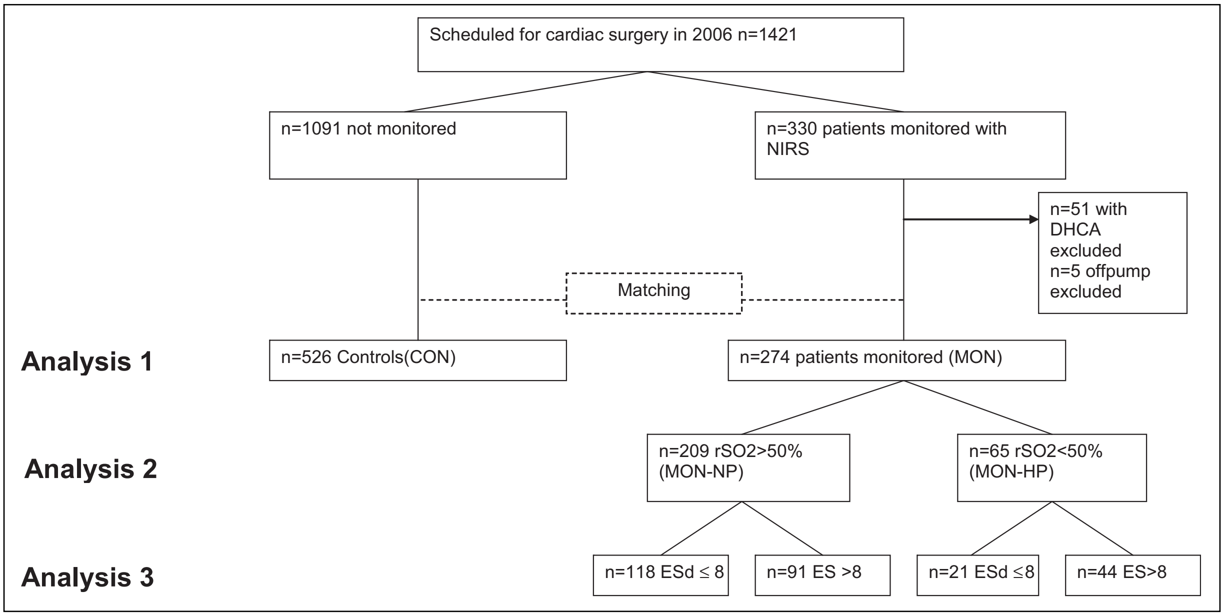

Figure 1. Flowchart demonstrating the procedure of analysis. DHCA: Deep hypothermic cardiac arrest, ES: Euroscore

analyses were performed to determine if cerebral hypoperfusion (defined as a minimal rSO2 reading < 50% absolute in baseline or during the procedure) was associated with clinically relevant outcomes. Chart analysis revealed 65 patients with rSO2 levels lower than 50% absolute and 109 patients with rSO2 levels equal or higher than 50%. On account of the differences in Euroscore in the three groups we grouped the patients according to the median Euroscore (median=8) for further analysis (see figure 1).

Statistical analyses

Normally distributed continuous data were analyzed parametrically by Student's t-test and analysis of variance (ANOVA). Not-normally distributed variables were analyzed by Fisher's exact test, Kruskal-Wallis-Test, or Mann-Whitney-U-Test, respectively. Data are given as mean ± standard deviation or as median (minimum-maximum) as appropriate. A $p < 0.05$ indicates statistical significance.

Results:

Analysis 1: Comparisons between the monitored and the control group

The groups did not differ with respect to Euroscore, age, height, and weight, but significantly more female patients were in the control group. More patients in the monitored group revealed peripheral as well as carotid artery disease and chronic kidney dysfunction. Duration of surgery, cardiopulmonary bypass and aortic crossclamp time were significantly longer in MON group compared to CON (table 1).

Analyses of postoperative outcome showed no differences in pulmonary complications (need for reintubation or prolonged ventilation), need for renal replacement therapy or stroke. There was no difference in the major complication score (MaCS). Duration of ventilation and hospital length of stay were comparable, but the need for high dependency unit care was shorter in CON (table 1).

Table 1: Analysis 1: Comparisons between the monitored and the control group

	CON **n=526**	**MON** **n=274**	**P**
Euroscore	8,38 ± 3,17	8,59 ± 3,23	ns
Age (years)	67,57 ± 10,15	68,53 ± 9,99	ns
Height (m)	1,71 ± 0,09	1,71 ± 0,08	ns
Weight (kg)	80,89 ± 15,35	80,06 ± 14,22	ns
Gender	male n=354(67,3%) female n=172(32,7%)	male n=205(74,8%) female n=69(25,2%)	,029*
Peripheral artery disease	n=75 (14,3%)	n=67 (24,5%)	,000***
Carotid artery disease	n=6 (1,1%)	n=10 (3,6%)	,029*
Diabetes	n=138 (26,2%)	n=86 (31,4%)	ns
Chronic kidney disease	n=102 (19,4%)	n=75 (27,4%)	,012*
Duration of Operation (min)	235,29 ± 64,97	257,29 ± 83,59	,000***
Bypass (min)	111,90 ± 44,99	123,20 ± 57,14	,002**
Aortic Crossclamp (min)	87,38 ± 37,93	93,54 ± 42,46	,037*
Duration of ventilation (h)	26,88 ± 66,67	32,91 ±87,85	ns
Pulmonary complications	n=58 (11,0%)	n=39 (14,2%)	ns
Need for renal replacement therapy	n= 46 (8,8%)	n=25 (9,1%)	ns
Incidence of stroke	n=13 (2,5%)	n=10 (3,6%)	ns
Duration on high dependency unit (h)	96 (24-912)	96 (24-1320)	,02*
Hospital length of stay (d)	8,98 ± 6,43	9,47 ± 8,26	ns
Postoperative major complication score	0 (0-4)	0 (0-4)	ns
30 day mortality	n=18 (3,4%)	n=13 (4,7%)	ns
180 day mortality	n=27 (5,1%)	n=19 (6,9%)	ns

Data are given as mean ± standard deviation or median and range as appropriate. Analysis is performed with Students T-Test for normally distributed data, Fisher's exact test for nominal or Mann-Whitney-U-Test for continuous, not-normally distributed data. A p<,05 indicates statistical significance. CON: Control group; MON-NP: patients monitored with bi-hemispheric near-infrared spectroscopy, minimal regional SO2 >50%; MON-HP: patients monitored with minimal regional SO2 <50%.

Analysis 2: Comparison between monitored patients showing normal perfusion (rSO2 ≥ 50%) or hypoperfusion (rSO2 < 50%)

Comparisons between patients with normal perfusion (n=109) and hypoperfusion (n=65) showed a significant difference regarding Euroscore (table 2) with a higher mean Euroscore in the rSO2 <50% group. Furthermore the groups differed in the preoperative risk factors: peripheral and carotid artery disease and chronic kidney disease. Duration of surgery, cardiopulmonary bypass, and aortic crossclamp time were significantly longer in the rSO2 <50% in comparison to both other groups.

Outcome analyses (table 2) revealed that the rSO2 <50% group had significantly longer duration of ventilation, a longer stay in the high dependency unit and a longer hospital length of stay than the patients in group with normal cerebral perfusion. Furthermore patients with cerebral hypoperfusion had more pulmonary complications (i.e. prolonged ventilation time, need for reintubation) and needed renal replacement therapy more often than the other groups, leading to a higher MaCS in the rSO2 <50% group in comparison with the rSO2 ≥ 50% group. 30 or 180 day mortality were not different between both groups.

Table 2: Analysis 2: Comparisons between patients with or without low cerebral oxygen saturation

	rSO2 ≥ 50% **n=209**	**rSO2 <50%** **n=65**	**p**
Euroscore	8,21 ± 3,15	9,85 ± 3,21	0,001
Age (years)	68,73 ± 9,82	67,86 ± 10,54	ns
Height (m)	1,71 ± ,084	1,71 ± ,078	ns
Weight (kg)	81,56 ± 14,05	75,26 ± 13,79	0,009
Gender	male n=157 female n=52	male n=48 female n=17	ns
Peripheral artery disease	n=51 (24,4%)	n=16 (24,6%)	ns
Carotid artery disease	n=6 (2,9%)	n=4(6,2%)	0,014
Diabetes	n=63 (30,1%)	n=23 (35,4%)	ns
Chronic kidney disease	n=49 (23,4%)	n=26 (40,0%)	ns
Duration of Operation (min)	231,0 (130-590)	251,0 (135-620)	ns
Bypass (min)	106,0 (41-418)	120,0 (59-417)	< 0,0001
Aortic Crossclamp (min)	91,56 ±40,39	99,91 ±48,31	ns
Duration of ventilation (h)	6 (6-792)	6 (6-576)	0,01
Pulmonary complications	n=21 (10,0%)	n=18 (27,7%)	< 0,0001
Need for renal replacement therapy	n=13 (6,2%)	n=12 (18,5%)	0,01
Incidence of stroke	n=6 (2,9%)	n=4 (6,2%)	ns
Duration on high dependency unit (h)	96 (24-1128)	144 (24-1320)	< 0,0001
Hospital length of stay (d)	7 (1-77)	10 (1-55)	< 0,0001
Postoperative major complication score	0 (0-4)	0 (0-3)	< 0,0001
30 day mortality	n=10 (4,8%)	n=3 (4,6%)	ns
180 day mortality	n=13 (6,2%)	n=6 (9,2%)	ns

Data are given as mean ± standard deviation or median and range as appropriate. Analysis was performed with unpaired Student's t-test for normally distributed data or Kruskal-Wallis-test for not-normally distributed data. A p<0,05 indicates statistical significance. rSO2 ≥ 50%: patients monitored with bi-hemispheric near-infrared spectroscopy with a minimal regional SO2 ≥ 50% absolute; rSO2 < 50%: patients with minimal regional rSO2 < 50%.

Analysis 3: Comparison between monitored patients showing normal perfusion (rSO2 ≥ 50%) or hypoperfusion (rSO2 < 50%) grouped according to Euroscore ≤ or > 8

Euroscore ≤ 8: Subgroup analysis of monitored patients with a Euroscore ≤ 8 was performed in 118 patients with normal perfusion and 21 monitored patients with hypoperfusion. More patients in the rSO2 < 50% group had chronic kidney disease. Duration of operation was significantly longer but cardiopulmonary bypass and aortic crossclamp time were comparable (table 3). Postoperatively, the hypoperfusion group had significantly more pulmonary complications, was more often treated with renal replacement therapy postoperatively, and had a higher MaCS in comparison to the normal perfusion group. Additionally, hypoperfusion patients required longer high dependency unit care treatment (figure 2) and longer hospital length of stay (table 3 and figure 3).

Euroscore > 8: Subgroup analysis of patients with a Euroscore > 8 included n=91 patients with normal perfusion and n=45 patients with hypoperfusion (table 4). The groups showed no differences in demographic data, duration of operation and cardiopulmonary bypass time and clinical outcomes with the exception of a high dependency unit care in the hypoperfusion group (table 4).

Table 3: Analysis 3: Comparisons between the hypoperfusion and the normal perfusion group in patients with Euroscore ≤ 8

	rSO2 ≥ 50% n=118	**rSO2 < 50% n=21**	**p**
Euroscore	5,96 ± 1,65	6,00 ± 1,30	ns
Age (years)	64,96 ± 9,87	62,38 ± 10,823	ns
Height (m)	1,72 ± 0,08	1,74 ± 0,07	ns
Weight (kg)	83,14 ± 14,28	74,86 ± 12,43	0.032
Gender	male n=97 (82,2%) female n=21 (17,8%)	male n=18 (85,7%) female n=3 (14,3%)	ns
Duration of Operation (min)	242,31 ± 65,96	270,43 ± 94,44	ns
Bypass (min)	111,81 ± 46,87	128,43 ± 76,86	ns
Aortic Crossclamp (min)	87,15 ± 38,21	90,43 ± 55,12	ns
Peripheral artery disease	n=17 (14,4%)	n=3 (14,3%)	ns
Carotid artery disease	n=2 (1,7%)	n=0 (0,0%)	ns
Diabetes	n=33 (28,0%)	n=5 (23,8%)	ns
Chronic kidney disease	n=20 (16,9%)	n=8 (38,1%)	0.009
Duration of ventilation (h)	6 (6-792)	6 (6-576)	ns
Pulmonary complications	n=5 (4,2%)	n=6 (28,6%)	< 0.0001
Need for renal replacement therapy	n=3 (2,5%)	n=5 (23,8%)	< 0.0001
Incidence of stroke	n=3 (2,5%)	n=0 (0,0%)	ns
Duration on high dependency unit (h)	72 (24-792)	108 (48-864)	0.017
Hospital length of stay (d)	6 (3-33)	9 (4-49)	0.008
Postoperative major complication score	0 (0-2)	0 (0-3)	< 0.0001
30 day mortality	n=3 (2,5%)	n=1 (4,8%)	ns
180 day mortality	n=3 (2,5%)	n=1 (4,8%)	ns

Data are given as mean ± standard deviation or median and range as appropriate. Analysis was performed with unpaired Student's t-test for normally distributed data or Kruskal-Wallis-test for not-normally distributed data. A p<0,05 indicates statistical significance. rSO2 ≥ 50%: patients monitored with bi-hemispheric near-infrared spectroscopy with a minimal regional SO2 ≥ 50% absolute; rSO2 < 50%: patients with minimal regional rSO2 < 50%.

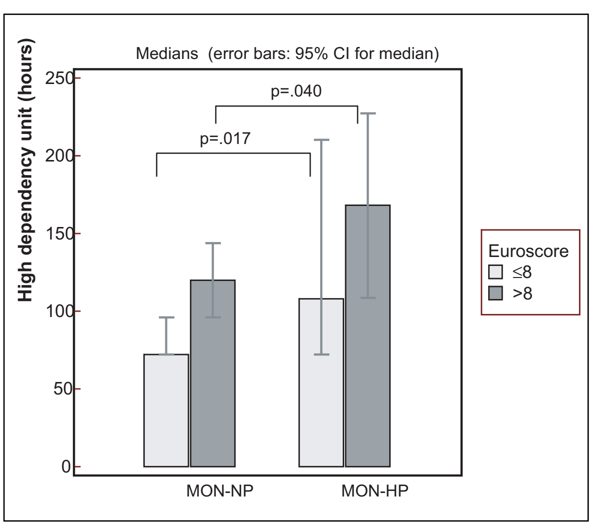

Figure 2. Analysis 3: Comparisons between the hypoperfusion and normal perfusion group following grouping according to Euroscore ≤ or > 8: Duration on high dependency unit. MON-NP: monitored patients with minimal rSO2>50%, MON-HP: monitored patients with minimal rSO2<50%

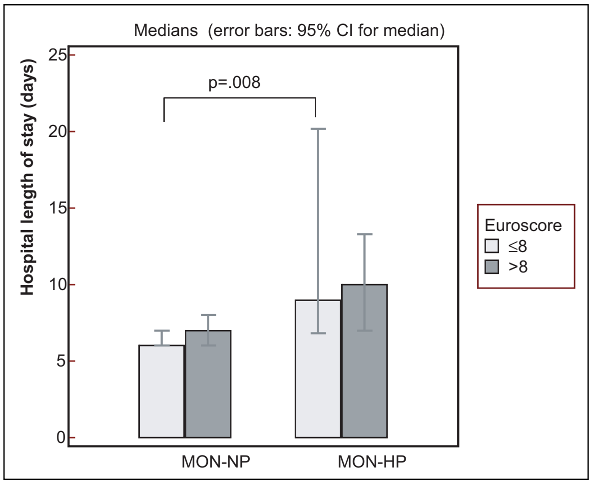

Figure 3. Analysis 3: Comparisons between the hypoperfusion and normal perfusion group following grouping according to Euroscore ≤ or > 8: Hospital length of stay. MON-NP: monitored patients with minimal rSO2>50%, MON-HP: monitored patients with minimal rSO2<50%

Table 4: Analysis 3: Comparisons between the hypoperfusion and the normal perfusion group in patients with an Euroscore > 8

	rSO2 < 50% **n=91**	**rSO2 ≥ 50%** **n=45**	**p**
Euroscore	11,12 ± 2,04	11,68 ± 1,96	ns
Age (years)	73,63 ± 7,31	70,48 ± 9,44	ns
Height (m)	1,70 ± ,09	1,70 ± ,08	ns
Weight (kg)	79,49 ± 13,54	75,45 ± 14,54	ns
Gender	male n=60 (65,9%) female n=31 (34,1%)	male n=30 (68,2%) female n=14 (31,8%)	ns
Duration of Operation (min)	234 (130-590)	258,5 (135-620)	ns
Bypass (min)	126,45 ± 58,02	144,57 ± 64,02	ns
Aortic Crossclamp (min)	97,26 ± 42,58	104,43 ± 44,66	ns
Peripheral artery disease	n=34 (37,4%)	n=13 (29,5%)	ns
Carotid artery disease	n=4 (4,4%)	n=4 (9,1%)	ns
Diabetes	n=30 (33,0%)	n=18 (40,9%)	ns
Chronic kidney disease	n=29 (31,9%)	n=18 (40,9%)	ns
Duration of ventilation (h)	30,73 ± 71,74	48,55 ± 71,88	ns
Pulmonary complications	n=16 (17,6%)	n=12 (27,3%)	ns
Need for renal replacement therapy	n=11 (12,1%)	n=12 (27,3%)	ns
Incidence of stroke	n=3 (3,3%)	n=4 (9,1%)	ns
Duration on high dependency unit (h)	120 (48-1128)	168 (24-1320)	0,04
Hospital length of stay (d)	9,70 ± 9,75	12,26 ± 9,49	ns
Postoperative major complication score	0 (0-4)	0 (0-3)	ns
30 day mortality	n=7 (7,7%)	n=2 (4,5%)	ns
180 day mortality	n=10 (11,0%)	n=5 (11,4%)	ns

Data are given as mean ± standard deviation or median and range as appropriate. Analysis is performed with paired Student's t-test for normally distributed data or Kruskal-Wallis-Test for not-normally distributed data. A p<,05 indicates statistical significance.

Discussion

Cerebral near infrared spectroscopy (NIRS) is a non-invasive tool to monitor regional cerebral oxygen saturation (1, 4). The technique is based on measurement of the intravascular oxyhemoglobin fraction in a small area of frontal lobe cortex using an infrared light source and two detectors in definite distance to the light, detecting the specific absorption spectra of oxygenated and deoxygenated hemoglobin (5, 6).

Perioperative cerebral desaturation has been associated with an adverse neurological and general clinical outcome in patients undergoing cardiac and general surgery (2, 3, 7-11). Yao and coworkers (7) have shown that a perioperative decrease in rSO2 below 35% absolute or an area under the curve of more than 10 minutes below 60% of baseline value was associated with postoperative neuropsychological dysfunction in a prospective observational trial in 101 cardiac surgery patients. In a prospective randomized trial the same group showed that maintaining cerebral oxygen saturation above 30% significantly reduced the incidence of postoperative stroke and/or coma in this setting (8). Goldman and coworkers observed a decreased rate of stroke and shorter ventilation times in a cohort of 1034 CABG patients undergoing cerebral oxygen saturation monitoring in comparison with a historical control group with n=1245 (9). Murkin and coworkers observed a reduced combined rate of major organ morbidity and mortality in a prospective randomized trial including 200 patients undergoing CABG surgery (2).

Recently, Dullenkopf and coworkers have shown that rSO2 levels determined by NIRS reflect trends of changes in mixed venous oxygen saturation (10). rSO2 may thus not only reflect direct cerebral perfusion but may also serve as an indirect marker for global perfusion and the systemic oxygen balance. It is well accepted that perioperative hypoperfusion, i.e. a mismatch between oxygen delivery and demand is associated with a worse clinical outcome (12). Inadequate cerebral perfusion thus may not only result in an adverse neurological outcome but may also be associated with increased morbidity.

Absolute thresholds as well as the maximal duration of low rSO2 periods indicating a potentially harmful cerebral desaturation during cardiac surgery are still a matter of debate. We chose a threshold of rSO<50% absolute according to Edmonds and coworkers (13), who postulated that an absolute rSO2 <50% or a decline of 20% of baseline are reflective of cerebral hypoperfusion and should thus be regarded as thresholds for intervention. Edmonds recommendations are based on findings in patients during carotid endarteriectomy (14) or defibrillator/cardioverter-testing showing syncope (15) and/or decrease in somatosensory evoked potentials with a decline of rSO2 -20% of baseline or 50% absolute. These findings are in line with a recent study (16) showing that prolonged desaturation beyond rSO2 levels of 50% is associated with increased postoperative neurological dysfunction in patients undergoing isolated coronary artery bypass grafting (CABG).

Analysis 1

We found no differences in relevant outcome parameters in comparison between cardiac surgery patients with or without cerebral oxygen saturation monitoring. However, the monitored group had a significantly higher risk profile (i.e. vascular disease and chronic kidney disease) and markedly longer duration of operation, cardiopulmonary bypass, and aortic crossclamp time (i.e. more severe surgical insult). Thus the monitored group would have been expected to have a higher morbidity and mortality than the control group (17). In contrast, the monitored group showed no differences to the controls in terms of major complications and hospital length of stay. Unlike our findings Goldman and coworkers observed improved outcomes in a large cohort study with a historical control group in CABG patients (9). However, in contrast to these investigators we did not have specific treatment algorithms to prevent cerebral desaturation or to restore rSO2 levels to a "normal" range. Thus the "relatively" improved outcome in the monitored group cannot be related to specific predefined therapeutic measures. However, the psychological effect of an additional monitoring, eventually displaying rSO2 levels of potentially harmful degree cannot be ignored and may have influenced the therapeutic decisions of the attending anesthetists and/or perfusionists.

Analysis 2

The second analysis was performed to determine if cerebral hypoperfusion (defined as a minimal rSO2 reading < 50% at baseline or during the procedure) was associated with clinically relevant outcomes. This analysis revealed that patients with a rSO2 of less than

<50% had a higher Euroscore. Euroscore predicts mortality after heart surgery on the basis of patient-related, cardiac, and surgical factors (18). The relationship between Euroscore and minimal rSO2 in the present study could be due to the higher incidence of peripheral and cerebral artery disease as well as chronic kidney disease in the group with low rSO2 who all contribute to a higher Euroscore. Low rSO2 seems to reflect the higher degree of preoperative morbidity which is only partially registered with Euroscore, a score that has been developed for risk stratification according to postoperative mortality.

A major limiting factor for the interpretation of the ventilation times is the roughness of documentation in the cardiac surgery data base giving only 6 to 12 hour intervals thus leading to extraordinarily high ventilator times. To overcome this limitation we introduced the variable "pulmonary complications" which combines prolonged ventilator-times (i.e. longer than 24 hours) and failure of weaning (i.e. need for reintubation). The higher rate of pulmonary complications in the group with cerebral desaturation is not sufficiently explained by higher Euroscore but rather by the more increased surgical insult (i.e. longer duration of operation, longer CPB, and aortic crossclamping). Besides many other factors, arterial vascular disease and CPB times of more than 120min have been shown to be predictors for extubation failure (19) and may thus contribute to the longer stay in high dependency unit care and hospital length of stay.

Analysis 3

To adjust for heterogeneity of preoperative risk factors we stratified the patients according to the median Euroscore; thereby selecting subgroups with minor to moderate (Euroscore ≤ 8) and patients with a high risk (Euroscore > 8). Interestingly, patients in the Eurocore ≤ 8 group presenting with rSO2 levels below 50% had a higher postoperative "major complication score" (MaCS) compiling in a longer stay in the high dependency unit and longer hospital length of stay. In contrast, no relation between complication variables and low rSO2 levels was observed in the Euroscore > 8 group but the patients with hypoperfusion still required a longer duration in the high dependency unit. These findings suggest that low rSO2 levels not only indicate cerebral but may also be indicative of systemic hypoperfusion – a complication frequently associated with postoperative major organ dysfunction. This is especially relevant in patients with a low to moderate risk profile, i.e. if the perioperative course is influenced more by the clinical management than by the prevailing severity of the disease. It is of note that Goldman and coworkers observed the greatest effects of cerebral oxygenation monitoring in patients with a lower preoperative New York Heart Association grade (9).

Limitations

The most important limitation applies to the retrospective nature of this study and the fact that the rSO2 levels were derived from handwritten anesthesia charts. Consequently we cannot make statements about the exact duration of these desaturation periods. The duration of desaturation, however, has been reported to be an important aspect for the interpretation of rSO2 levels; since prolonged desaturation periods have been shown to be much more detrimental than short "dips" with subsequent restoration of oxygenation in patients with selective cerebral perfusion (20).

Another limitation is the fact that we stratified our group according to rSO2<50% at baseline or throughout the surgical procedure. Possibly a low rSO2 prior to induction of anesthesia reflects a state of imbalance of cerebral oxygen-delivery and demand that may be a different pattern in comparison with patients presenting with intraoperative desaturation i.e. during CPB from a normal baseline. Which of these incidents is more detrimental in terms of clinical outcome has to be clarified in further observational trails.

Conclusion

The present retrospective analyses suggest that – even if no specific treatment algorithms have been established – the use of intraoperative cerebral oxygenation monitoring is associated with a "relatively" improved outcome in patients undergoing on-pump cardiac surgery; i.e. patients being monitored had comparable postoperative complications despite a tremendously higher risk profile and a more severe surgical insult. If this is an expression of the "indirect" psychological effects of a monitor displaying unwarranted hypoperfusion during cardiac surgery or the effect of other unmeasured variables remains to be determined.

Patients with a higher risk profile for cerebral vascular accidents and renal dysfunction may benefit from cerebral oxygenation monitoring. rSO2 levels higher than 50% in this group seem to be beneficial for outcome. However, this association seems to be restricted to patients with a low to moderate risk profile (Euroscore ≤ 8). In patients with a Euroscore > 8 no association between cerebral oxygenation and outcome was observed.

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