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## Research Article

# Features of Oxygen Extraction Ratio and Temperature Homeostasis during Early Postoperative Period after Major Abdominal Surgery

## Abstract

In some situations, tissue hypoxia may exist despite normal values obtained by conventional haemodynamic monitoring such as arterial blood pressure, central venous pressure, heart rate, and urine output.

The study was performed in early postoperative period after major abdominal surgery in 160 patients and was conducted in the following stages: 1- admission from operating room; 2 - in 1-3 hours; 3 - 4-7 hours; 4 - 8-12 hours; 5 - after 13-24 hours after the surgery.

Depend on rate of oxygen extraction index (ERO<sub>2</sub>) patients was divided in four groups depending on ERO<sub>2</sub> on admission: group 1 (n=44) - low ERO<sub>2</sub> (< 21%) followed by recovery to normal levels to stage 2-3 (ERO<sub>2</sub> = 22-32%), group 2 (n=42) - normal level ERO<sub>2</sub> (22-32%) in all the stages, group 3 (n=40) - high levels ERO<sub>2</sub> (>33%) with recovery to normal levels to stage 2, group 4 (n=34) - high ERO<sub>2</sub> (> 35%) in all the stages. Central hemodynamic, gas exchange, metabolic rate and temperature parameters were assessed.

Maintaining an adequate tissue oxygenation is the cornerstone of metabolic response and postoperative recovery in patient after major abdominal surgery. Oxygen extraction index at admission to ICU after surgery can be normal (26.25% of patients), reduced (27.5% of patients) or high (46.25% of patients). When oxygen extraction ratio is reduced metabolic recovery occurs classically after 4-7 hours; when ERO<sub>2</sub> is elevated - after 8-12 hours. For patients with high oxygen extraction ratio marked venous hypoxemia is typical, which recovery to 4-12 hours post-surgery.

Core temperature improvement is connected with the restoration of oxygen homeostasis. So, under normal and reduced ERO<sub>2</sub> even mild central hypothermia after surgery were not observed, and at an elevated ERO<sub>2</sub> moderate hypothermia after surgery was observed with only to 4-7 hours post-surgery restoration.

## Abbreviations

HR: Heart Rate; SI: Stroke Index; CI: Cardiac Index; SVR: Systemic Vascular Resistance; DO<sub>2</sub>: O<sub>2</sub> Delivery; VO<sub>2</sub>: O<sub>2</sub>: Oxygen Consumption; ERO<sub>2</sub>: Oxygen Extraction Ratio

## Introduction

About 100 years ago, the German physiologist Pflüger stated that the cardio-respiratory system fulfils its physiological task by guaranteeing cellular oxygen supply and removing waste products of cellular metabolism. In his opinion, everything else is of secondary importance: arterial oxygen content, arterial pressures, blood flow velocity, mode of cardiac work, and

mode of respiration, all are incidental and subordinate; they all combine their actions only in service to the cells. Although the modern technology of the 21st century, we are mostly monitoring parameters which Pflüger called "unanticipated and dependent", insufficient lighting oxygen homeostasis complex changes, particularly during and after major surgery. Continuous measurement of the systemic blood pressure and heart rate are routinely obtained in critically ill patients. It is a very basic question; to what extent the routinely measured cardiorespiratory parameters provide information about the adequacy of oxygen transport and, more importantly, on the quality of tissue oxygenation? Recognition, prevention, and treatment of tissue hypoxia play a key role in intensive care

medicine. The aim of cardiovascular monitoring is the early recognition of impending tissue hypoxia. In some situations, tissue hypoxia may exist despite normal values obtained by conventional haemodynamic monitoring such as arterial blood pressure, central venous pressure, heart rate, and urine output [1-3].

That is why we think it is important to establish a particular change of oxygen, temperature homeostasis and central hemodynamics after major abdominal surgery under combined epidural anesthesia.

## Materials and Methods

Prospective study examined 160 patients who underwent major abdominal surgery over a 12-month period from October of 2012 to October of 2013 in Krasnodar regional hospital #2. There were 92 male and 68 female patients. The physical condition of patients corresponded to 3 class of ASA. The median age was 46.0 (38.0- 62.0) years. Duration of the surgery was 6,4 (4,8-9,5) hours. Surgery was performed under combined epidural anesthesia (epidural ropivacain 0.5% 8-12 ml/h at ThVII-ThIX level) with mechanical ventilation. Patients were eligible if they were planned for major surgery, could give informed consent, and did not have disseminated cancer disease. We excluded the pregnant or lactating women, chronic lung disease, septic shock and major bleeding. The trial was approved by the ethical committees of Kuban State Medical University.

Depend on rate of oxygen extraction index ( $ERO_2$ ) patients was divided in four groups depending on  $ERO_2$  on admission to the ICU after surgery: group 1 (n=44)-low  $ERO_2$  (< 21%) followed by recovery to normal levels to stage 2-3 ( $ERO_2$  = 22-32%), group 2 (n=42)-normal level  $ERO_2$  (22-32%) in all the stages, group 3 (n=40)-high levels  $ERO_2$  (>33%) with recovery to normal levels to stage 2, group 4 (n=34)-high  $ERO_2$  (> 35%) in all the stages. Hemodynamic profiles consisted of determinations of intravascular pressures, cardiac output, and

arterial and venous gases. Oxygen transport variables were calculated by standard formulas [4,5]. Central hemodynamic, gas exchange, metabolic rate and temperature parameters were assessed in the following stages: 1- admission from operating room; 2 - in 1-3 hours; 3 - 4-7 hours; 4 - 8-12 hours; 5 - after 13-24 hours after the surgery.

Statistical analysis was performed using Friedman test and Kruskal - Wallis test by Statistica 6. Data are presented as medians and percentiles (p25 and p75).

## Results

Variety of hemodynamic, microcirculation and blood gas changes during the major surgery are occurred. As listed in Table 1 group 1 had normal core temperature, mild tachycardia, normal parameters of systemic hemodynamics, moderate, not much pronounced decline of oxygen delivery, consumption and oxygen extraction index, supranormal oxygen tension in the arterial blood and its normal tension in the venous blood. Statistically significant differences between groups in terms of  $DO_2$  and  $VO_2$  and  $PaO_2$  were not observed.

Group 2 was characterized by normal values of heart rate, a decrease of stroke index and cardiac index, increased peripheral vascular resistance, and oxygen extraction index within normal ranges. In group 3 moderate hypothermia was observed, lower values of peripheral temperature, increased peripheral vascular resistance, high values oxygen extraction index and pronounced decrease in  $SvO_2$ . In group 4 moderate hypothermia was also observed, with a pronounced decrease in stroke index and cardiac index. High values of oxygen extraction index and pronounced decrease in  $SvO_2$  were also observed in group 4.

We should also mention the main differences between the other groups. In groups 3 and 4 pronounced disorders of temperature homeostasis, increased oxygen extraction index and reduced  $SvO_2$ , compared with group 2 were observed,

**Table 1:** Patient's parameters after admission from the operation room.

Parameter	Group 1	Group 2	Group 3	Group 4
Core T. (°C)	36,2(36,0-37,0)	36,6 (36,3-36,7)	34,3 (34,2-34,4) **##	34,55 (34,0-35,2) #°
Peripheral T. (°C)	28,1 (26,9-28,3)	28,4 (25,7-31,0)	26,0 (25,9-26,4) *	26,6 (24,8-27,9)
HR (Beat/min)	104,0 (99,0-105,0)	80,5 (76,5-84) *	72,0 (65,0-86,0) **	68,5 (66,0-71,8) #°
SI (ml/m <sup>2</sup> )	35,0 (32,0-36,0)	26,5(22,8-32,5) *	41,8 (36,7- 45,4) ##	27,7 (25,4-30,9) #°°
CI (l×min <sup>-1</sup> ×m <sup>2</sup> )	3,5 (3,4-3,8)	2,25 (1,9-2,7) *	2,8 (2,6-3,5)##	1,95 (1,7-2,3) #°°°
SVR (dys×cm <sup>-5</sup> )	1393,0 (1000,0-1408,0)	2033,0 (1843,5-2354,8) *	1632,0 (1371,0-1642,0) ##	1642,0 (940,4-2128,8)
$DO_2$ (ml/kg/min)	11,6 (6,0-25)	9,2 (8,0-11,3)	7,7 (6,0-8,8)	7,2 (6,0-9,5)
$VO_2$ (ml/kg/min)	2,65 (1,6-3,6)	2,3 (2,1-2,7)	2,7 (2,1-4,7)	2,7 (2,5-3,0)
$ERO_2$ (%)	14,5 (13,5-16,3)	24,0(24,0-25,9) *	35,0 (35,0-48,0)**##	42,0 (36,3-43,0) #°
$paO_2$ (%)	132,0 (127,0-180,0)	157,3 (138,0-170,0)	158,5 (153,3-195,8)	165,0 (132,0-195,3)
$pvO_2$ (mmHg)	49,4 (45,4-55,2)	42,1 (41,3-42,5)	32,2 (30,3-34,1) **##	29,7 (26,4-31,7) #°°°°
$SvO_2$ (%)	84,4 (83,5-85,1)	75,6(73,5-75,7) *	64,2(64,1-64,2) **##	62,5(58,4-64,8) #°

\* p<0,05 within 1 and 2 group , \*\* p<0,05 within 1 and 3 group,

# p<0,05 within 1 and 4 group, ° p<0,05 within 4 and 2 group

## p<0,05 within 3 and 2 group by Kruskal - Wallis test

although vascular tone was significantly higher in group 2 in comparison with a group 4.

On the basis of the presented data it can be summarized that the early postoperative period is characterized by disturbances of temperature homeostasis in conjunction with the low values of SvO<sub>2</sub> in Groups 3 and 4, indicating on the expressed microcirculatory disorders in comparison with groups 1 and 2.

Within 1–3 hours after the surgery oxygen extraction index recovery to normal values in group 1.

In the other groups tendency of stabilization of systemic hemodynamics (stroke index and cardiac index) was observed, although vascular tone remained higher than in group 1. In the groups 3 and 4 central hypothermia was remained; in group 3 – oxygen extraction index returned to normal ranges, and group 4 – continued to grow.

Within 4–7 hours after the surgery (Table 2) in group 1 stable normal state of homeostasis was remained. In group

2 – high system vascular resistance was persisted. In group 3 – central temperature recovery and improvement of systemic hemodynamics was observed. The group 4 the core temperature was normal, but a steady decline of venous oxygen saturation, reduced delivery and increased oxygen consumption was observed.

Within 13–24 hours after surgery in group 1 normal homeostatic function were remained. In group 2 all patient homeostatic parameters were observed with maintaining vasoconstriction as a result of decrease in oxygen delivery. In group 3 reduced oxygen consumption and low oxygen extraction ratio were remained Table 3.

Our data show that the postoperative period might be associated with a reduction or elevation in tissue ability to extract oxygen.

Restoration of global oxygen delivery is an important goal in early resuscitation as tissue hypoxia may exist despite normal values obtained by conventional hemodynamic monitoring.

**Table 2:** Patient's parameters at 4-7 hours after surgery.

Parameter	Group 1	Group 2	Group 3	Group 4
Core T. (°C)	37,1 (36,2-37,3)	37,1 (36,6-37,6)	36,9 (36,5-37,5)	37,0 (36,7-37,3)
Peripheral T. (°C)	33,0 (31,9-33,2)	32,85 (31,7-33,8)	26,3 (25,9-27,5)	26,9 (26,5-28,8)
HR (Beat/min)	102,0 (67,0-107,0)	87,0 (83,0-89,8)	67,0 (63,5-78,5)##	84,5 (76,0-88,3)
SI (ml/m <sup>2</sup> )	40,0 (32,0-46,0)	25,9 (20,6-31,5) *	50,6 (46,8-51,2) **##	36,4 (25,7-41,9) °°
CI (l×min <sup>-1</sup> ×m <sup>-2</sup> )	3,0 (3,0-5,0)	2,5 (1,7-3,0) *	3,5 (3,0-4,0) ##	2,6 (2,3-3,3)
SVR (dyn×s×cm <sup>-5</sup> )	1000,0(832,0-1223,0)	1964,0(1617,3-2512,0) *	1453,0(1289,0-1497,0) **##	1468,0(1121,5-1678,5)
DO <sub>2</sub> (ml/kg/min)	14,2 (10,5-18,6)	11,5 (9,1-15,2)	12,0 (8,7-12,6)	9,5 (7,8-11,6)
VO <sub>2</sub> (ml/kg/min)	4,6 (3,3-5,3)	3,5 (2,5-4,6)	1,6 (1,3-2,5) **##	3,5 (3,0-4,0)
ERO <sub>2</sub> (%)	27,0 (21,8-31,8)	27,0 (21,8-33,8)	18,0 (15,0-23,5) **##	35(33,0- 40,8) #,°°
paO <sub>2</sub> (%)	137,5 (132,8-142,5)	124,1 (94,8-153,8)	134,5 (118,3-148,3)	147,8 (125,3-158,0)
pvO <sub>2</sub> (mmHg)	41,15 (36,5-46,2)	39,3 (35,1-43,1)	42,6 (40,7-45,9)	34,7 (32,2-38,7) #,°°
SvO <sub>2</sub> (%)	71,8 (67,4-77,3)	71,7 (64,5-77,8)	82,7 (77,0-84,5) **##	64,3 (58,6-67,2)

\* p<0,05 within 1 and 2 group , \*\* p<0,05 within 1 and 3 group,

# p<0,05 within 1 and 4 group, ° p<0,05 within 4 and 2 group

## p<0,05 within 4 and 3 group by Kruskal - Wallis test.

**Table 3:** Patient's parameters at 13-24 hours after surgery.

Parameter	Group 1	Group 2	Group 3	Group 4
Core T. (°C)	36,3 (36,2-36,5)	37,0 (36,7-37,3)	36,7 (36,5-37,0)	36,8 (36,2-37,3)
Peripheral T. (°C)	34,85 (34,3-35,4)	33,35 (32,7-34,1)	31,6 (29,9-32,6)	34,3 (33,3-35,5)
HR (Beat/min)	94,0 (87,8-102,8)	85,5 (73,8-96,3)	76 (71-84,5) **	88,5 (78,5-101,5)
SI (ml/m <sup>2</sup> )	39,0 (28,5-52,3)	34 (28-39)	46,3 (41,7-51,2) **##	39,2 (33,4-42,5) °°
CI (l×min <sup>-1</sup> ×m <sup>-2</sup> )	3,8 (2,6-5,2)	2,9 (1,9-3,9)	4,3 (3,4-4,3) **	3,7 (2,9-4,7)
SVR (dyn×s×cm <sup>-5</sup> )	1008,0(701,0-1297,0)	1720,0(1150,8-2339,8)	1575,0(1311,5-1653,5) **	1150,0(942,5-1228,0) °°
DO <sub>2</sub> (ml/kg/min)	10,05 (8,0-14,0)	9,01 (7,7-13,6)	13,2 (9,4-14,5)	13,10 (9,9-16,4)
VO <sub>2</sub> (ml/kg/min)	3,4 (2,3-4,3)	2,9 (2,5-3,9)	1,2 (1,2-2,0) **##	3,5 (3,2-4,4) °°
ERO <sub>2</sub> (%)	22,5 (22,0-25,8)	29,0 (26,8-31,5) *	17,0 (12,5-19,5) **##	28,0 (24,3-34,3) °°
paO <sub>2</sub> (%)	123,0 (121,3-137,0)	98,3 (86,7-114,3) *	132 (120,6-136,5)	164,9 (111,8-176,0)
pvO <sub>2</sub> (mmHg)	41,85 (39,2-43,5)	37,7 (36,6-47,0)	42,2 (39,6-50,1)	38,0 (34,2-40,4)
SvO <sub>2</sub> (%)	76,7 (73,7-77,3)	70,2 (68,0-71,3)	75,8 (73,7-82,4)	71,1 (63,6-75,0)

\* p<0,05 within 1 and 2 group , \*\* p<0,05 within 1 and 3 group,

# p<0,05 within 1 and 4 group, ° p<0,05 within 4 and 2 group

°° p<0,05 within 4 and 3 group by Kruskal - Wallis test.



## Conclusion

Maintaining an adequate tissue oxygenation is the cornerstone of metabolic response and postoperative recovery in patient after major abdominal surgery. Oxygen extraction index at admission to ICU after surgery can be normal (26.25% of patients), reduced (27.5% of patients) or high (46.25% of patients). When oxygen extraction ratio is reduced metabolic recovery occurs classically after 4-7 hours; when  $ERO_2$  is elevated - after 8-12 hours. For patients with high oxygen extraction ratio marked venous hypoxemia is typical, which recovery to 4-12 hours post-surgery.

Core temperature improvement is connected with the restoration of oxygen homeostasis. So, under normal and reduced  $ERO_2$  even mild central hypothermia after surgery were not observed, and at an elevated  $ERO_2$  moderate hypothermia after surgery was observed with only to 4-7 hours post-surgery restoration.

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