OPTIMIZING ADEQUATE PERFUSION

WORKSHOP - INTERACTIVE SESSION

VO_2 / DO_2 BASIC INFORMATION

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Further, Together

OPTIMIZING ADEQUATE PERFUSION

How can:

- oxygen consumption - VO_2
- oxygen delivery- DO_2
- and oxygen extraction ratio - O_2ER

help us to improve the perfusion quality?

Let us look at the basic science of those parameters.

OPTIMIZING ADEQUATE PERFUSION

VO_2 - oxygen consumption

- VO_2 is a function of the following parameters:
  - Blood Flow (Qb - LPM)
  - Arterial saturation (A_{sat} - %)
  - Venous Saturation (V_{sat} - %)
  - Hemoglobin (Hb – g/dl)
  - P_a02 (arterial pO_2 - mmHg)
  - P_vO_2 (venous pO_2 - mmHg)

$$VO_2 = CO \times (Ca_{O_2} - Cv_{O_2})$$

$$VO_2 = Qb \times 10 \times [(A_{sat} - V_{sat}) \times (Hb \times 1.34) + ((P_aO_2 - P_vO_2) \times .003))]$$

$$VO_2 = 4.5 \times 10 \times [(100-80) \times (9 \times 1.34) + ((200-45) \times .003))]$$

$$VO_2 = 109\ ml/O_2/min$$

OPTIMIZING ADEQUATE PERFUSION

VO_2 - oxygen consumption

$VO_2 = 4.5 \times 10 \times [(100-80) \times (9 \times 1.34) + ((200-45) \times .003))]$

$VO_2 = 109$ ml/O_2/min

$VO_2 = 4.5 \times 10 \times [(100-80) \times (9 \times 1.34)]$

$VO_2 = 108.5$ ml/O_2/min

- VO_2 is a function of the following parameters:
  - Blood Flow (Qb)
  - Arterial saturation (A_{sat})
  - Venous Saturation (V_{sat})
  - Hemoglobin (Hb)

$$VO_2 = Qb \times 10 \times [(A_{sat} - V_{sat}) \times (Hb \times 1.34)]$$

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DO_2 - oxygen delivery

- DO_2 is a function of the following parameters:
  - Blood Flow (Qb - LPM)
  - Arterial saturation (A_{sat} - %)
  - Hemoglobin (Hb – g/dl)

$$DO_2 = CO \times Ca_{O_2}$$

$$DO_2 = Qb \times 10 \times [(A_{sat} \times (Hb \times 1.34)) + PaO2 \times .003)] \text{ - ml/min}$$

$$DO_2 = Qb \times 10 \times [(A_{sat} \times (Hb \times 1.34)) + PaO2 \times .003)] \text{ - ml/min}$$

$$DO_2 = 4.5 \times 10 \times [(100) \times (9 \times 1.34)$$

$$DO_2 = 543 \text{ ml}/O_2/\text{min}$$

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O_2ER - oxygen extraction ratio

- O_2ER is a function of the following parameters:
  - VO_2
  - DO_2

$O_2ER = VO_2 / DO_2 \times 100$

$O_2ER = 109 / 543 \times 100$

$O_2ER = .20$ or 20%

The normal extraction fraction ranges from 20 to 30%

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O_2ER - oxygen extraction ratio

$$O_2ER = VO_2 / DO_2 \times 100$$

- Global oxygen delivery (DO_2) is the total amount of oxygen delivered to the tissues per minute irrespective of the distribution of blood flow

- Under resting conditions with normal distribution of cardiac output, DO_2 is more than adequate to meet the total oxygen requirements of the tissues (VO_2) and ensure that **aerobic metabolism** is maintained

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O_2ER - oxygen extraction ratio

$$O_2ER = VO_2 / DO_2 \times 100$$

- The oxygen transport system normally operates to maintain VO_2 in conditions where DO_2 varies widely

- If global DO_2 decreases then O_2ER increases to maintain adequate oxygen supply

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O_2ER - oxygen extraction ratio

$$O_2ER = VO_2 / DO_2 \times 100$$

- If DO_2 continues to decrease, a point is reached where the O_2ER is maximal and cannot increase further. This point is called the '**critical DO_2**', and it is the point below which energy production in cells becomes limited by the supply of oxygen.

- Any further reduction in DO_2 will result in tissue hypoxia, conversion to anaerobic metabolism and the production of lactic acid.

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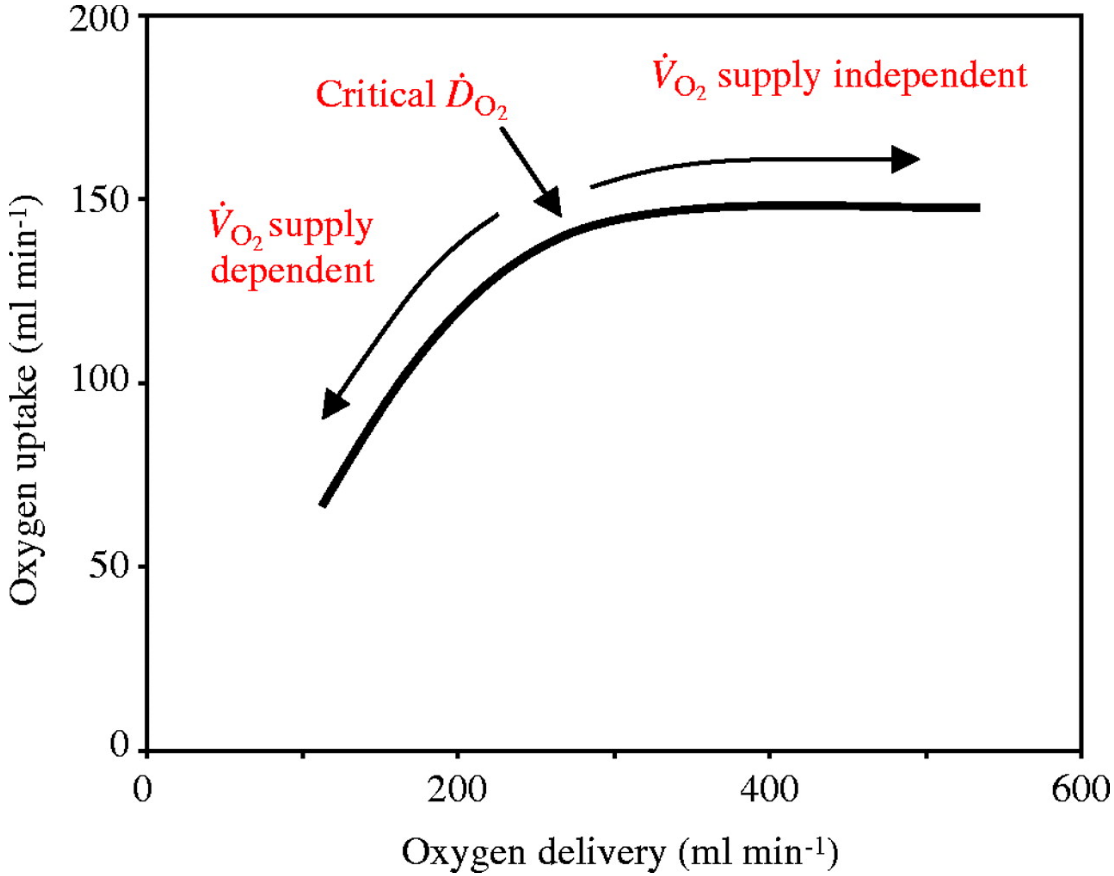
The oxygen supply and demand relationship



McLellan S A , and Walsh T S Contin Educ Anaesth Crit Care Pain 2004;4:123-126

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O_2ER - oxygen extraction ratio

$$O_2ER = VO_2 / DO_2 \times 100$$

- Global markers of tissue hypoxia (plasma acidosis and lactate concentration) are useful but non-specific

- Gastric tonometry and near infrared spectroscopy (NIRS) could be better indicators for the evaluation of regional oxygenation

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O_2ER - oxygen extraction ratio

NORMAL O_2ER VALUES:

- The normal total body O_2ER is 0.20 to 0.30, indicating that only 20 – 30% of the delivered oxygen is utilized.

- VO_2 is approximately 250 ml/min in adults at rest

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Emergent Cardiopulmonary Bypass for a 180 Kilogram Patient: Support with a Single Oxygenator

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Abstract: As obesity increases in prevalence, so will cases in which patients present at the boundaries of care. We report the support of a class III obese man, having a body mass index of 60.8 kg/m^2 and in acute renal failure, with a single Trillium™-coated Affinity® NT Hollow Fiber oxygenator in cardiopulmonary bypass for an emergent aortic valve replacement secondary to infective endocarditis. A maximum oxygen delivery of 807.51 mL of oxygen per minute is reported for this oxygenator in this case report. **Keywords:** cardiopulmonary bypass, oxygen transfer, obesity. *JECT. 2013;45:178–182*

As cardiac surgical patient populations continue to include higher morbidity demographics, greater incidences of treating patients who are at the boundaries of care will occur. One of these morbidities, obesity, is a major risk factor for cardiovascular disease with a nationwide prevalence of 37.5% (1) and negatively affecting life expectancy (2). Previous case reports disclose the support of a 159-kg patient in normothermic cardiopulmonary bypass (3). We report the support of a class III obese man, having a body mass index (BMI) of 60.8 kg/m^2 and in acute renal failure with a single Trillium™-coated Affinity® NT 511T Hollow Fiber oxygenator with mild hypothermic cardiopulmonary bypass (CPB) for an emergent aortic valve replacement secondary to infective endocarditis.

DESCRIPTION

A 49-year-old African American male, weighing 180 kg with a height of 172 cm, and a body surface area (BSA) of 2.73 m^2 with a recent medical history of a urinary tract infection and significant medical history of morbid obesity, obstructive sleep apnea, and hyperlipidemia presented to an outside hospital for angina. One week before the onset of angina, the patient was treated for a urinary tract infection at a separate medical facility. The patient reported increasing severity of angina and electrocardiographic (ECG) analysis demonstrated ST segment elevation in inferior ECG leads. The patient was then treated with a tenecteplase regimen with mild improvement of angina and was then transferred to our facility for subsequent cardiac catheterization. Results of the cardiac catheterization demonstrated only luminal irregularities of both coronary artery systems but a left ventricular end-diastolic pressure of 43 mmHg. After cardiac catheterization, the patient reported tachypnea and dyspnea, and nitroglycerin therapy was initiated but slowly reduced as a result of hypotension. The patient was then given 100 mg furosemide intravenously with a 10 mg per hour intravenous infusion and 1000 mg intravenous bolus of chlorothiazide. Despite several hours of diuretic therapy, the patient remained anuric.

Approximately 15 hours before surgery, the patient went into cardiac arrest in the intensive care unit followed by clonic movement and agonal breaths. The patient was resuscitated with basic life support of external chest compressions, epinephrine, atropine, sodium bicarbonate, calcium gluconate, and magnesium boluses. After these therapies, the patient went into ventricular fibrillation with 200 of direct current cardioversion, immediate endotracheal intubation, and mechanical ventilation. Multiple

Received for publication April 30, 2012; accepted August 12, 2013.
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The senior author has stated that the authors have reported no material, financial, or other relationship with any healthcare-related business or other entity whose products or services are discussed in this paper.

A 49-year-old male, weighing 180 kg with a height of 172 cm, and a body surface area (BSA) of 2.73 m2.

Theoretical pump flow:

- BSA X 2.4 = 6.55 lpm
- BSA x 2.0 = 5.46 lpm

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Emergency Cardiopulmonary Bypass for a 180 Kg Patient: Support with a Single Oxygenator

Table 1. Cardiopulmonary bypass data.

Time (minutes)	8	23	38	53	68
Blood flow [Q] (L/min)	2.61	4.70	4.70	5.25	5.04
Gas flow [V] (L/min)	8.5	5.0	7.0	9.5	9.5
FiO_2 (%)	100	100	100	100	100
pH	7.39	7.28	7.41	7.48	7.46
P_{CO_2} (mmHg)	32	39	34	38	34
P_{O_2} (mmHg)	521	350	408	335	369
$[HCO_2]^-$	19	19	23	28	24
Base deficit/excess (mEq/L)	–5	–8	–3	+5	+1
K^+ (mEq/L)	4.6	4.1	3.8	4	4.2
Ca^{++} (mmol/L)	.77	.85	.77	.69	.7
Hematocrit (%)	24	32	35	31	28
Hemoglobin (g/dL)	7.27	10.67	11.67	10.33	9.33
Mixed venous saturation [S_{VO_2}] (%)	40	58	69	57	53
Oxygen delivery [mL O_2/minute]	301.62	734.67	807.51	793.73	698.99
$Temperature_{Art}$ (C)	36.4	33.4	33.1	37.7	36.5

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COULD PERFUSION HAVE BEEN BETTER?

- The old classical mistake is to look only at the arterial sample. Still valid in some hospitals to cut expenses.

Timing	8	23	38	53	68	min
Temp	36.4	33.4	33.1	37.7	36.5	°c
Qb	2.61	4.7	4.7	5.25	5.04	LPM
A_{sat}	100	100	100	100	100	%
P_aCO_2	32	39	34	38	34	mmHg
P_aO_2	521	350	408	335	369	mmHg
Hb	7.27	10.67	11.67	10.33	9.33	mg/dl

This tells you only if the oxygenator is working well or not.

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OPTIMIZING ADEQUATE PERFUSION

COULD PERFUSION HAVE BEEN BETTER?

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DO_2	301.6	734.7	807.5	793.7	699.0	ml/O_2/min

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OPTIMIZING ADEQUATE PERFUSION

COULD PERFUSION HAVE BEEN BETTER?

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P_aCO_2	32	39	34	38	34	mmHg
P_aO_2	521	350	408	335	369	mmHg
Hb	7.27	10.67	11.67	10.33	9.33	mg/dl
V_{sat}	40	58	69	57	53	%
VO_2	192.4	328.6	281.8	361.6	349.1	$ml/O_2/min$
DO_2	301.6	734.7	807.5	793.7	699.0	$ml/O_2/min$
O_2ER	0.64	0.45	0.35	0.46	0.50	%

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COULD PERFUSION HAVE BEEN BETTER?

- Only at 1 point during this case we reach an O_2ER that is close to normal (35%). Sample 3 at 38'.
- This is due to an increased Hb (+10%) comparing to sample 2.

Timing	8	23	38	53	68	min
Temp	36.4	33.4	33.1	37.7	36.5	°c
Qb	2.61	4.7	4.7	5.25	5.04	LPM
A_{sat}	100	100	100	100	100	%
Hb	7.27	10.67	11.67	10.33	9.33	mg/dl
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DO_2	301.6	734.7	807.5	793.7	699.0	$ml/O_2/min$
O_2ER	0.64	0.45	0.35	0.46	0.50	%

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COULD PERFUSION HAVE BEEN BETTER?

As the Hb values are not really low in this case the perfusionist could have:

- **Increased the flow**, resulting in more O_2 available for the body. Venous saturation would go up.
  - CO in this case was always below 2.0 LPM/m^2
  - BSA of this patient was 2.73 m^2, calculated CO for 2.4 LPM/m^2 = 6.5 LPM
- And (theoretically) contact the anesthesiologist when the patient is consuming too much O_2 (**increasing level of anesthesia** will also reduce O_2 consumption).

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COULD PERFUSION HAVE BEEN BETTER?

Theoretically yes……

- By measuring DO_2 , VO_2 and O_2ER ratio you have excellent parameters to judge the quality of perfusion based on delivery and consumption of oxygen

- By acting in response of increased O_2ER ratios you might be able to avoid anaerobic metabolism and lactate production

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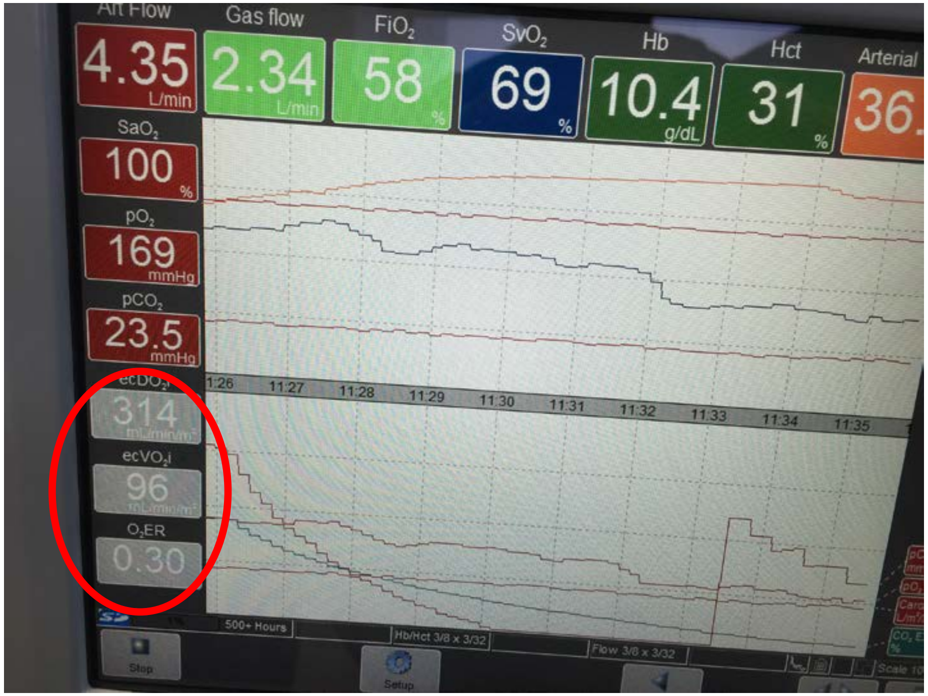
COULD PERFUSION HAVE BEEN BETTER?



This on-line monitoring is emerging as a key monitoring requirement (Italy and UK)

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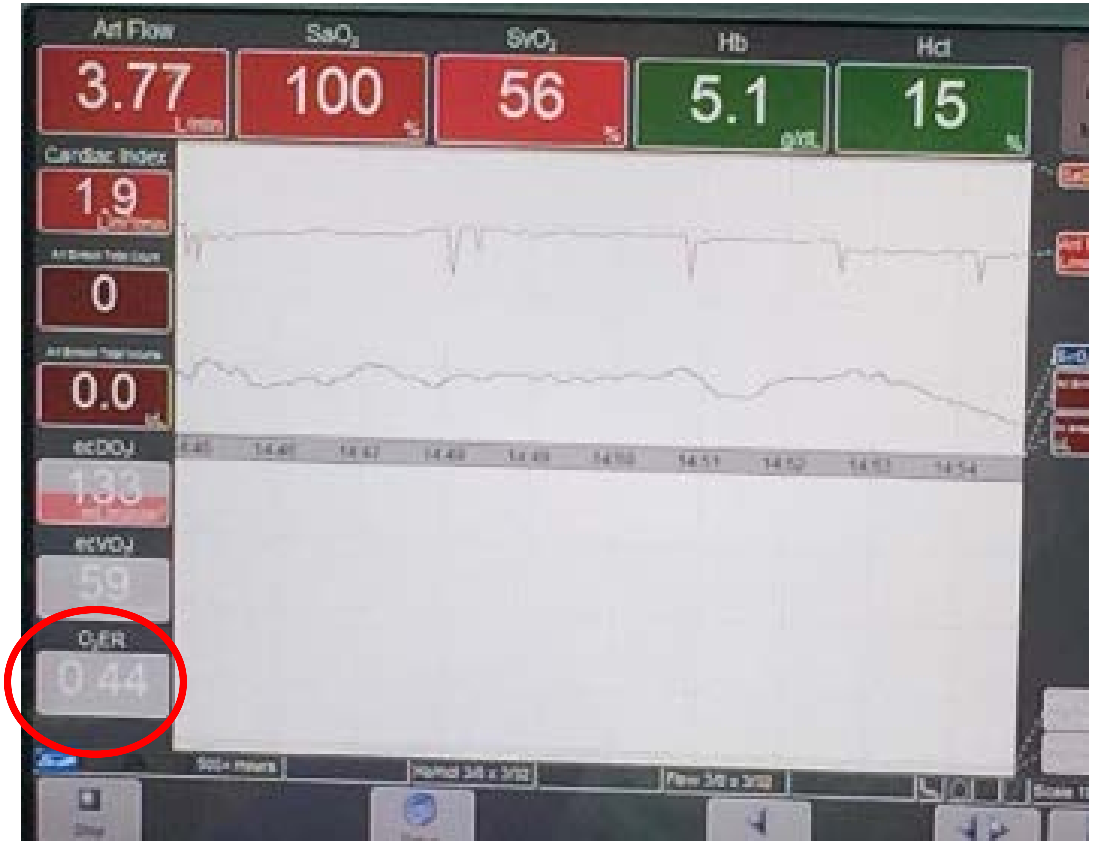

- After 30' on bypass the perfusionist notices a high OER due to a low flow and low Hb. First he ask the surgeon to correct the position of the venous cannulae …

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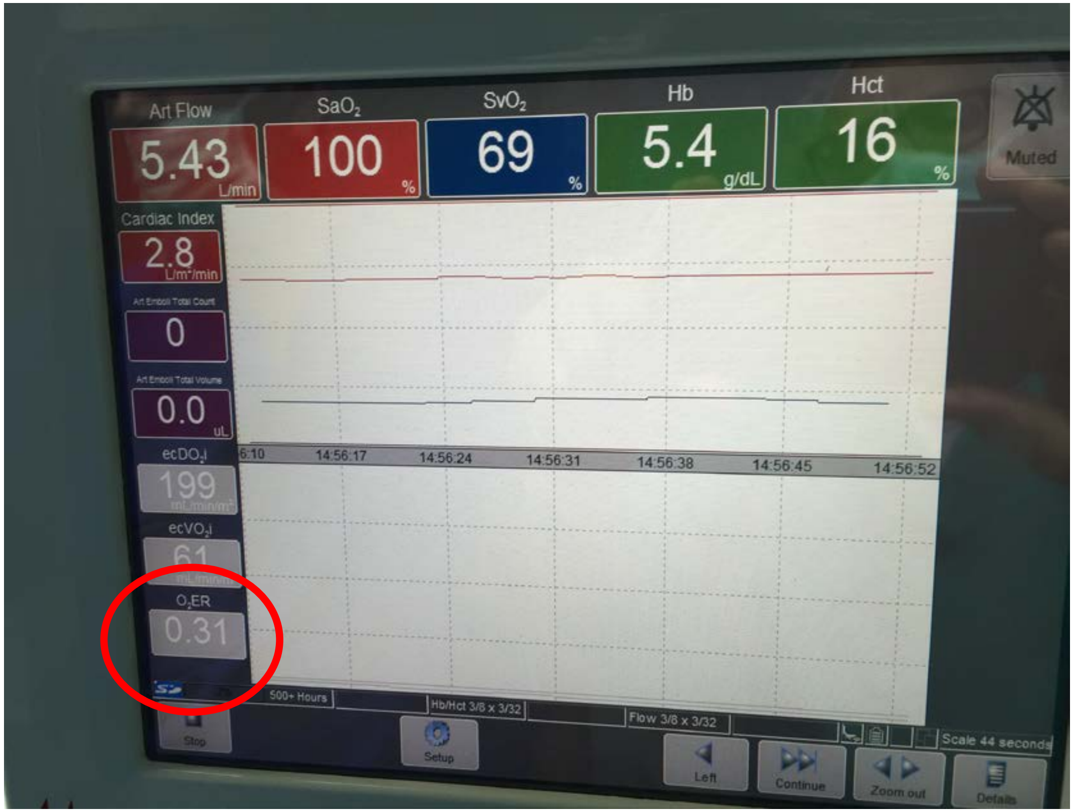

- …and he can increase the CO. As a result the venous saturation goes up and OER goes down. Almost back to normal: 31%.

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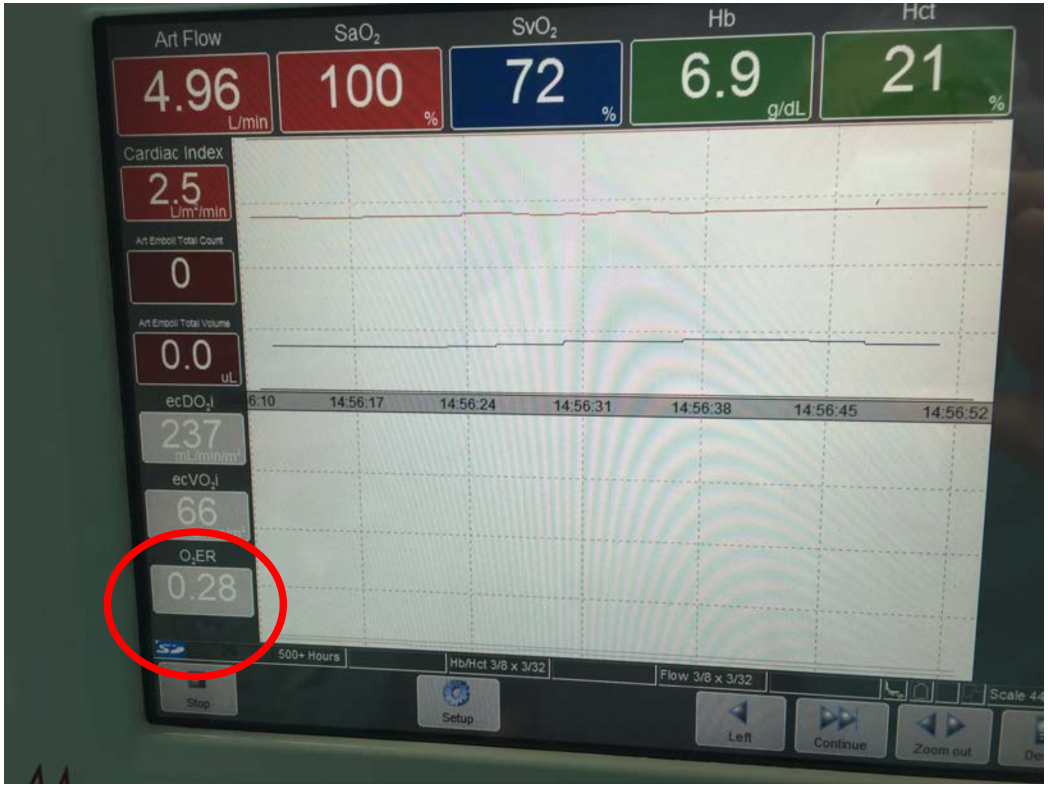

- Next he adds PC to increase the Hb level and the OER goes below 30%.

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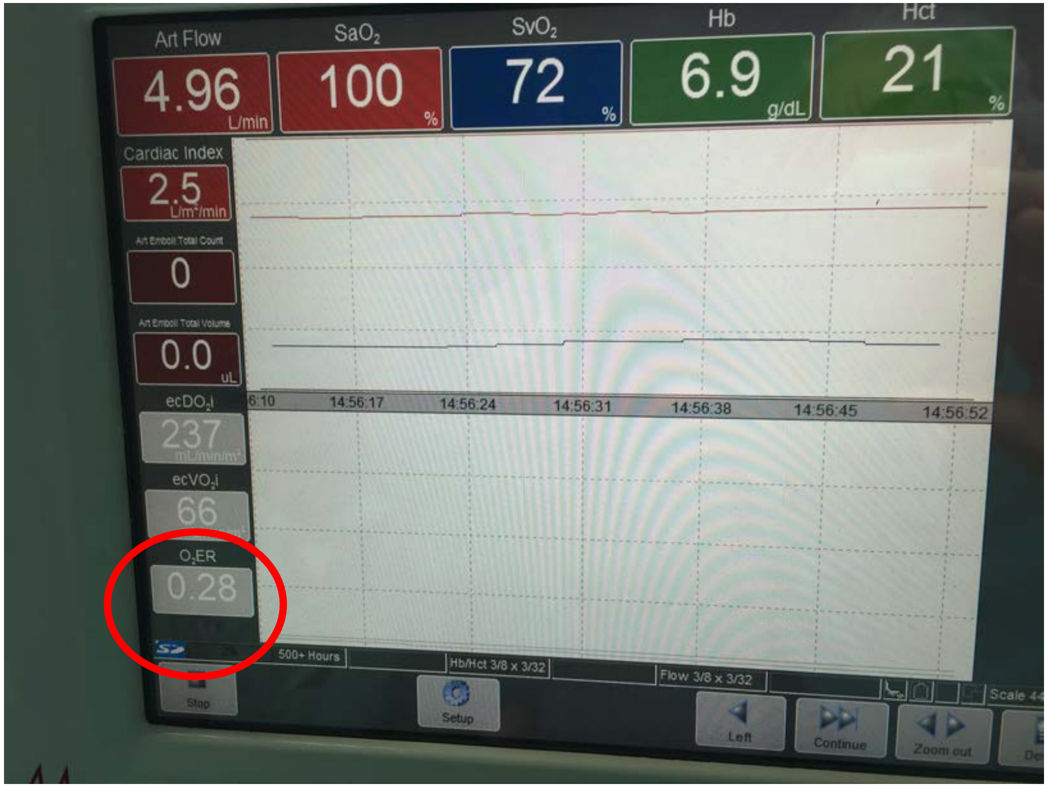

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спасибо

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