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IMPAIRED BLOOD-GAS EXCHANGE

Intraoperative blood gas analysis

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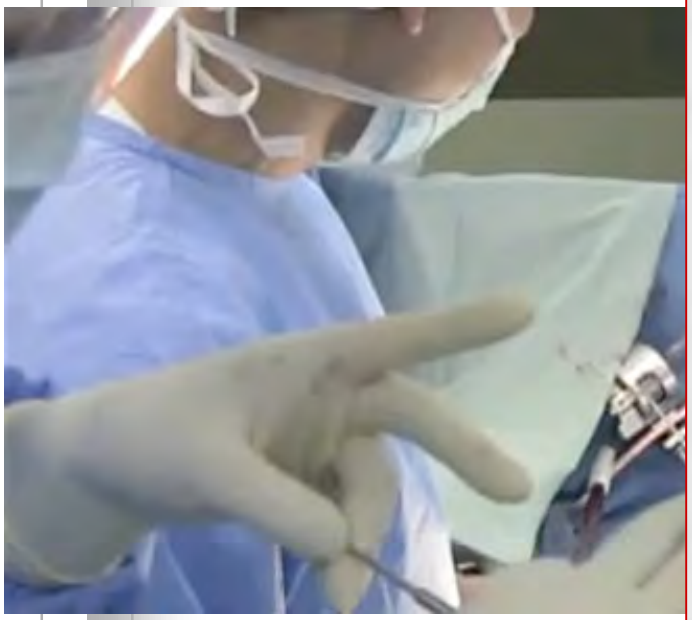
SARTD-CHGUV Sesión de Formación Continuada

Valencia 30 de Octubre de 2012

When do you perform BGA Intraoperatively?



RADIOMETER SERIE ABL 700

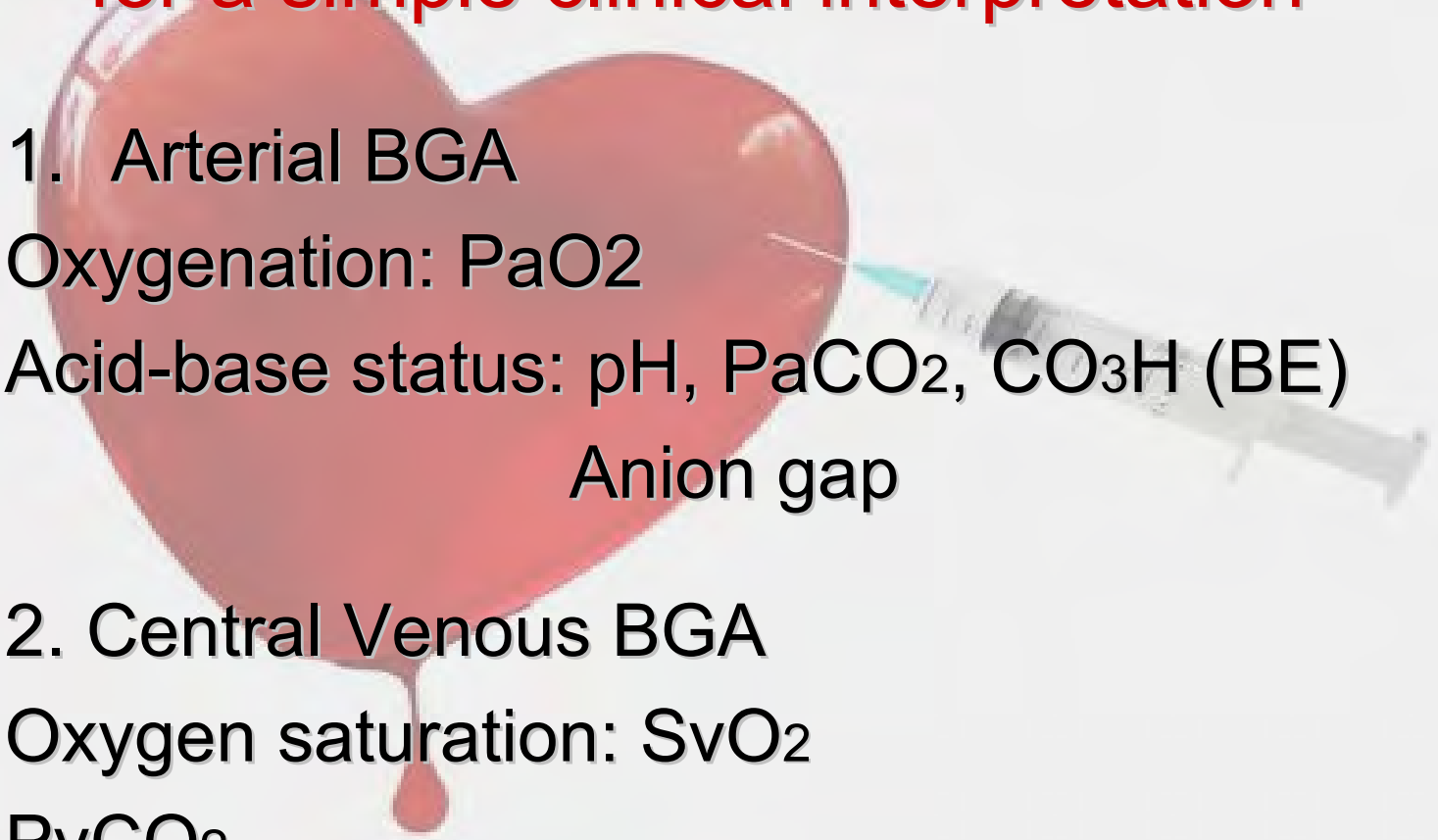
ABL725 CLINICO-REANIMACION 19:52:00 2004-05
INFORME PACIENTE Jeringa - J 195 uL Muestra # 3

Identificaciones			
ID paciente	203		
Apellido			
Nombre			
Tipo muestra	Arterial		
temp	37,0 °C		
$FO_2(I)$	21,0 %		
Valores de Gases en Sangre			
pH	7,373		[7,350 - 7,450]
pCO_2	37,6	mmHg	[32,0 - 48,0]
↑ pO_2	121	mmHg	[83,0 - 108]
Valores de Oximetría			
↓ $ctHb$	8,2	g/dL	[12,0 - 17,5]
↑ sO_2	99,8	%	[95,0 - 99,0]
FO_2Hb	96,1	%	[94,0 - 98,0]
↑ $FCOHb$	2,9	%	[0,5 - 1,5
$FHHb$	0,2	%	
$FMetHb$	0,8	%	[0,0 - 1,5
Hct_c	25,5	%	
Valores de Electrólitos			
cK^+	3,9	meq/L	[3,4 - 4,5
cNa^+	137	meq/L	[136 - 146
↓ cCa^{2+}	4,31	mg/dL	[4,61 - 5,17
↑ cCl^-	113	meq/L	[98 - 106
Anion Gap,K^+_c	6,6	meq/L	
Valores de Metabolitos			
↑ $cGlu$	125	mg/dL	[70 - 105
?↑ $cLac$	1,8	mmol/L	[0,5 - 1,6
Estado Ácido-Base			
ABE_c	-3,0	mmol/L	
$cHCO_3^-(P)_c$	21,4	mmol/L	
SBE_c	-3,0	mmol/L	
$cHCO_3^-(P,st)_c$	21,9	mmol/L	
$ctCO_2(B)_c$	45,7	Vol%	
$FShunt_e$	-5,0	%	
Estado de Oxigenación			
$p50_e$	26,30	mmHg	
$pO_2(a)/FO_2(I)_c$	574	mmHg	
$pO_2(A\text{-}a)_e$	.....	mmHg	

Routine:Thoracic, Cardiac,Neurosurgery

Emergency situation
Drop in SpO2
Ventilatory problems
Circulatory problems

Basic physiopathological approach for a simple clinical interpretation



1. Arterial BGA

Oxygenation: PaO_2

Acid-base status: pH, $PaCO_2$, CO_3H (BE)

Anion gap

2. Central Venous BGA

Oxygen saturation: SvO_2

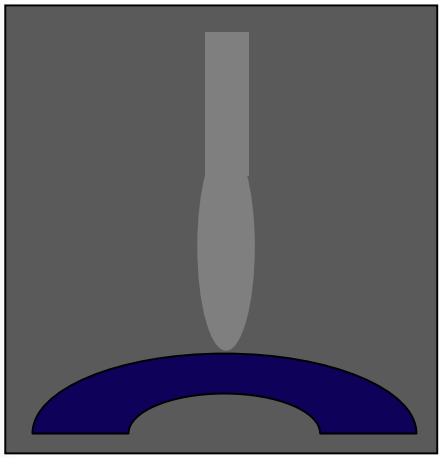
$PvCO_2$

Lung V/Q relationship

Tricompartimental model of Riley and Cournard

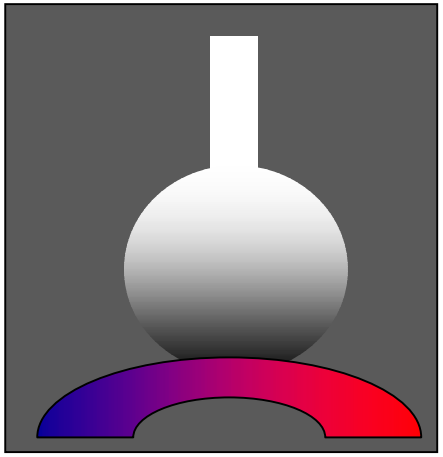
Effect on arterial blood gas

No V: Shunt



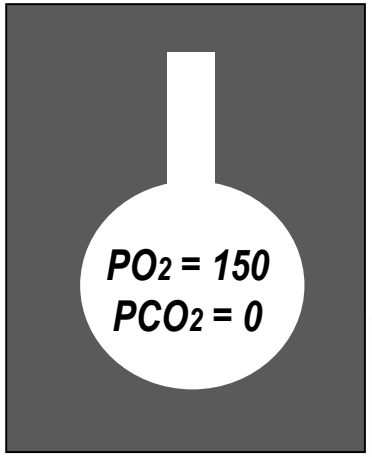
$PO_2 = 40$
$PCO_2 = 45$

Normal V/Q



$PO_2 = 100$
$PCO_2 = 40$

No Q: Dead space

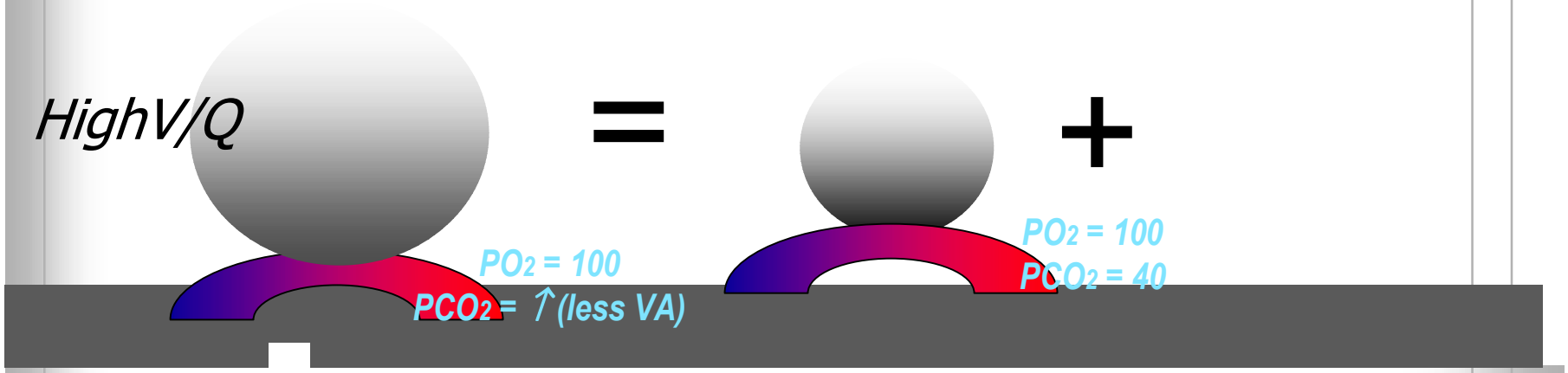


LOWV/Q ***NORMAL*** ***HIGH V/Q***

0 ***∞***

Lung V/Q relationship

Intermediate alveoli



Clinical conditions affecting V/Q

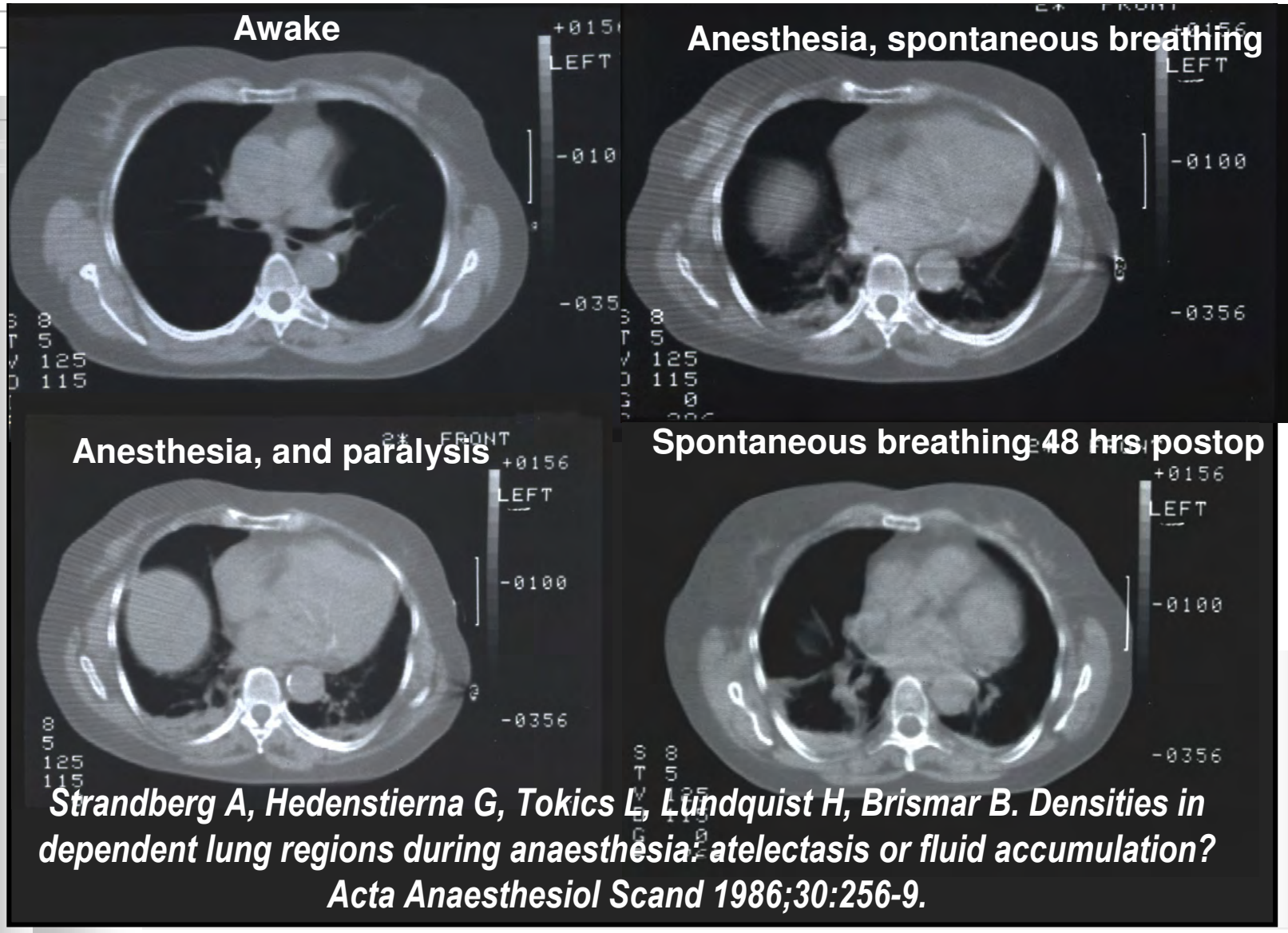
Conditions producing shunt effect:

Any situation reducing lung volume

Atelectasis, abdominal compresion, obesity, pleural efussion, pneumothorax, lobar-lung colapse, pneumonia….

Effect: Hypoxemia

Measurement: PaO_2/FiO_2



Strandberg A, Hedenstierna G, Tokics L, Lundquist H, Brismar B. Densities in dependent lung regions during anaesthesia: atelectasis or fluid accumulation? Acta Anaesthesiol Scand 1986;30:256-9.

Morbid obesity and pulmonary atelectasis.

The cruel reality

Postoperative Pulmonary Complications following Abdominal Surgery

	NORMAL	OBESE
ATELECTASIS	20%	50%
PNEUMONIA	15%	40%

Acta Anaesth Scand 1977; Am J Med 1981; Am Rev Respir Dis 1984; Chest 1997

NEJM 1999; Chest 2003; Crit Care Med 2004; Ann Intern Med 2006

Clinical conditions affecting V/Q

Conditions producing shunt effect:

Any situation reducing lung volume

Atelectasis, abdominal compresion, obesity, pleural efussion, pneumothorax, lobar-lung colapse, pneumonia….

Effect: Hypoxemia

Measurement: PaO_2/FiO_2

Conditions producing dead space:

Any situation reducing lung perfusion

Pulmonary embolism

Hipoperfusion: Low CO

Effect: Hypercapnia

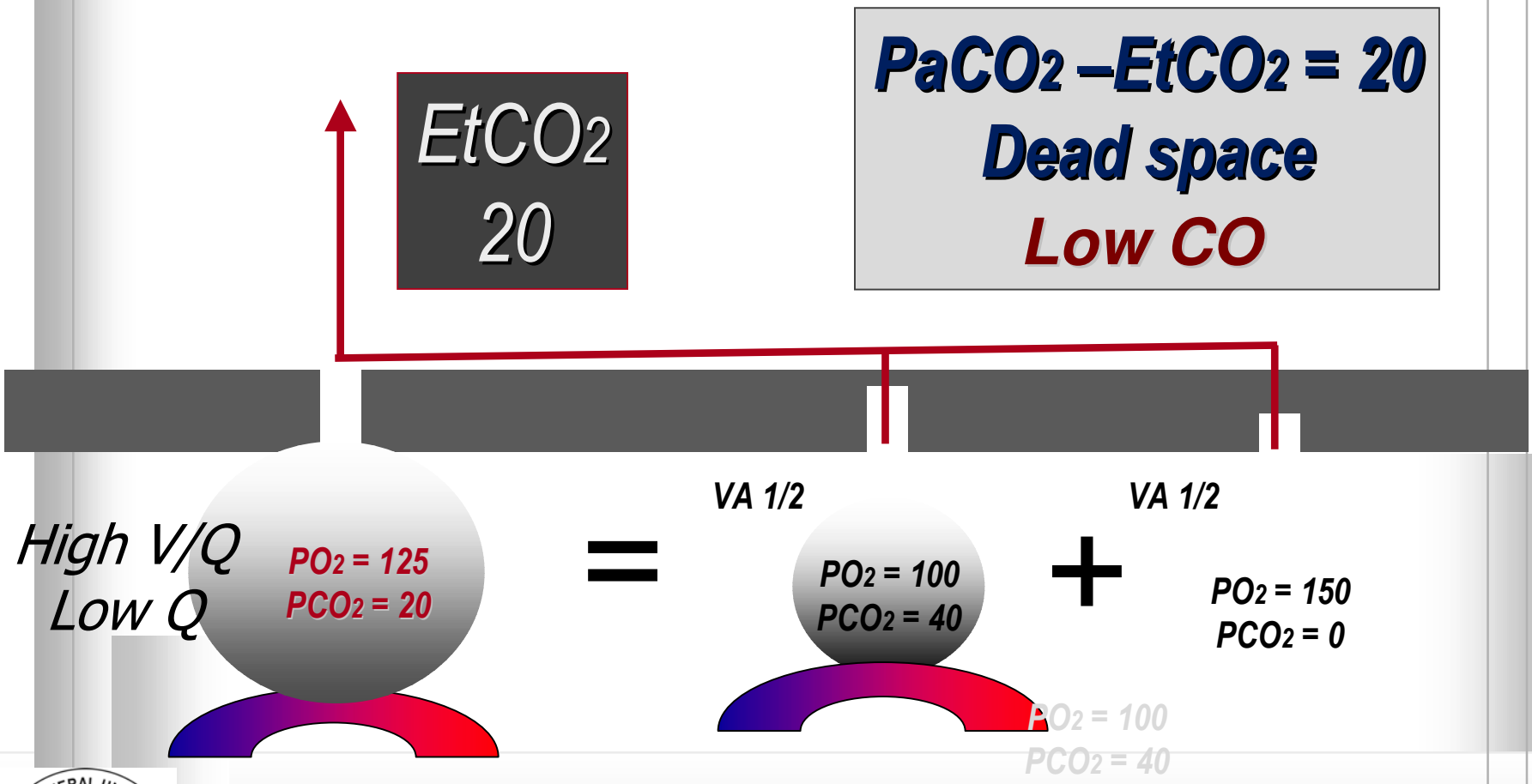
Measurement: $PaCO_2$

Why measuring $PaCO_2$ having $EtCO_2$

Clinical estimation of Physiological dead space

Why measuring $PaCO_2$ having $EtCO_2$

Clinical estimation of Physiological dead space



Basic clinical approach

1. Arterial BGA

Oxygenation: PaO2

Acid-base status: pH, PaCO2, CO3H (BE)

2. Central Venous BGA

Oxygen saturation: SvO2

PCO2

Not to forget on pH

Normal (physiological) range: 7.35-7.45

Acid sources in tissues:
-Metabolism
-Respiration (CO_2)

Metabolic acid production: buffered by bicarbonate
Excreted by the kidneys
Excess acids = reduction in bicarbonate

Respiratory acid production (CO_2): buffered by the blood
Eliminated by the ventilation
Excess CO_2 (reduced VE) = increase in $PaCO_2$
(not affecting bicarbonate)

pH (f) CO_3H / $PaCO_2$

Intraoperative disorders

1. Acidosis pH < 7.35

Metabolic: CO_3H reduction < 22 mEq/L (BE<0)

- Increase of metabolic acids
  Lactic, ketoacids, uremia
- Bicarbonate loss or reduced production (renal failure)

Respiratory: $PaCO_2$ increase > 45 mmHg

- Increase of CO_2 production (rebreathing, hyperthermia)
- Reduced elimination by ventilation
  Dead Space (hypoperfusion) - Hipoventilation (SB)

Both

2. Alkalosis pH > 7.45

Intraoperative disorders

1. Acidosis pH < 7.35
2. Alkalosis pH > 7.45

Metabolic: CO_3H increase > 26 mEq/L (BE>0)

- Loose of metabolic acids: ? (kidney –not that fast)
- Increase bicarbonate (external infusion)

Respiratory: $PaCO_2$ reduction < 35 mmHg

- Decrease in CO_2 production (hypothermia)
- Hyperventilation (high VE setting: VT-RF)

Both

Examples

pH: 7.24
PCO_2: 32
CO_3H: 12
EB: -15

pH: 7.55
PCO_2: 44
CO_3H: 38
EB: +15

pH: 7.24
PCO_2: 65
CO_3H: 21
EB: -2

pH: 7.55
PCO_2: 20
CO_3H: 20
EB: -3

Intraoperative acute disorders: not compensated

Arterial BGA intraoperative

Valores de Gases en Sangre		
↓ pH	7,318	
pCO_2	34,8	mmHg
↑ pO_2	119	mmHg
Valores de Oximetría		
↓ ctHb	9,8	g/dL
Hct_C	30,5	%
sO_2	98,8	%
FO2Hb	96,3	%
Valores de Electrólitos		
cK^+	3,8	mmol/L
cNa^+	145	mmol/L
↓ cCa^{2+}	3,79	mg/dL
↑ cCl^-	115	mmol/L
$Anion\ Gap_C$	12,9	mmol/L
Valores de Metabolitos		
↑ cGlu	245	mg/dL
↑ c.Lac	5,1	mmol/L
Estado Ácido-Base		
ABE_C	-7,6	mmol/L
$cHCO_3^-(P)_C$	17,3	mmol/L
$cHCO_3^-(P,st)_C$	18,3	mmol/L

Metabolic acidosis (acute)

- Hipoperfusion
  - ↑Lactate
- $DO2 = CO \times CaO2$
  - Volemia (Na)
  - Hb x 1,39 x Sat-HbO2
- ↑Glucose (ketoacids)

Renal function (Creatinine Urea)?

CO_3HNa administration: ????????

Mind the gap?

Hidden anions:
-Lactate
-Ketoacids (hyperglicemia)

are not hidden anymore

Forget the gap

Valores de Gases en Sangre			
↓ pH	7,329		[7,350 - 7,450]
↓ pCO_2	27,5	mmHg	[32,0 - 48,0]
↓ pO_2	63,4	mmHg	[83,0 - 108]
Valores de Oximetría			
$ctHb$	13,9	g/dL	[12,0 - 17,5]
↓ sO_2	91,6	%	[95,0 - 99,0]
↓ FO_2Hb	89,6	%	[94,0 - 98,0]
$FCOHb$	1,3	%	[0,5 - 1,5]
$FHHb$	8,2	%	
$FMetHb$	0,9	%	[0,0 - 1,5]
Hct_c	42,7	%	
Valores de Electrólitos			
cK^+	3,9	meq/L	[3,4 - 4,5]
cNa^+	137	meq/L	[136 - 146]
↓ cCa^{2+}	2,49	mg/dL	[4,61 - 5,17]
↑ cCl^-	117	meq/L	[98 - 106]
Anion Gap,K^+_c	10,2	meq/L	
Valores de Metabolitos			
↑ $cGlu$	193	mg/dL	[70 - 105]
↑			[0,5 - 1,6]

Valores de Metabolitos

↑	$cGlu$	193	mg/dL
↑	$cLac$	3,2	mmol/L

$FShunt_e$	31,1	%
Estado de Oxigenación		
$p50_c$	26,98	mmHg
$pO_2(a)/FO_2(I)_c$	127	mmHg
$pO_2(A\text{-}a)_e$	261,4	mmHg

Journal of Clinical Monitoring and Computing (2011) 25:223–230

PERIOPERATIVE METABOLIC ALKALEMIA IS MORE FREQUENT THAN METABOLIC ACIDEMIA IN MAJOR ELECTIVE ABDOMINAL SURGERY

Mona Boaz, PhD[1], Arkady Iskhakov, MD[2], Alexander Tsivian, MD[3], Mordechai Shimonov, MD[4], Haim Berkenstadt, MD[5], Alexander Izakson, MD[6], Peter Szmuk, MD[7,9], Shmuel Evron, MD[8,9], Michael Muggia, MD[2] and Tiberiu Ezri, MD[8,9]

Table 2. Incidence and type of perioperative acid base derangements

Acid base abnormality % of patients	Primary metabolic acidemia	Primary metabolic alkalemia	Primary respiratory acidemia	Primary respiratory alkalemia
Time				
Preoperative	0	13	0	9
Intraoperative	16	3	8	11
PACU	9	3	11	0
First three postoperative days	1	45	1	28
Overall perioperative percentage of acid–base derangements	23 *Mild—13 Moderate—7 Severe—3	49 **Mild—34 Moderate—11 Severe—4	18	38

Basic clinical approach

1. Arterial BGA

Oxygenation: PaO_2

Acid-base status: pH, $PaCO_2$, CO_3H (BE)

2. Central Venous BGA

Oxygen saturation: SvO_2

PCO_2

Hypovolemic-hypodynamic early phase

Circulatory insufficiency: Low CO

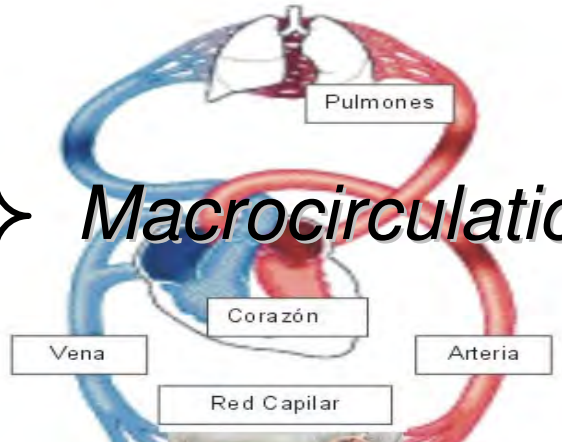
Hipovolemia

Miocardial depression

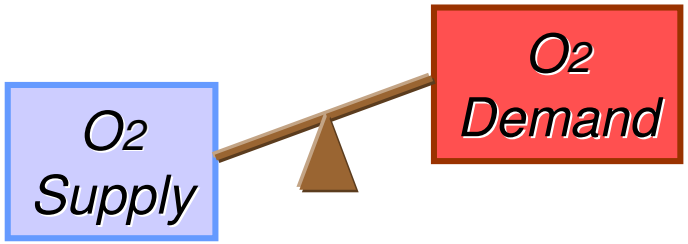
Vasoregulatory alteration

Hypoperfusion

Tisular ischemia



Macrocirculation



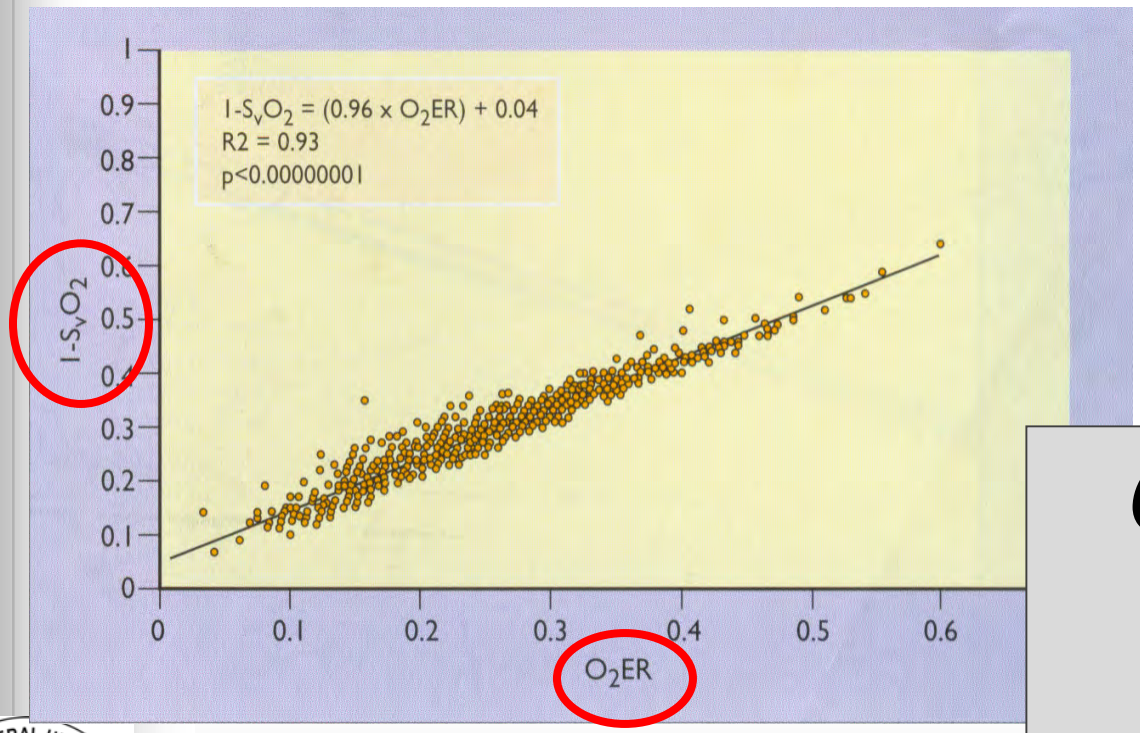
$$\uparrow O_2ER = \frac{\dot{V}O_2}{\dot{D}O_2}$$

Flow maldistribution

Tissue hypoxia

Reliability of SvO_2 as an indicator of the oxygen extraction ratio (O_2ER) demonstrated by a large patient data set

Keech J, Reed RL. J Trauma 2003 54:236-41



$$O_2ER \cong 1 - S_{\bar{v}}O_2$$

Circulatory failure

Low SvO_2

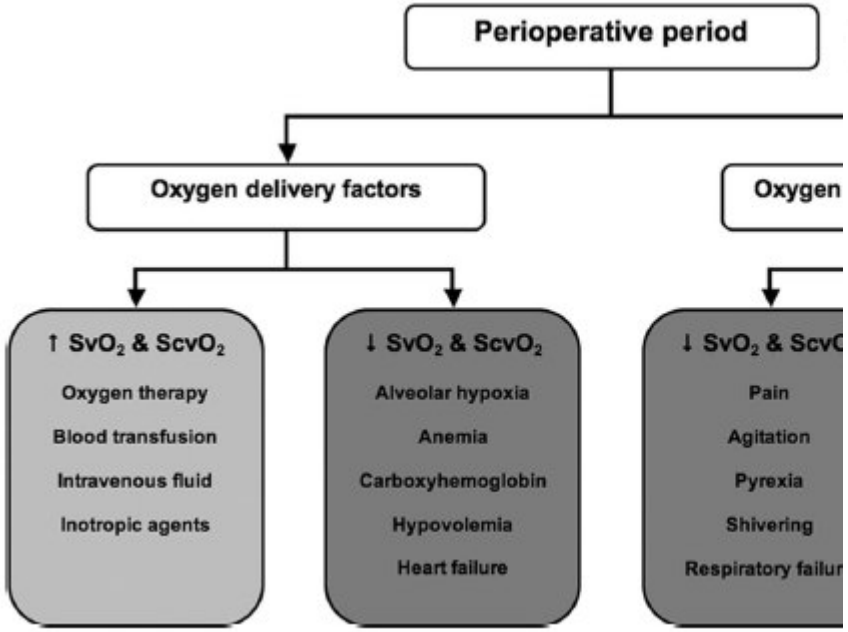
REVIEW ARTICLES

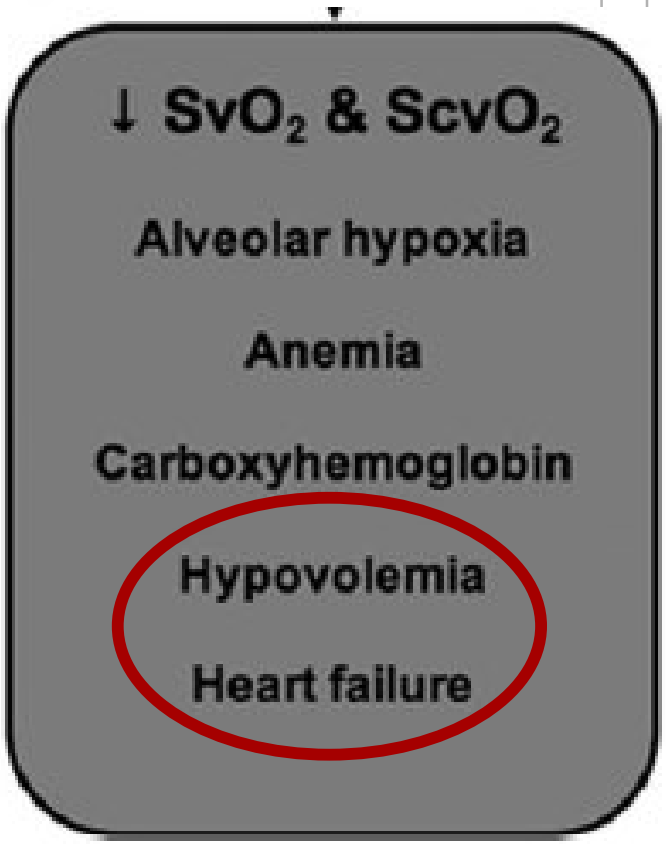
David S. Warner, M.D., and Mark A. Warner, M.D., Editors

Anesthesiology 2009; 111:649–56

Role of Central and Mixed Venous Oxygen Saturation Measurement in Perioperative Care

Stephen J. Shepherd, M.R.C.P., M.B.B.S., Rupert M. Pearse, F.R.C.A., M.B.B.S., M.D.†*





Normal SvO_2: 70 -77%

Research

Open Access

Multicentre study on peri- and postoperative central venous oxygen saturation in high-risk surgical patients

Collaborative Study Group on Perioperative ScvO2 Monitoring

Received: 5 Jul 2006 Revisions requested: 27 Jul 2006 Revisions received: 30 Aug 2006 Accepted: 13 Nov 2006 Published: 13 Nov 2006

60 patients intra-abdominal surgery >90 m

Shoemaker's criteria ≥2, ASA> 2

Table 2

Variables associated with postoperative complications

	Patients with complications ($n = 32$)	Patients without complications ($n = 28$)	P value[a]
$ScvO_2$ (percentage)			
Preoperative	74 ± 10	80 ± 9	0.031
Intraoperative			
After 1 hour of surgery	74 ± 10	80 ± 9	0.046
After 2 hours of surgery	73 ± 12	80 ± 11	0.022
After 3 hours of surgery	71 ± 11	81 ± 8	0.001
Lowest	60 ± 7	64 ± 7	0.036
Mean	70 ± 5	74 ± 6	0.005
Haemoglobin at ICU admission (g/l)	95 ± 17	105 ± 13	0.018
SAPS II	41 ± 14	27 ± 11	0.003
Hospital LOS (days)	13 ± 7	10 ± 4	0.001

Futier et al. Critical Care 2010, 14:R193
http://ccforum.com/content/14/5/R193

CRITICAL CARE

RESEARCH Open Access

Central venous O_2 saturation and venous-to-arterial CO_2 difference as complementary tools for goal-directed therapy during high-risk surgery

Emmanuel Futier[1*], Emmanuel Robin[2], Matthieu Jabaudon[1], Renaud Guerin[1], Antoine Petit[1], Jean-Etienne Bazin[1], Jean-Michel Constantin[1], Benoit Vallet[2]

Abdominal surgery: 36 restrictive fluid-GDT (6 ml/Kg)

34 standard fluid-GDT (12 ml/Kg)

GDT preload optimization for SvO2>71%

CO/SV (doppler): fluid boluses of 250 mL HES

Measurement: $PvCO_2 - PaCO_2 = Pv\text{-}aCO_2$

Rationale

Fick principle

Arterio-venous O_2 difference = O_2 consumption/Cardiac output

Applied to CO_2

Pv-a CO_2 = VCO_2/CO

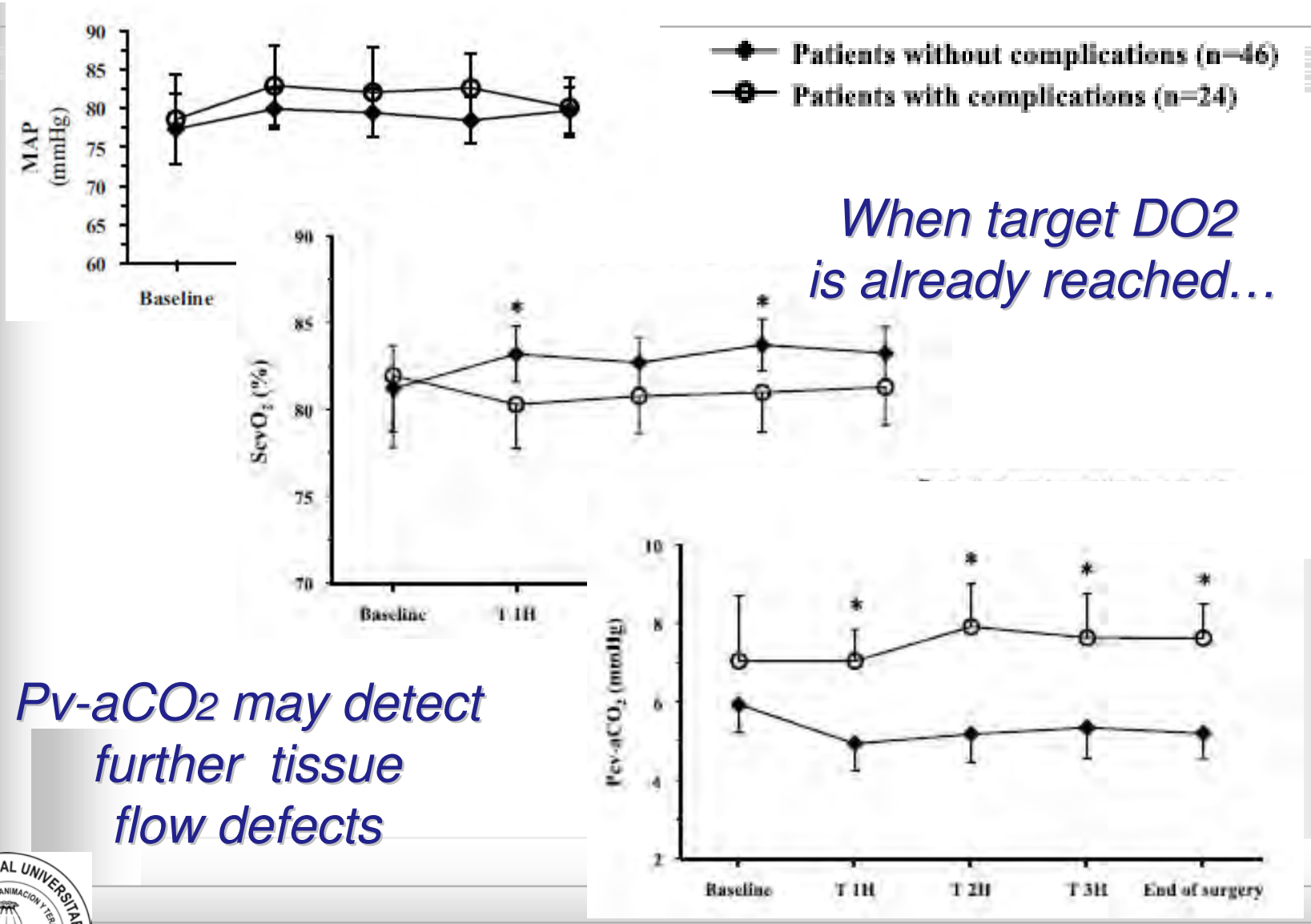
Respiratory quotient =VCO_2/VO_2

VCO_2 = RQ x VO_2

Pv-a CO_2 = VCO_2/CO = RQ x VO_2/CO

Table 3 Intraoperative biological data

	Patients with complications (n = 24)	Patients without complications (n = 46)	P
Arterial pH			
Baseline	7.42 ± 0.03	7.43 ± 0.04	0.27
T 1H	7.39 ± 0.04	7.41 ± 0.04	0.11
T 2H	7.39 ± 0.04	7.40 ± 0.02	0.17
T 3H	7.38 ± 0.05	7.39 ± 0.03	0.78
End of surgery	7.37 ± 0.05	7.38 ± 0.05	0.26
Arterial PO_2, mmHg			
Baseline	186 ± 39	195 ± 52	0.59
T 1H	185 ± 43	180 ± 41	0.56
T 2H	173 ± 44	179 ± 37	0.61
T 3H	172 ± 43	178 ± 35	0.46
End of surgery	178 ± 44	181 ± 37	0.59
Arterial PCO_2, mmHg			
Baseline	36 ± 5	36 ± 4	0.90
T 1H	37 ± 4	36 ± 3	0.41
T 2H	37 ± 4	36 ± 3	0.53
T 3H	36 ± 5	36 ± 3	0.62
End of surgery	36 ± 5	37 ± 3	0.36
BE, mmol L^{-1}			
Baseline	-1.7 ± 4.3	-0.5 ± 2.6	0.71
T 1H	-3.2 ± 2.7	-1.1 ± 2.2	0.02
T 2H	-2.6 ± 2.9	-1.5 ± 2.1	0.31
T 3H	-2.4 ± 2.8	-2.4 ± 2.2	0.65
End of surgery	-4.0 ± 2.6	-2.8 ± 2.7	0.11



When target DO2 is already reached…

Pv-aCO2 may detect further tissue flow defects

Summary: Intraoperative BGA

Rutine: High risk surgery/Emergency
Do not wait for problems

Arterial BGA:

- Oxygenation: P/F: lung volume/colapse/recruitment
- Acid-base status: pH, PCO_2, BE
  - Ventilation: High VT, low Tº: Respiratory alkalosis
  - Circulation: Low CO + High VD/VT
    - Respiratory acidosis (+low $EtCO_2$)
    - Metabolic acidosis (+↑lactate)

Central venous BGA: SvO_2: Low: Hypoperfusion

$PvCO_2$-$PaCO_2$: High:Hypoperfusion

Muchas gracias por vuestra atención