Goals of the coming lectures

To provide a physiological framework to patient care

Does instant access to compiled information undermine clinical cognition?

Prof Jerome Kassirer
Stanford University School of Medicine

The Lancet 2010; 376: 1510-11

"trainees are **learning the minimum**, they **cite** practice **guidelines**.."

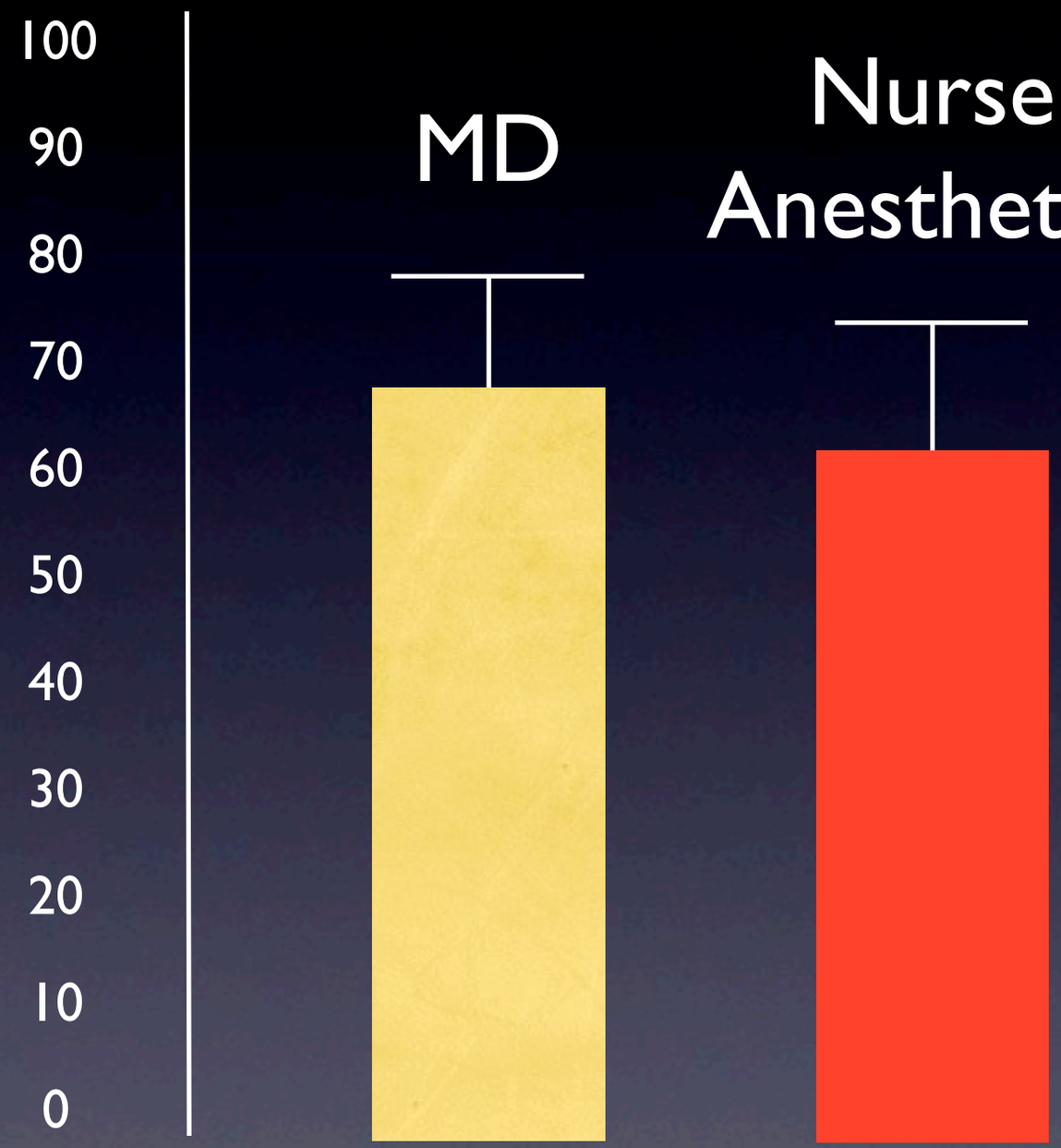
"..their **knowledge** of clinical medicine will be **superficial** ... their clinical reasoning skills will suffer."

"... little need to remember **pathophysiological mechanisms** ... when summaries are available ...

"...clinical decisions derived from practice guidelines **without understanding** the basis for the recommendations."

"As teachers, we are not blameless if the next generation is short-changed."

Performance of CRNAs vs Anesthesiologists in a simulation-based skills assessment



"..the overall difference...was small in magnitude"

Anesthesia Analgesia Vol. 108, No. 1, January 2009

Physiological approach to the sick patient

- Order from chaos - using basic principles
- Basic cellular physiology
- Oxygen delivery basics
  - "Big 3" factors
  - Oxygen extraction - last chance
- Other causes of dysoxia

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Clinical Case

38 year old male vs. lead projectile

BP = 75/45 HR = 122

Cold peripheries

RR = 37 Sat 02=90%

What are your priorities ?

Oxygen delivery ~

Cardiac output x Hb x % Sat O2

Cardiac output x Hb x % Sat O2

Preload

Effective blood volume
Capacitance
Obstruction
Septal shift
IV fluid
    volume
    C.O.P.

Pump failure

Arrhythmias
Ischaemia
Valvular problems
Septal shift

Afterload

RAA adaptaion
Sepsis
Valvular problems
Pulmonary embolism
Hypertension
Shunts

Heart rate

Anaemia

Fe def
Dilutional
Inflammatory
Vitamin deficiency
Aplastic

Abnormal Hb

Sickle cell
Thalassaemia
met Hb
CO Hb

Hemolysis

free Hb and NO
Pulmonary hypertension
Hypercoagulability

Hyperviscosity

PRV
Acclimatisation

Inspired O2

Altitude
Hyperbaric O2

Hypoventilation

Decreased respiratory drive
    drug induced
CVA
Fatigue (asthma)
Obstruction
    Sleep apnoea syndrome
    Decreased consciousness

Ventilation/perfusion abnormalities

Shunt
    Pneumonia
    Pulmonary oedema
Dead space
    Pulmonary embolism
    Fat embolism
Mixed
    COPD
    Asthma

A Physiological framework

Lectures :

- Introduction
- Cardiac output - assessing volume status 1+2
- Cardiac output - types of fluids
- Cardiac output - inotropes/vasopressors
- Haemoglobin
- Hypoxia - ARDS
- Putting it all together

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Man vs Machine

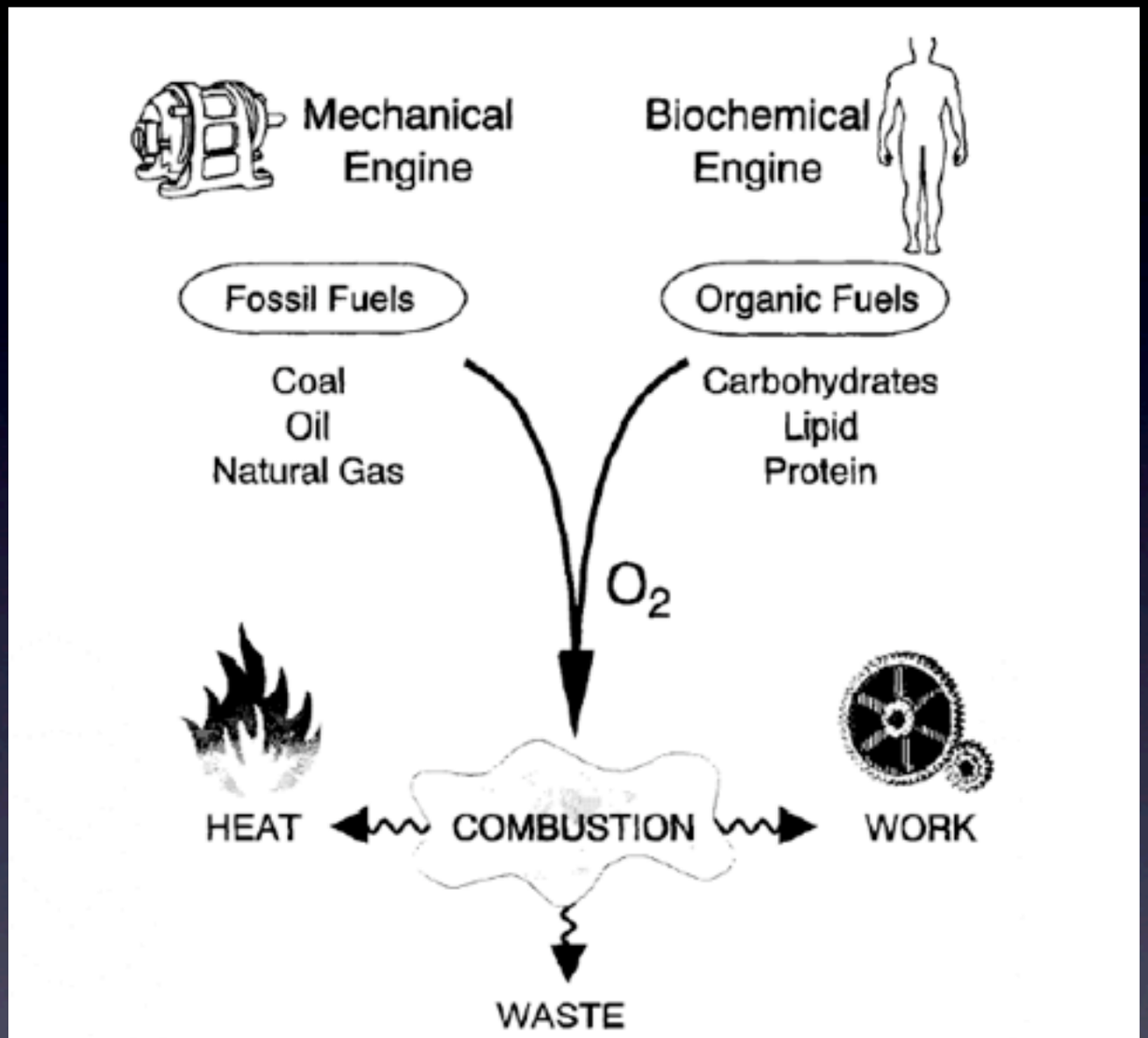
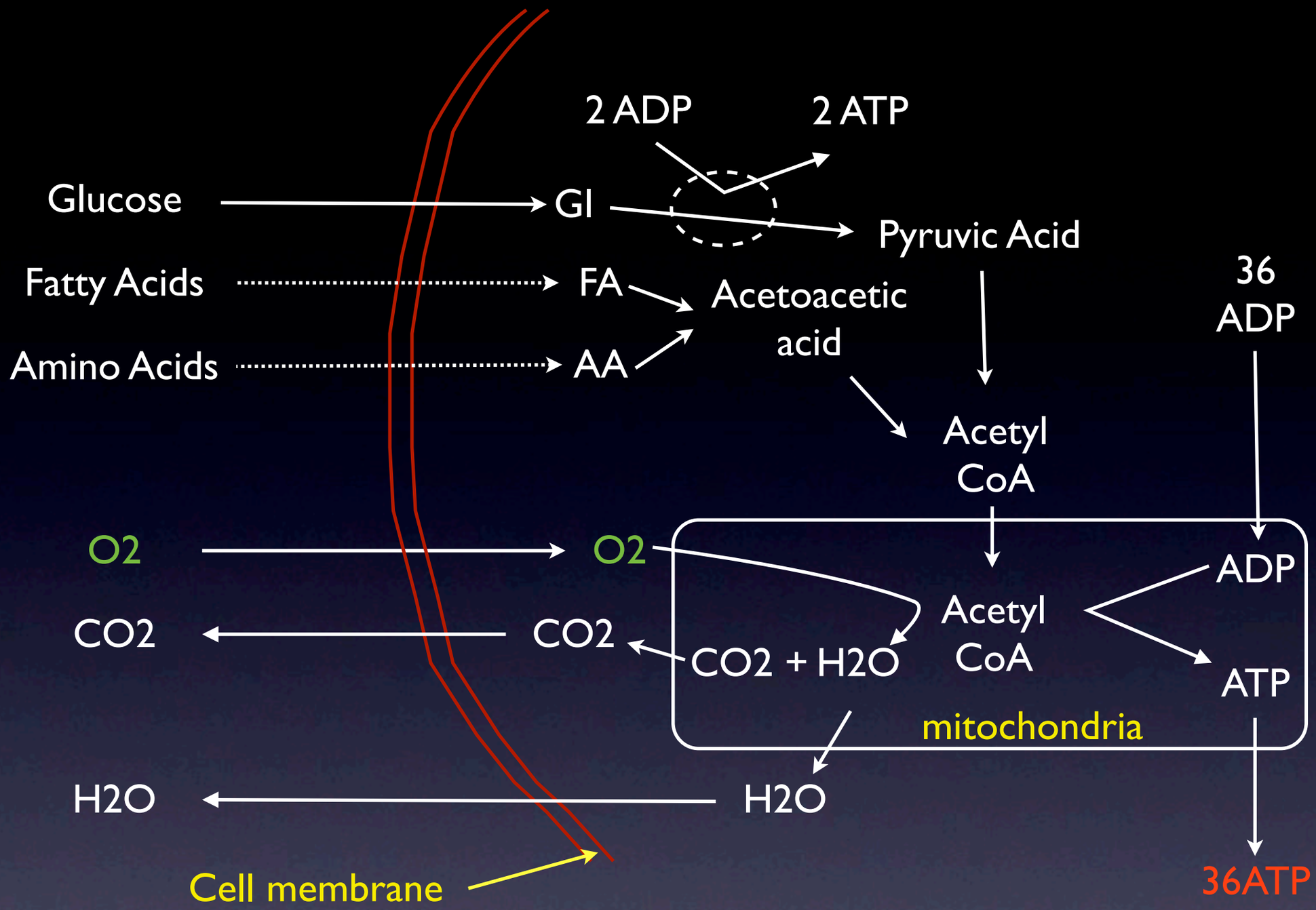


FIGURE 45.1 Energy conversion by two internal combustion engines. One engine is mechanical, and the other is biochemical.



Goal is to create energy (ATP) for :

- membrane transport
- protein synthesis
- muscle contraction

Glucose

Pyruvate → Lactate

**Anoxia

Endotoxin

Thiamine deficiency

(Oxidation)

36 ATP

2 ATP

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02 Delivery Compensation - 2 Phases

- Phase 1 - The *"Big 3"* compensate each other
  - Cardiac Output
  - Hb
  - O2 Saturation
- Phase 2 - *Oxygen Extraction*
  - If O2 delivery decreases, O2 extraction increases

At rest, body needs
~ 250 ml oxygen / min

Oxygen delivery ~

Cardiac output x Hb x % Sat O2

5 litre/min x 15 gm/dl (x1.34) x 100%

5 litre/min x 200 ml O2 / litre

= 1000 ml O2 /min delivered

Body needs ~ 250 ml oxygen / min

1000 ml O2 /min delivered

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Cardiac output x Hb x % Sat O2

- If one variable is halved, the oxygen delivery is reduced to 1/2
- If two variable is halved, the oxygen delivery is reduced to 1/4
- If all three variables are halved, the oxygen delivery is reduced to 1/8th

= 125 ml/min O2 delivered

this is **incompatible** with life

Clinical Case

- 79 year old woman 3rd day post total hip replacement
- Hb 7.5 gm/dL but well, therefore not for transfusion
- **Later** found to be confused, breathless and passes moderate quantity of melaena
- What are your main concerns?

Cardiac output x Hb x % Sat O2

5l 7.5 gm 100 %

500 O2 ml/min delivered

Cardiac output x Hb x % Sat O2

5l 7.5 gm 100 %

2.5 l 7.5 gm 100 %

250 O2 ml/min delivered

First compensatory phase

Cardiac output x Hb x % Sat O2

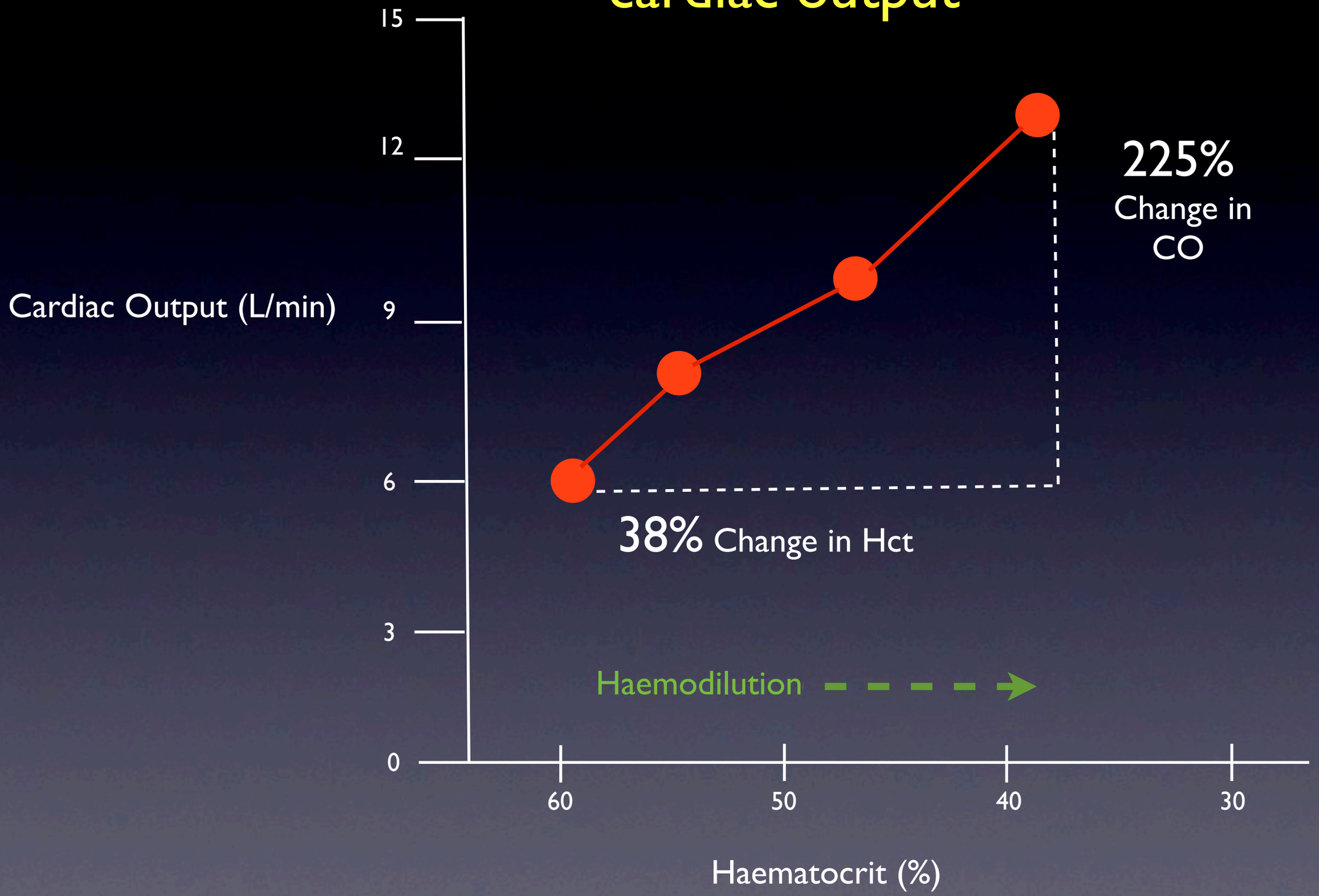
So how do the “Big 3” factors interact ?

Factor # 1 - Cardiac output

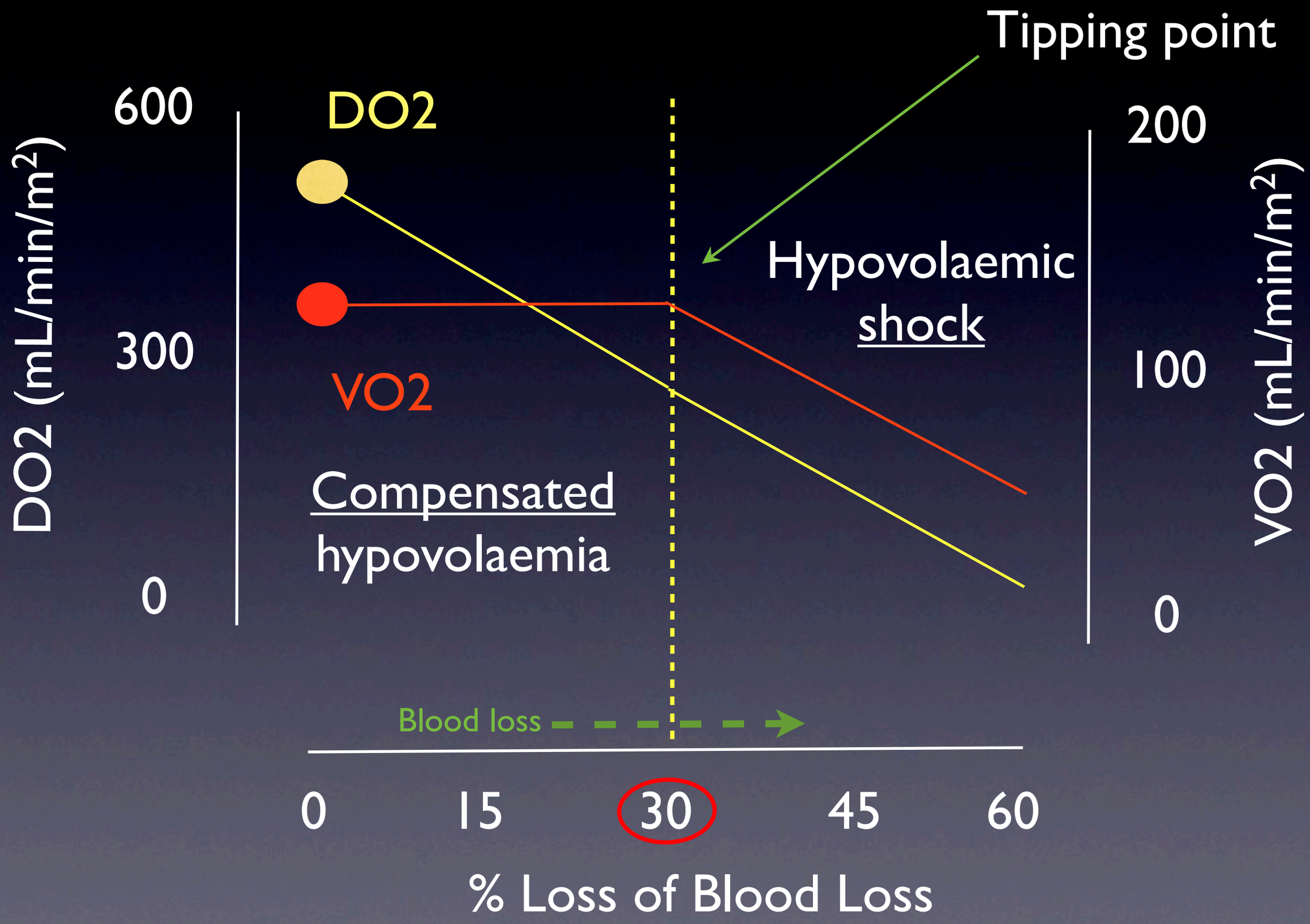
Cardiac output

- A non athlete can increase cardiac output by ~ **5 times**
  - due to sympathetic stimulation and parasympathetic inhibition
    - beware beta blockade and chronic heart failure
- Most important of the 3 factors
  - linear in clinical range
  - rapid response

Drop in Hb is compensated for by an increase in cardiac output



Decreased Cardiac Output - the most important factor in O2 delivery



Effective cardiac output

- Effective cardiac output = output meeting bodies needs without requiring compensatory mechanisms

- Circulatory volume - a major determinant of C.O.

- Use inotropes to achieve pre-morbid BP only AFTER volume resuscitation

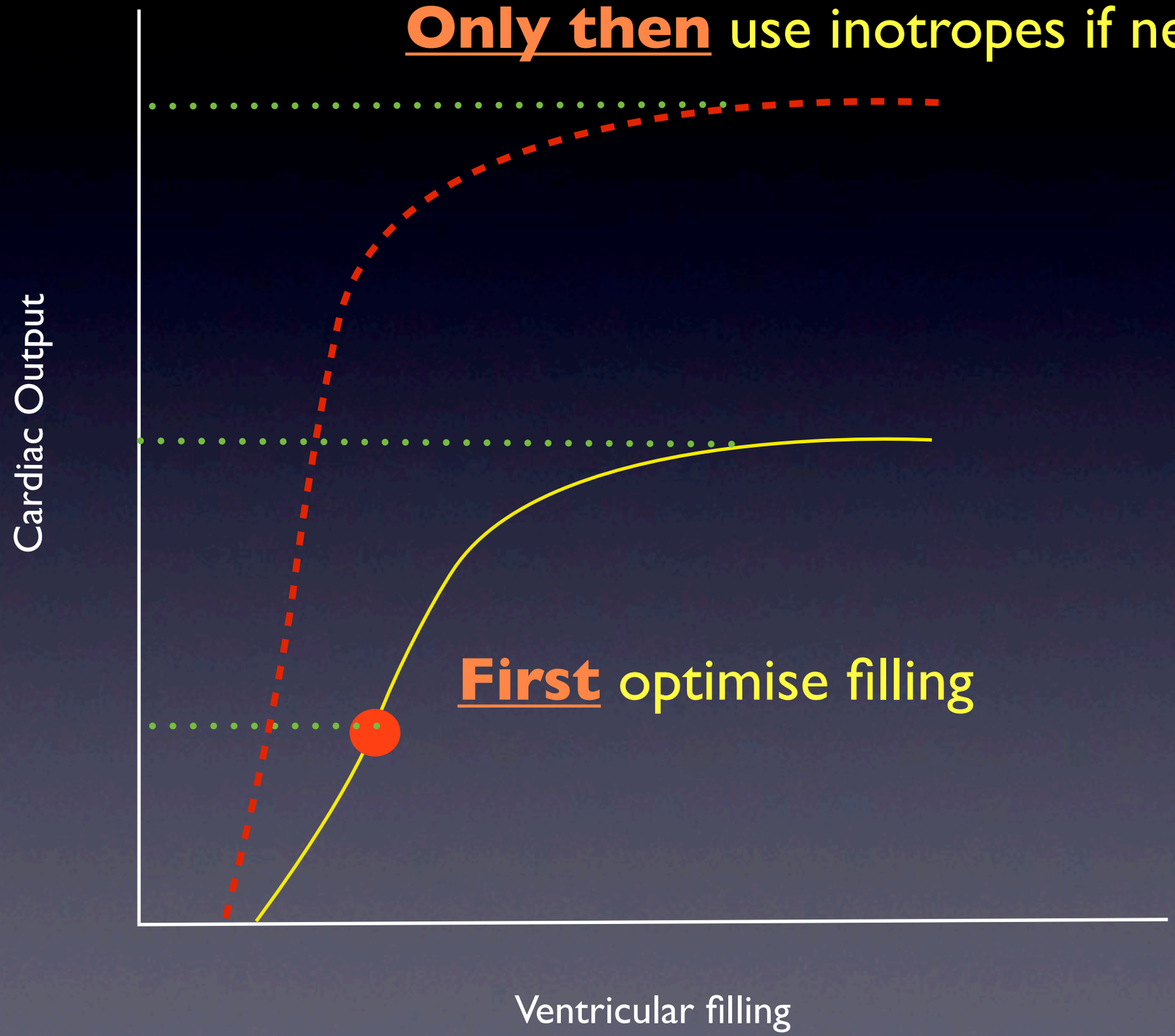
Adequate cardiac output

Aim for:

- Clinical
  - Warm toes
  - Normal BP
  - Good urine output
- Biochemical
  - SvO2 (normal ~ 75%)
  - Lactate
- Direct measurement

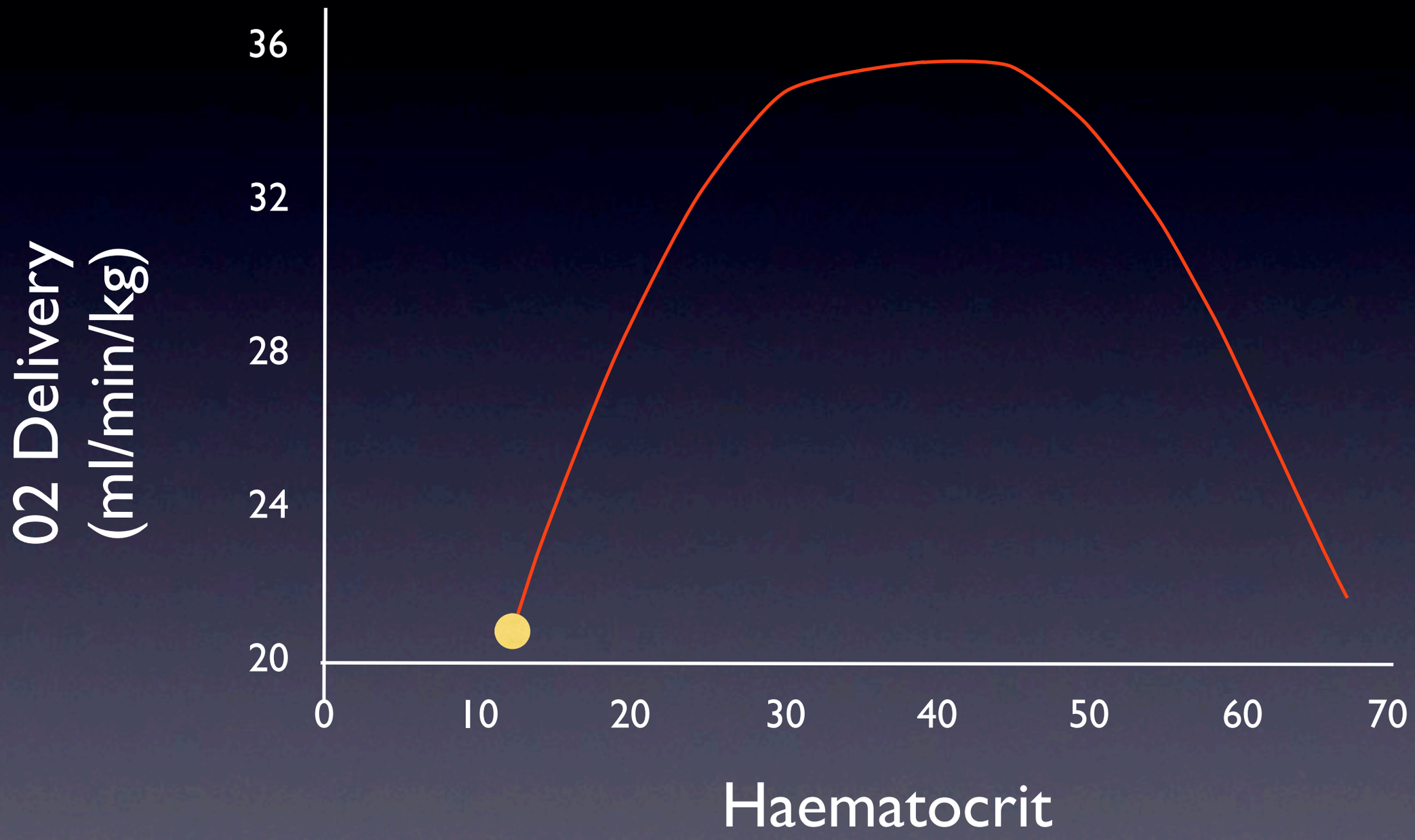
Achieving effective cardiac output

Only then use inotropes if needed



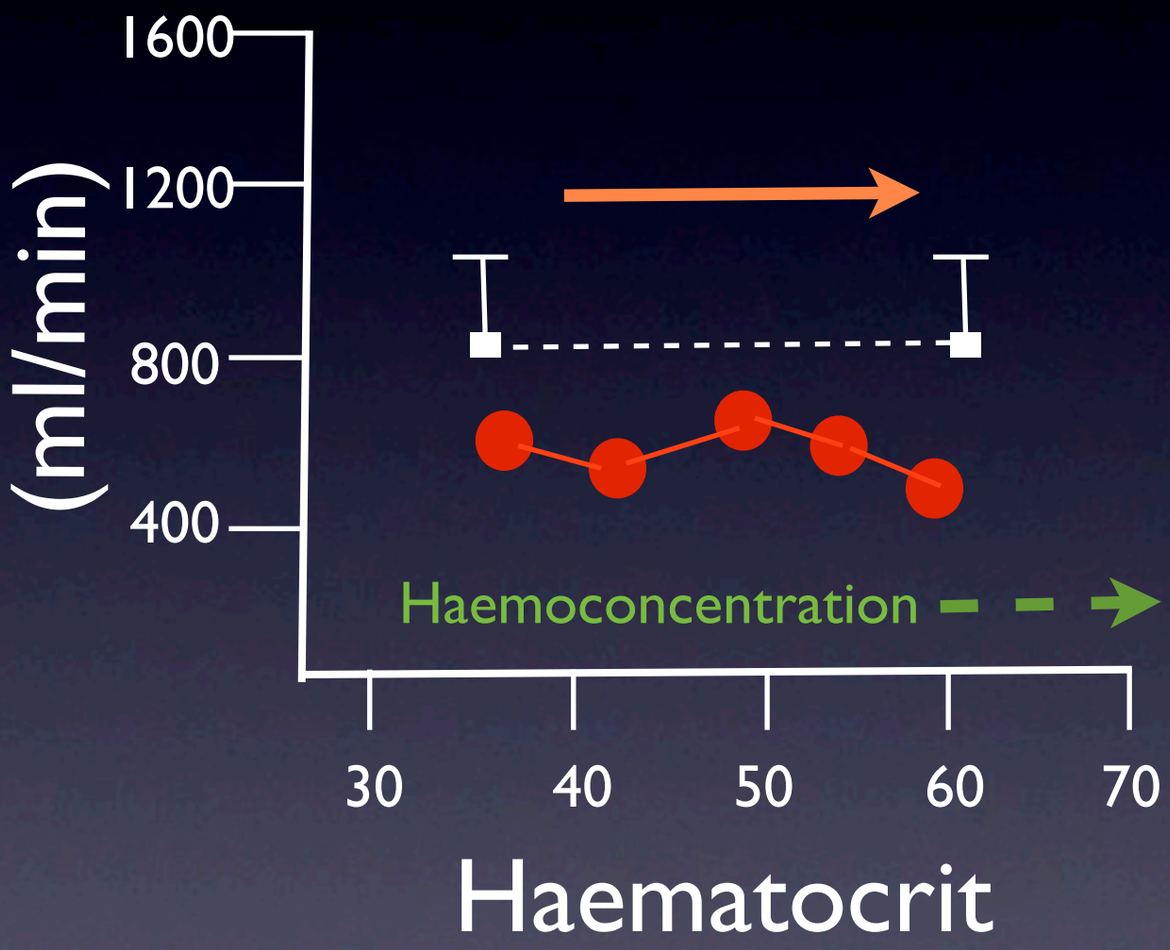
Factor # 2 - Haemoglobin

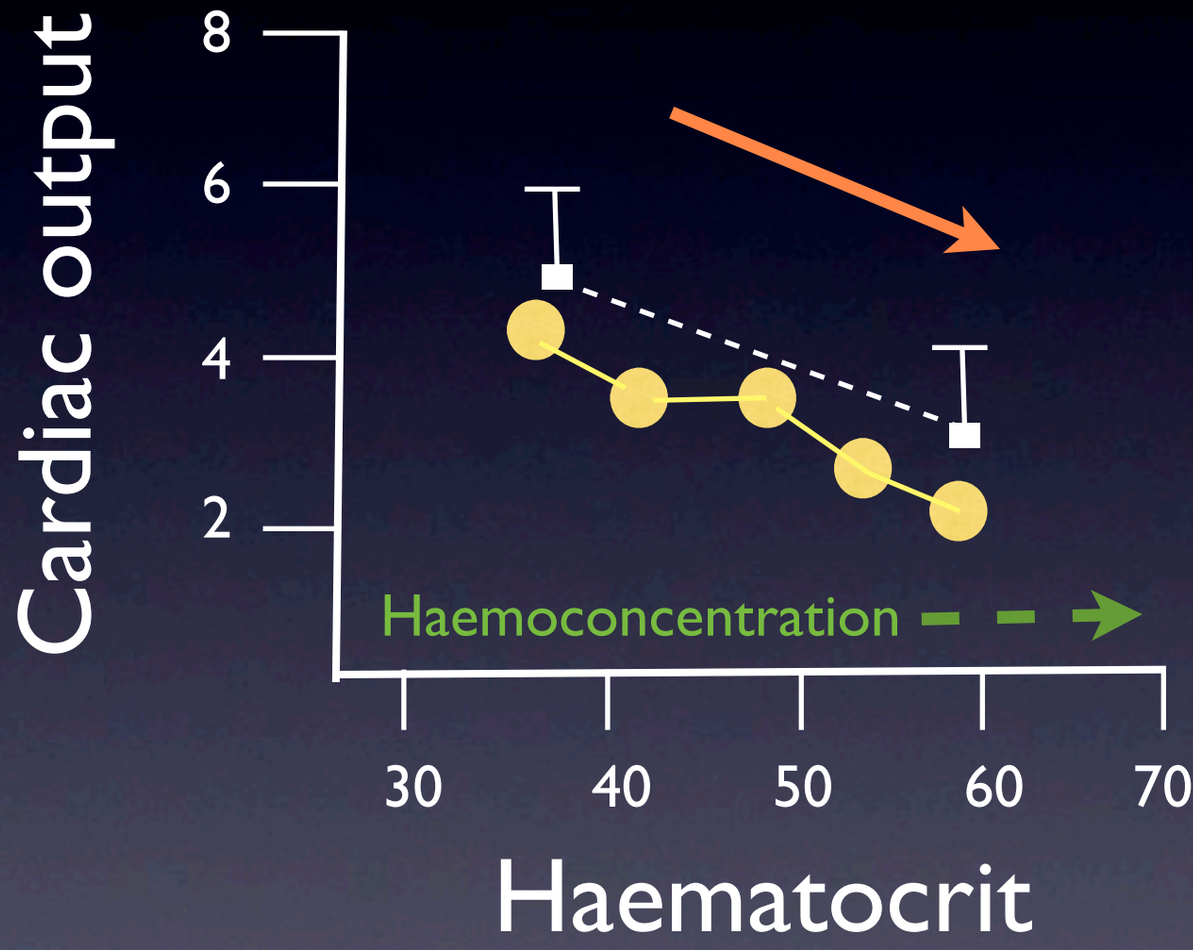
But there is a limit to the compensation by Hb



Circulation Research, Volume IX, January 1961

Hemodynamic response to normovolemic polycythemia during exercise in dogs

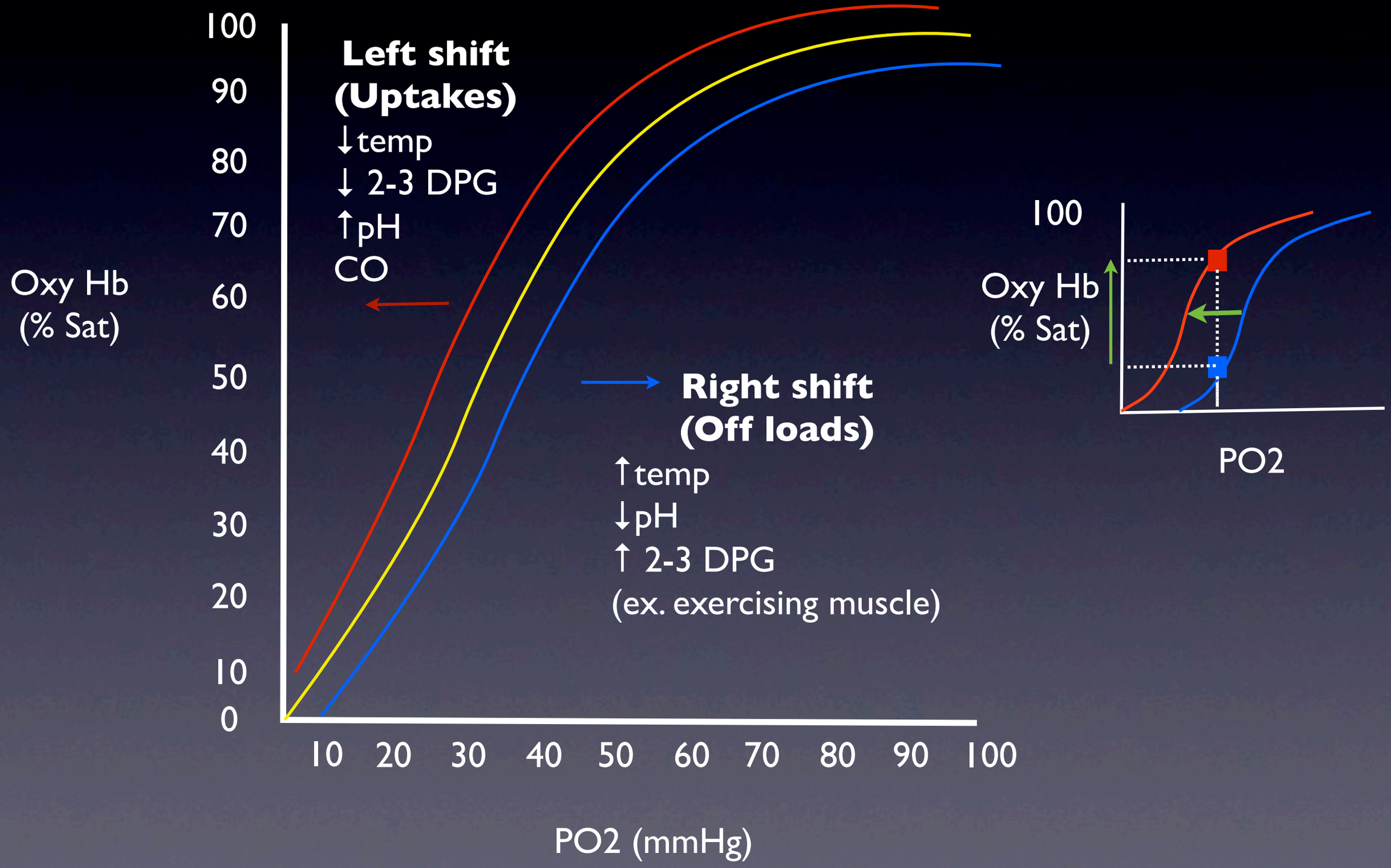




Circ Res 1985; 56: No. 6

Factor # 3 - Oxygen Saturation

Oxy-Hb dissociation curve



So how well do we tolerate a low p02?

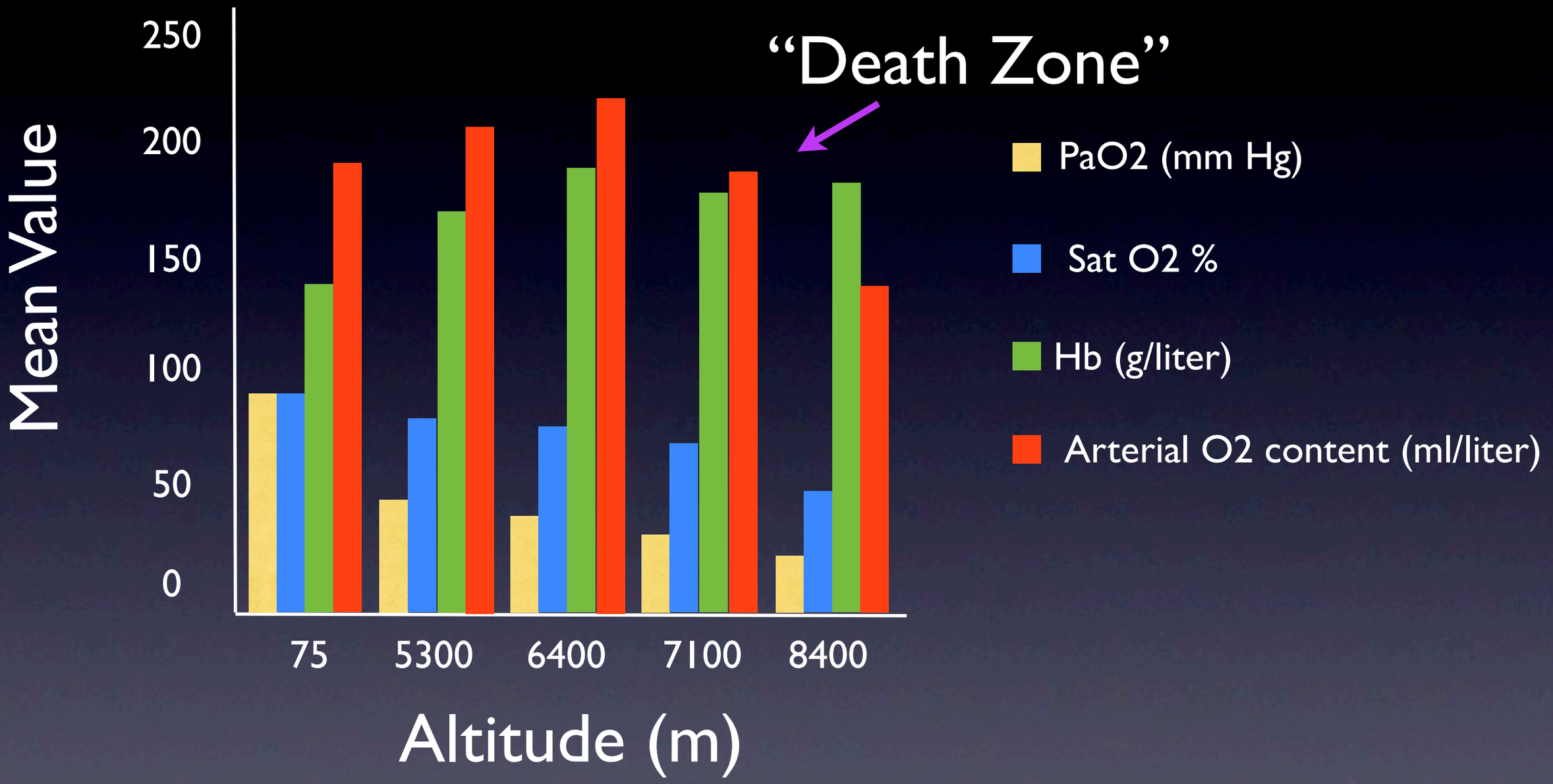
Arterial blood gases and derived values taken at 8400 m, during descent of Mt. Everest

8848 m
Barometric pressure
= 1/3rd sea level

Variable	N	Group Mean
pH	7.4	7.53
PaO2 (kPa)	13.3	3.27
Sat O2%	97	54%
PaCO2 (kPa)	5.32	1.77
Lactate (mmol/l)	1	2.2
Hb (g/l)	15	19.3

Grocott MPW et al. N Engl J Med 2009;360:140-149

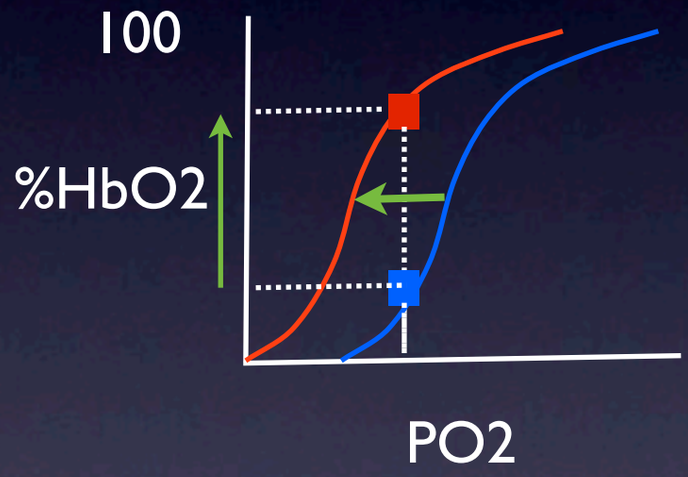
How do we adjust on the summit of Everest?



Grocott MPW et al. N Engl J Med 2009;360:140-149

Why was O2 content stable?

- Rise in Hb, increased oxygen carrying capacity
- Hyperventilation lowered pCO2 ⇨
- pH rises ⇨



- Left shift of oxyHb curve ⇨
  - Therefore greater saturation for a given pO2

But all factors are not created equal !

Clinical Case

- 55 yr old male pedestrian v car
- FAST scan shows large amounts of free fluid in abdomen
- Comminuted fracture of femoral shaft
- Taken to theatre after 3 l of colloid
- Blood on the way !
- Hct on Hemacue 15%
- O2 saturation is 80% on 6l/min MC mask
- CVP = 4 cm H2O
- BP 110/90; HR 95/min

Clinical Case

- With regards to O2 delivery, what do I worry about most:

  Hct or O2 Saturation ?

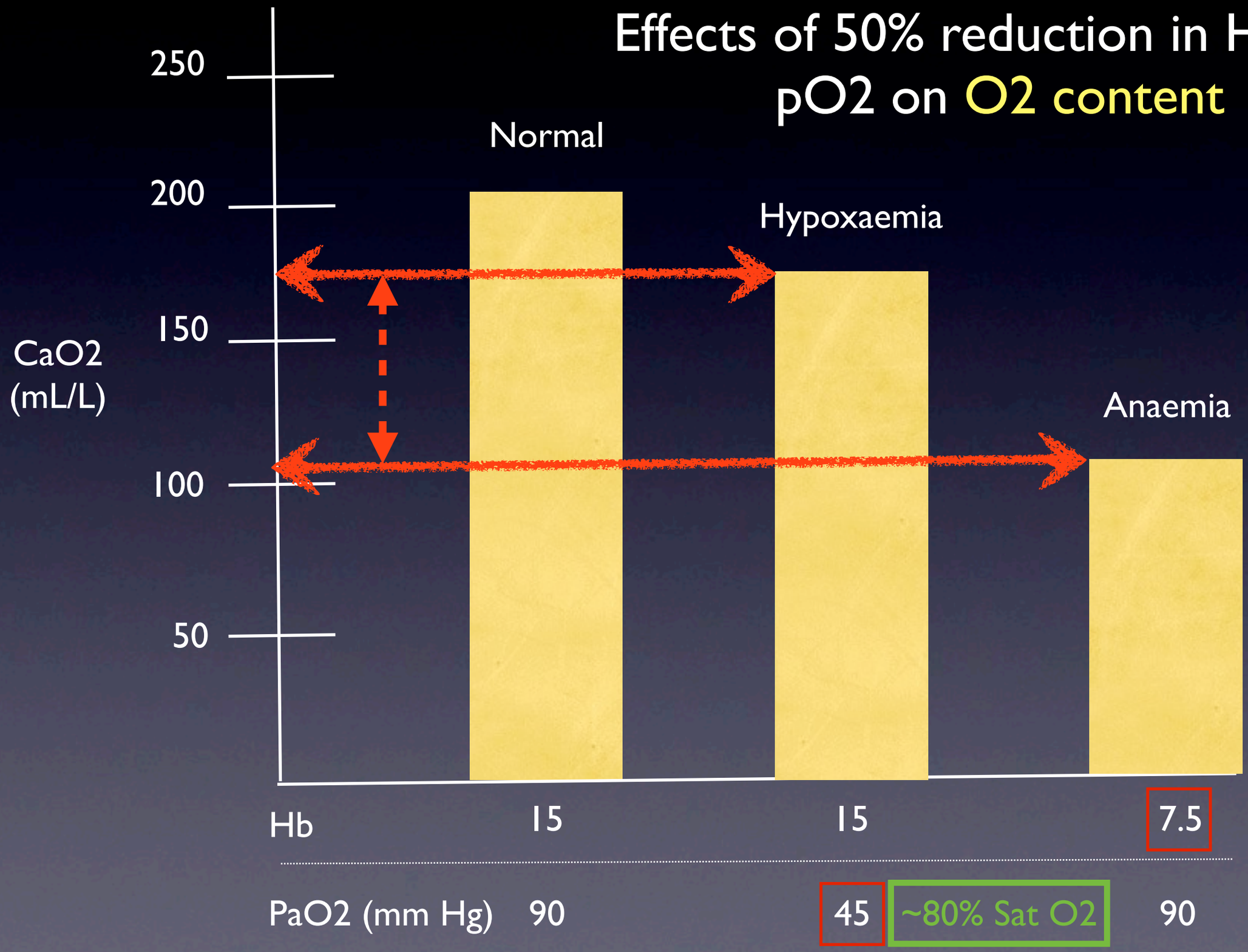
- What may happen on induction of anaesthesia?

  Why?

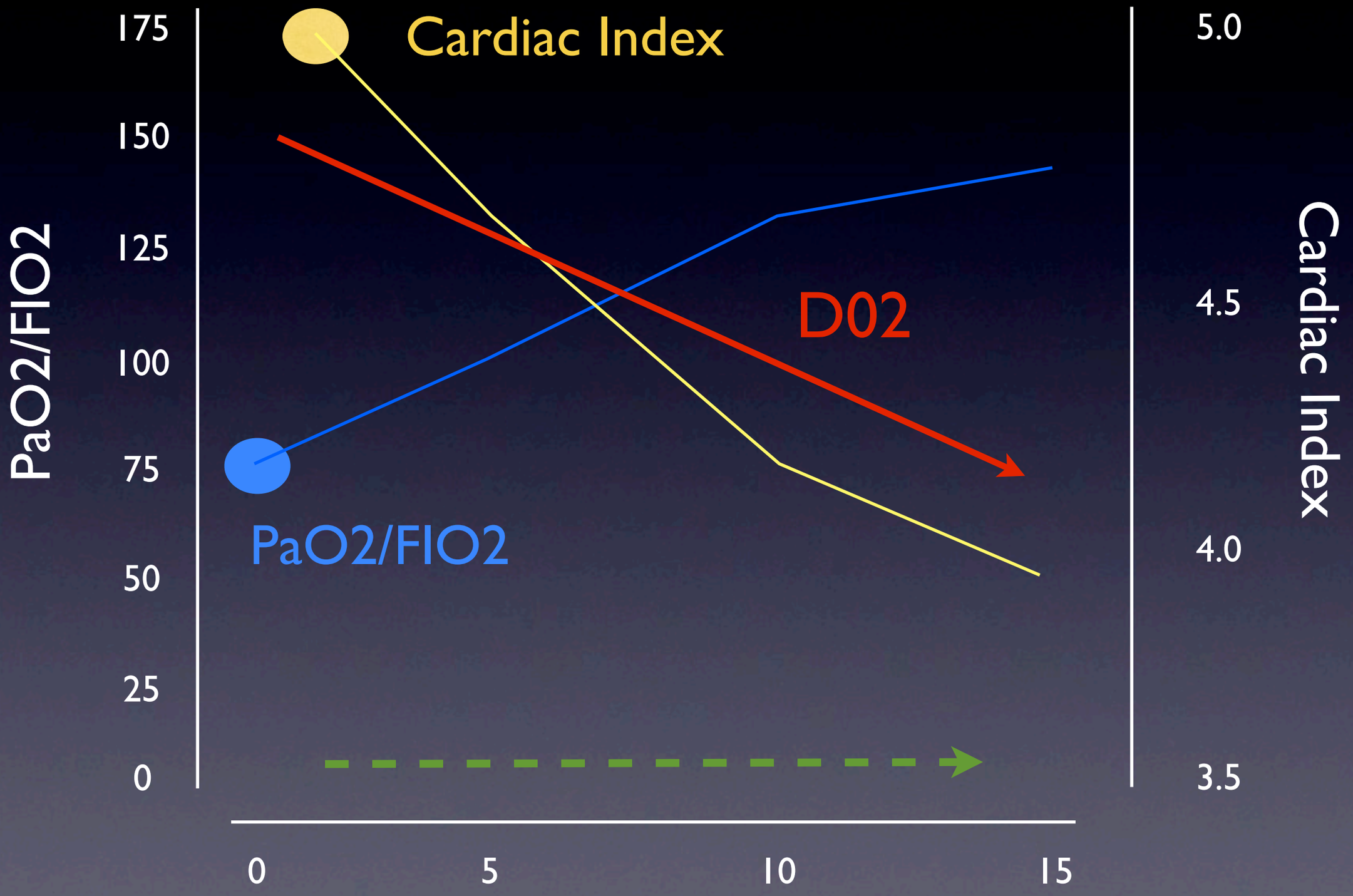
- Do I use PEEP to get increase pO2 ?
  - What might that do to O2 delivery?

Hct or O2 Saturation ?

Effects of 50% reduction in Hb and pO2 on O2 content



Effect of PEEP on lung efficiency vs. cardiac output



Crit Care Med 2003; 31: 2719-2726

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Clinical Case

- Patient v car
- Ruptured spleen and haemothorax (drained)
- Laparotomy --> ICU
- BP 105/75; HR 105; Sat O2 84%; P/F ratio = 46 (N~88)
- Hct 9%

What do you do?

Oh shi..., he's a Jehovahs Witness!

THE Sun

EXCLUSIVE

Jehovah dad 'died' in hospital

By NICK PARKER

Published: 07 Jun 2008

THE horrifically-injured Jehovah's Witness being denied a life-saving blood transfusion technically died in hospital, it was revealed last night.

John , 57, had to be resuscitated by medics when his heart stopped after he was mown down at 60mph by a suspected drunk driver.

But his wife Sheila, who is also a Witness, was last night **STILL** refusing to allow doctors to give him blood because it is banned by their faith.

The Sun told yesterday how the family is in turmoil, because the couple's two sons do not share their beliefs.

Family turmoil ... The Sun story

Sources revealed yesterday that John, of Southall, West London, lost half his blood and may lose his mangled left arm – if he survives at all.

He has internal injuries but surgeons cannot operate because he would need replacement blood.

Sons Jonathan, 36, and Tom, 29, are respecting their mother's wishes.

They joined her in a heartbreaking vigil at council worker John's bedside at Ealing Hospital, West London.

To fill or not to fill...that is the question

Effect on O2 delivery ?

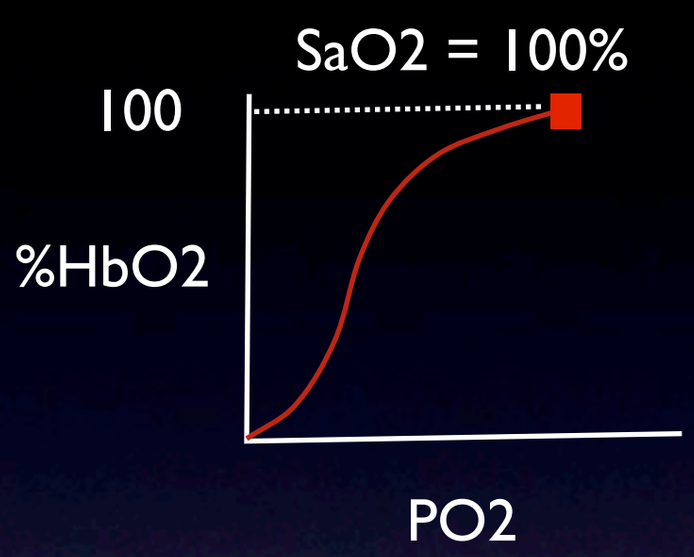
How do you know?

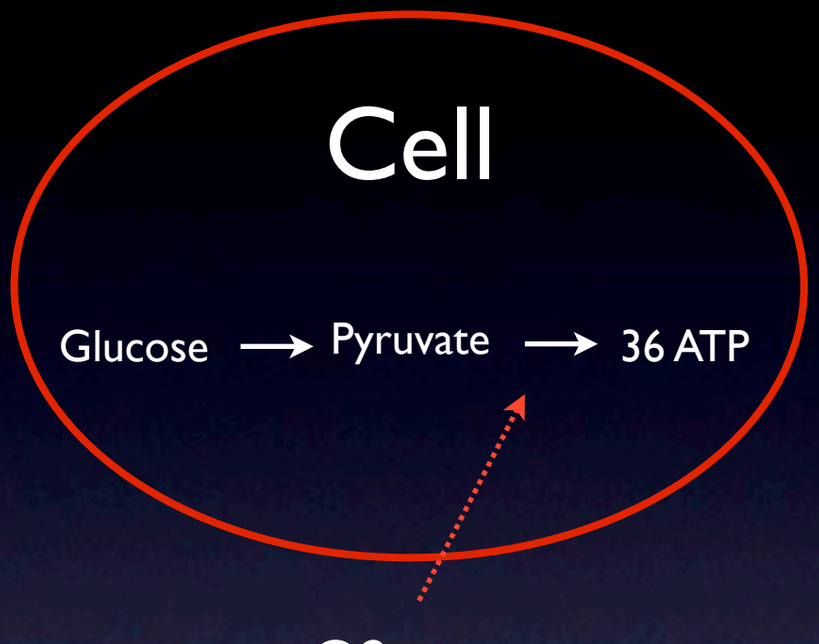
Check the SvO2 !

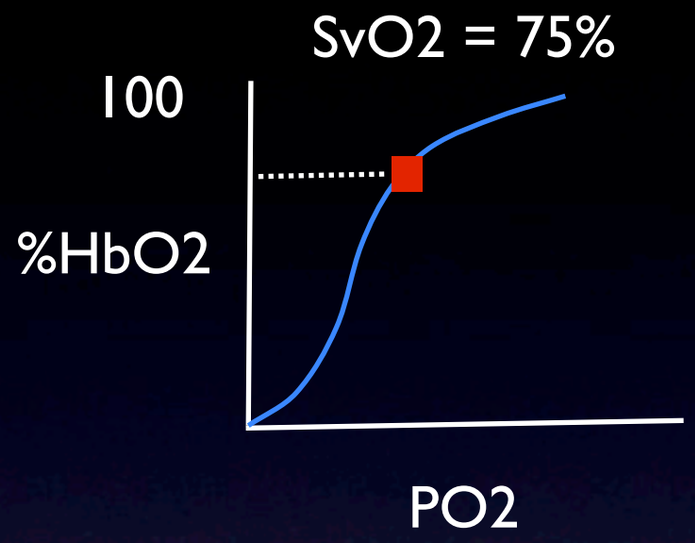
SvO2 = 73%

Whew !!!

Oxygen extraction



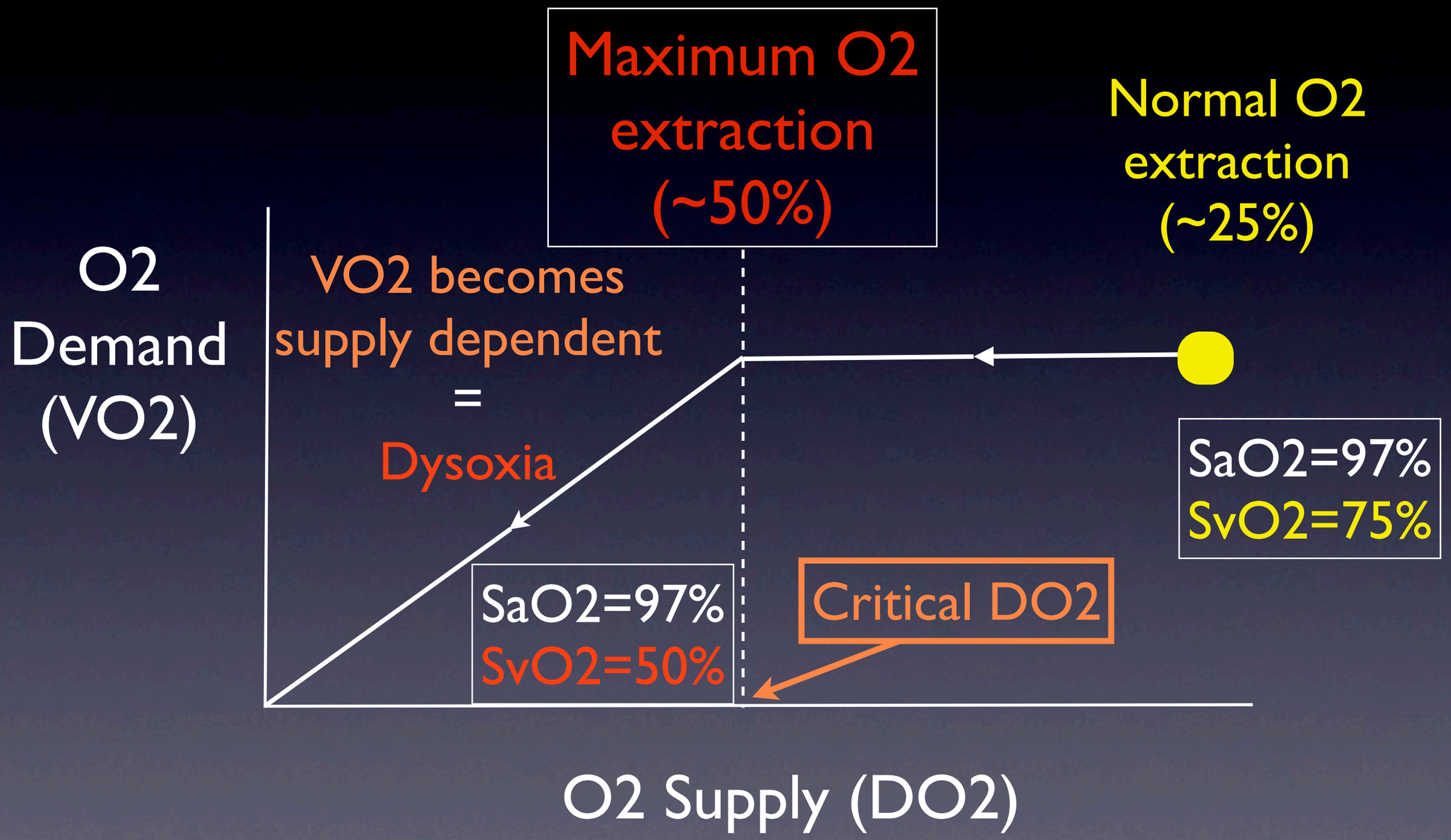




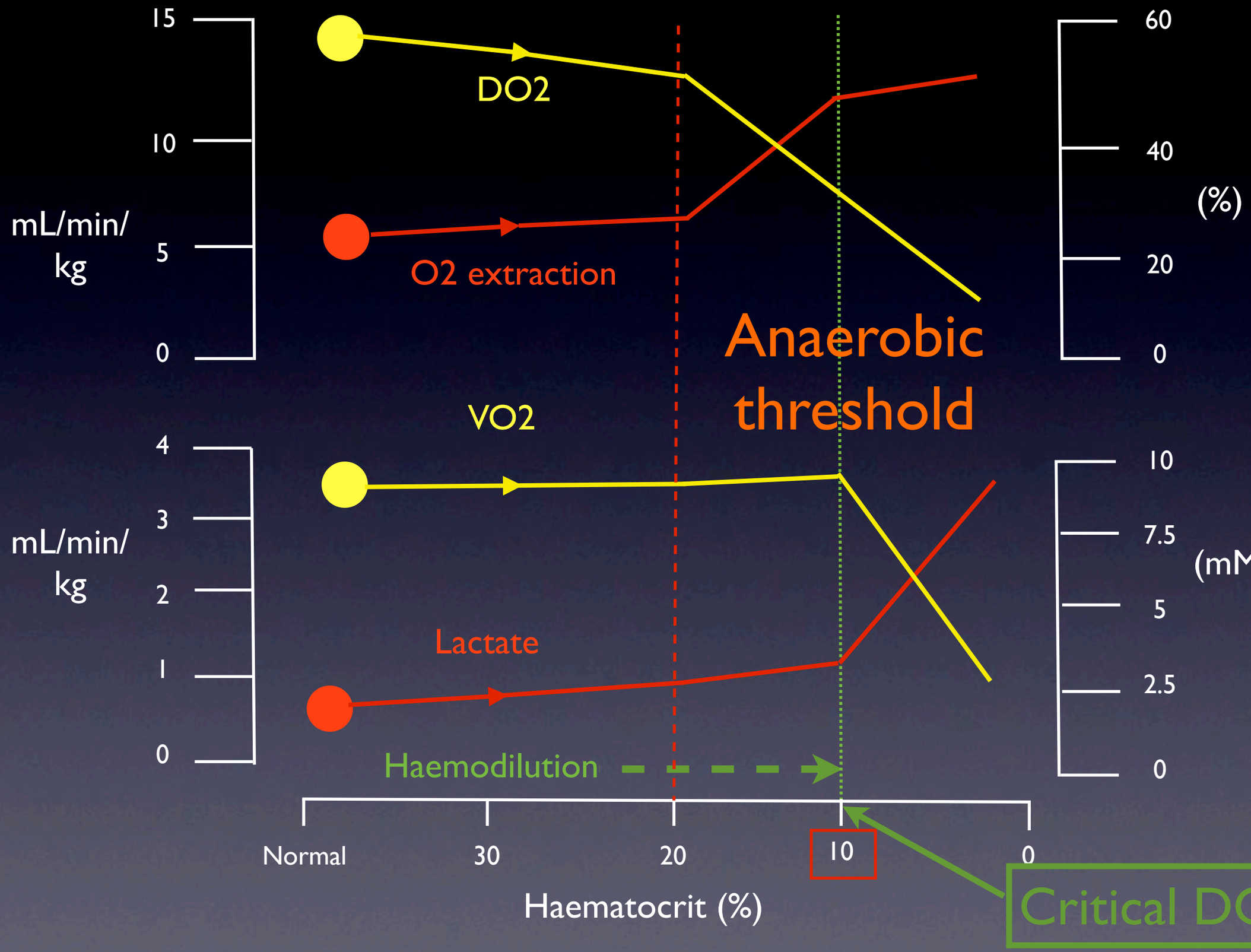
Arterial inflow

Venous outflow

O2 Demand = O2 Supply x O2 Extraction Ratio



VO2 = DO2 x O2 Extraction



J Surg Res 1987; 42 : 629-634

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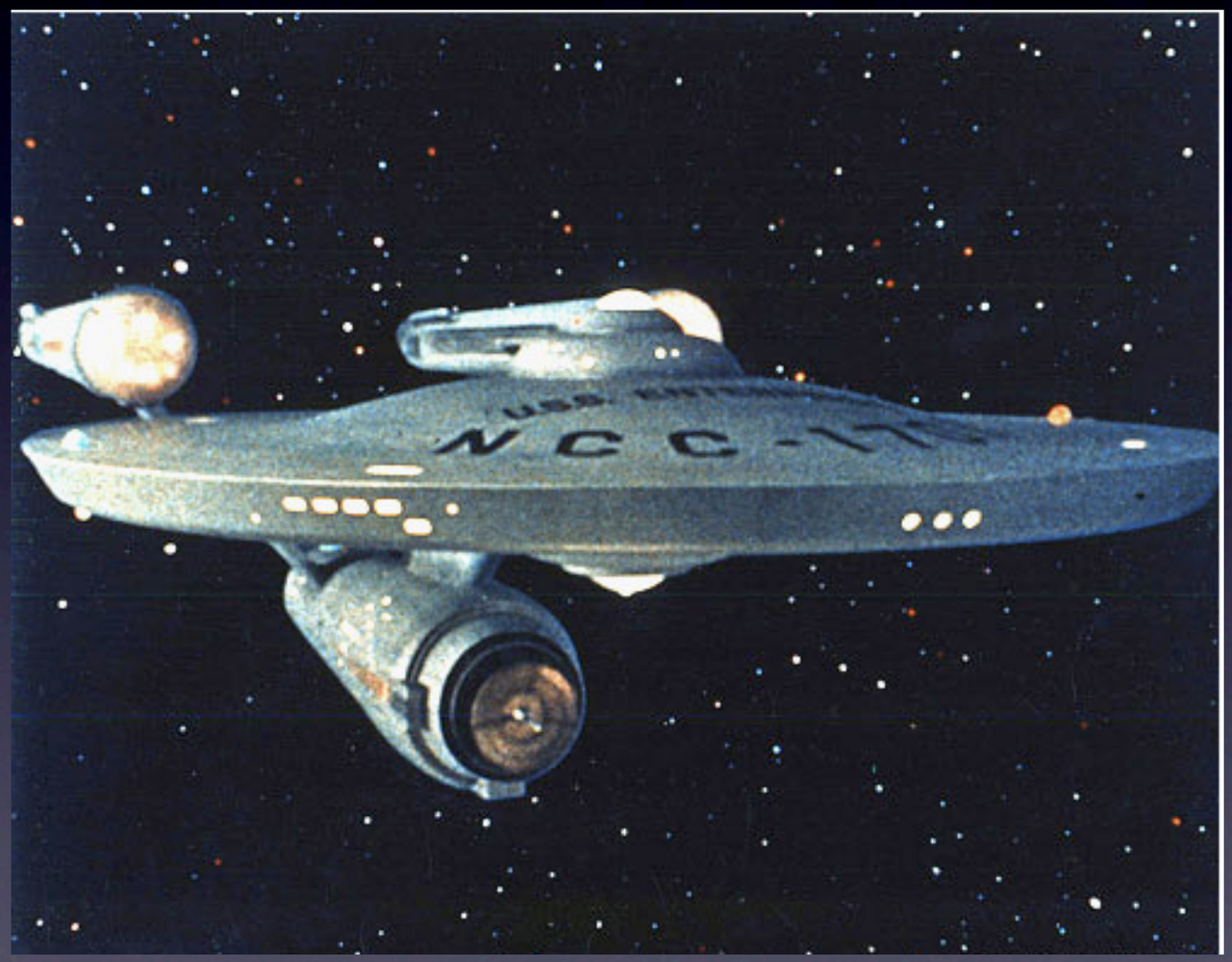
Is all dysoxia is due to inadequate O2 delivery ?

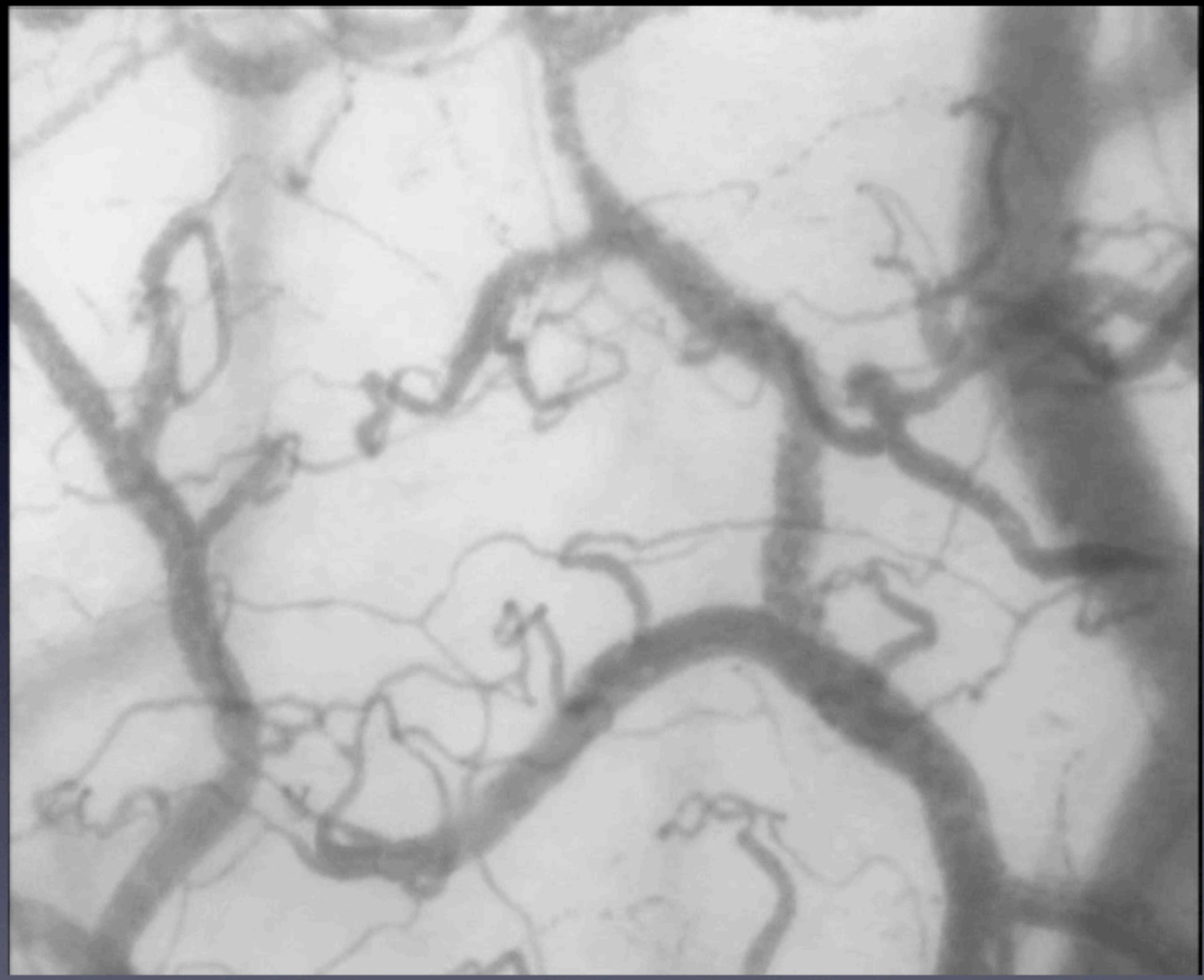
Other causes of dysoxia

- Impaired microvascular delivery
- “Sick Cell Syndrome”

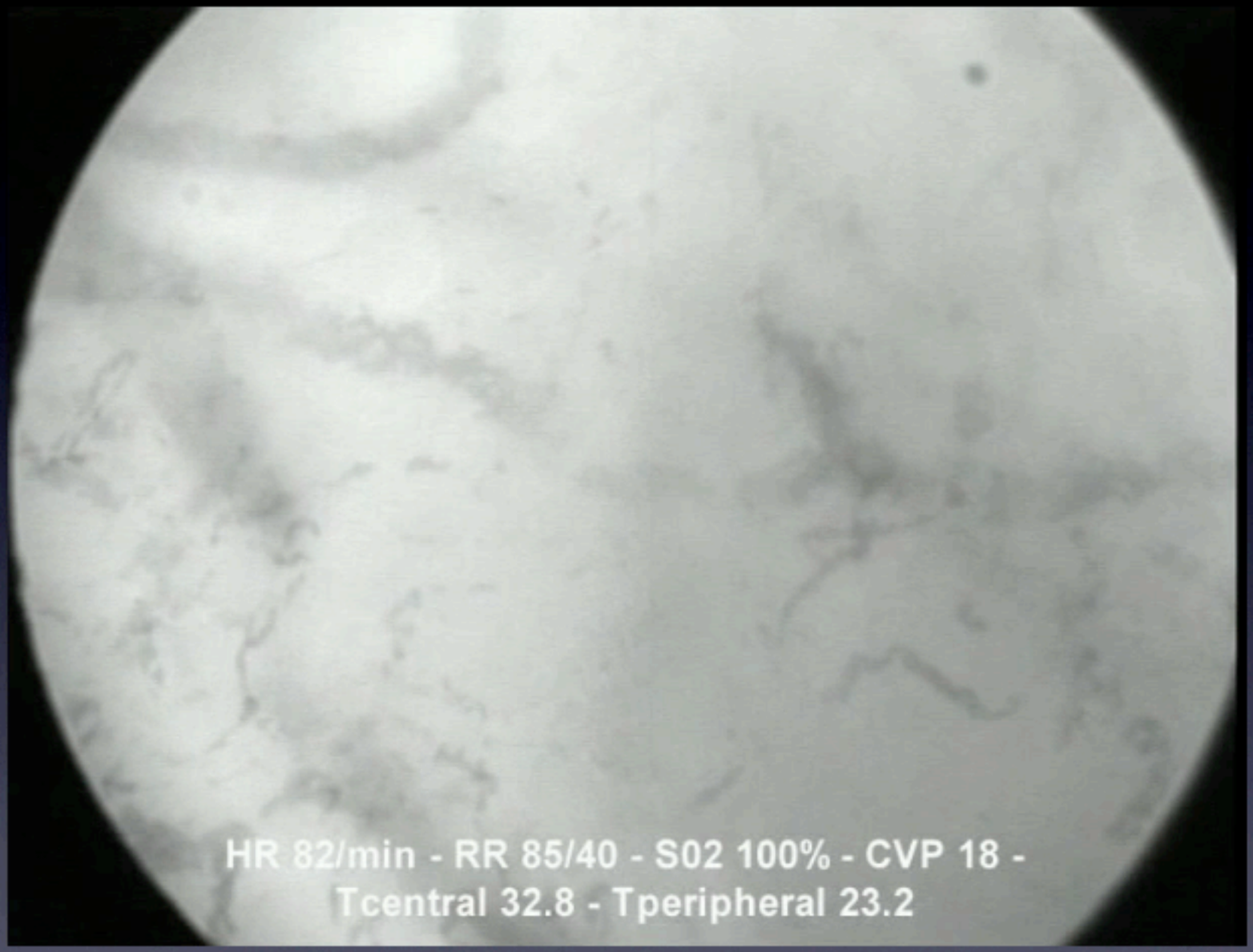
Microcirculation - the next frontier



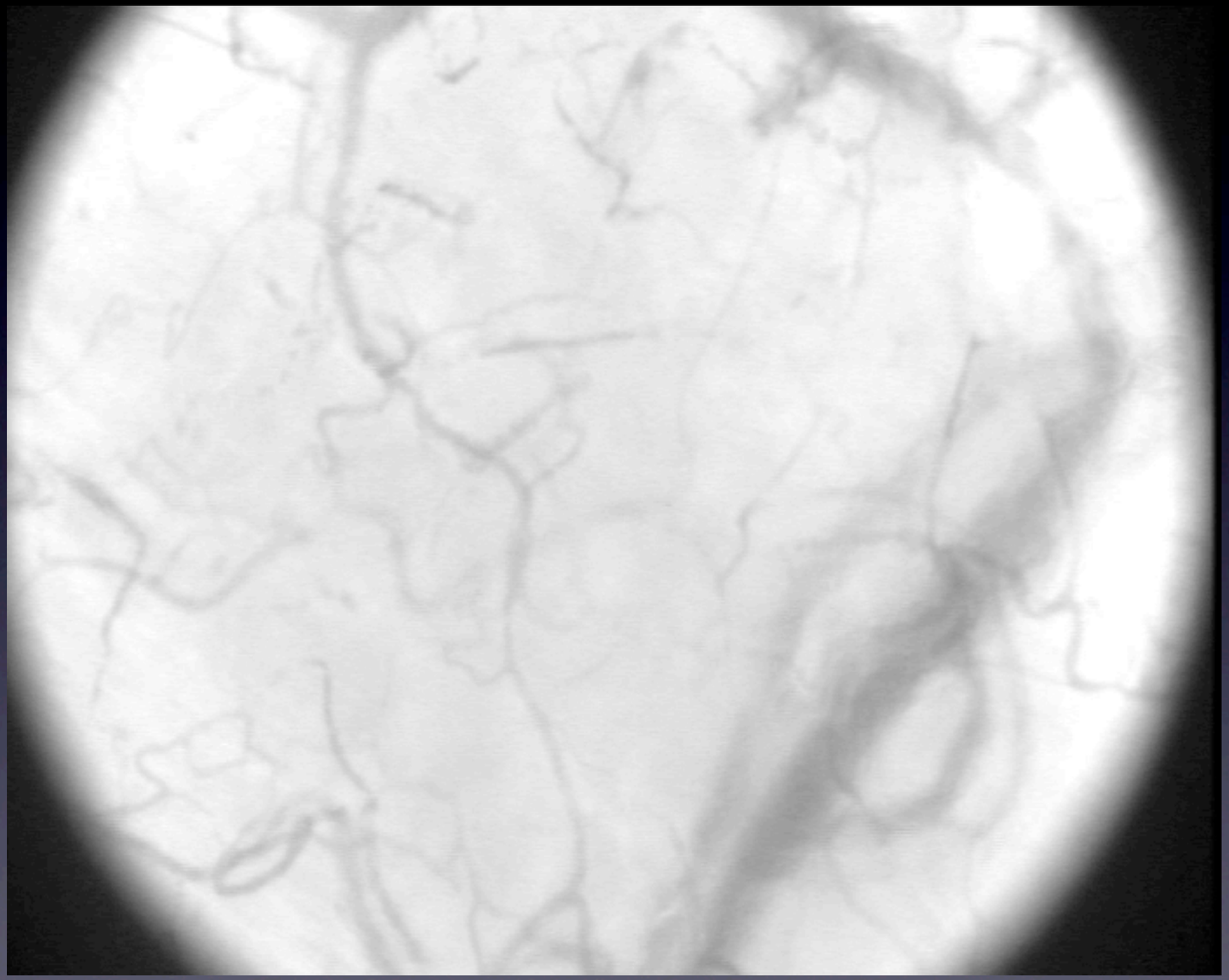
Normal microcirculation



Microcirculation in Sepsis

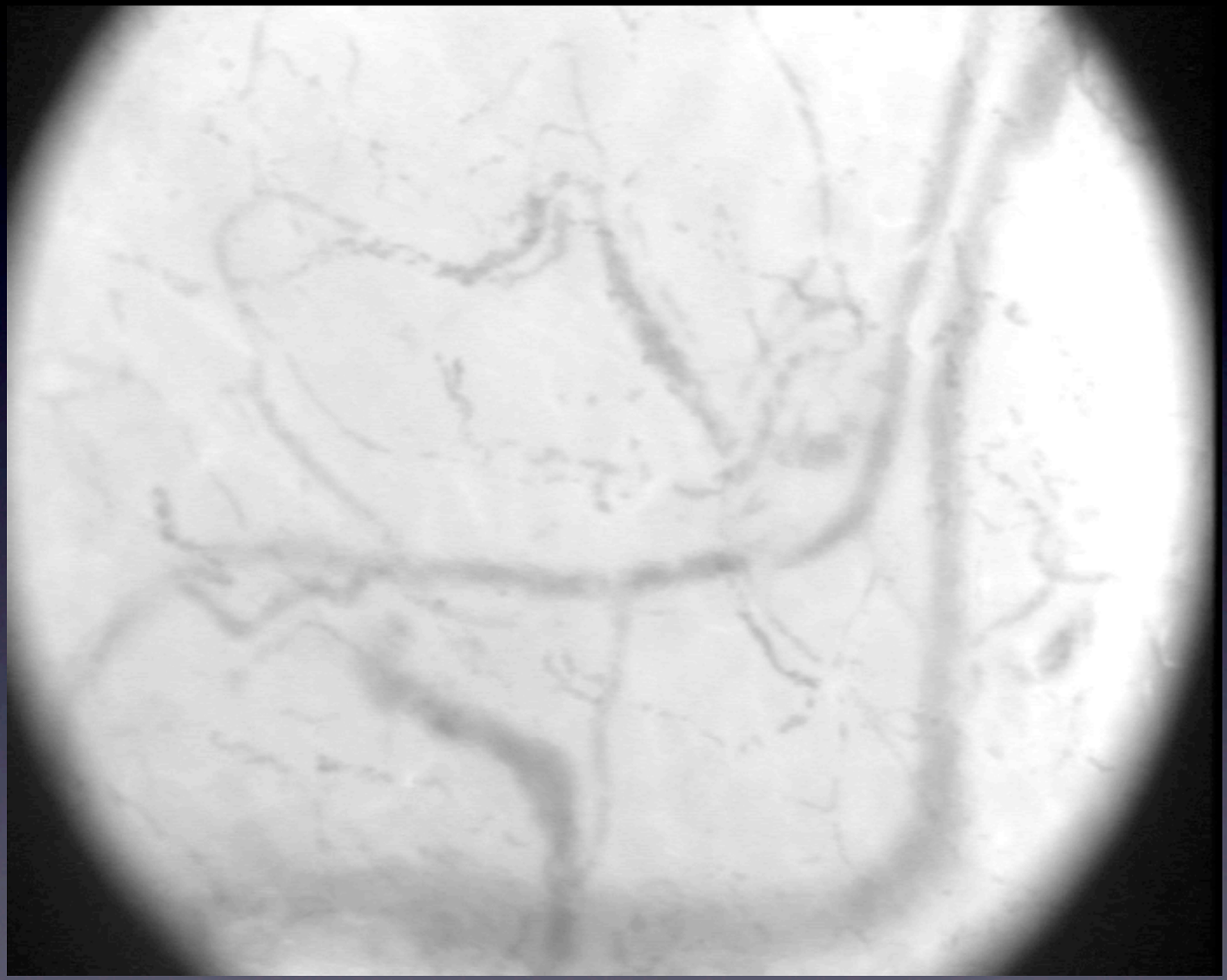


Microcirculation before terlipressin



MAP 58
HR 98
CVP 13
UO 20 ml/hr

Microcirculation after terlipressin



MAP 80
HR 98
CVP 12
UO 110 ml/hr

Microvascular dysfunction

- 50 ICU patients resuscitated to adequate global haemodynamic endpoints
- After successful resuscitation, peripheral perfusion assessed:
    - Capillary refill, Core-peripheral temperature, Peripheral Flow Index
- Compared lactate levels, on-going organ failure

Crit Care Med 2009 Vol. 37, No. 3

Microvascular dysfunction

Peripheral perfusion <u>after</u> resuscitation

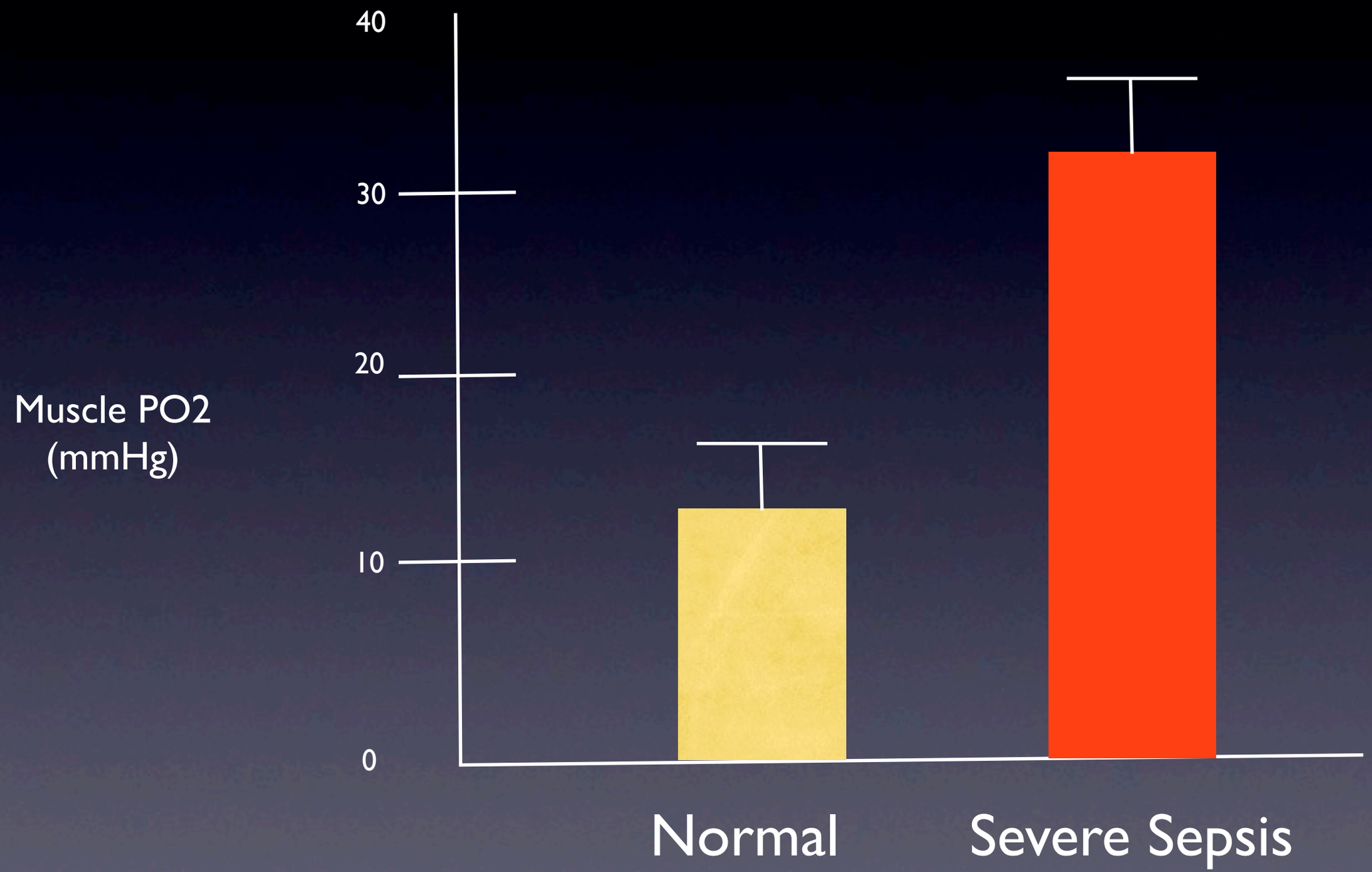
	Normal (27)	Abnormal (23)
HR	90	94
MAP	80	81
CVP	14	13
% Normal Lactate	69	31 **
△SOFA >0	23	77 **

Adequate global values with poor peripheral perfusion probably a sign of compensatory mechanisms still present.

Crit Care Med 2009 Vol. 37, No. 3

“Sick cell syndrome”

Tissue PO2 in forearm muscles in healthy vs patients with severe sepsis



Crit Care Med 2001; 29:1343

The NEW ENGLAND JOURNAL of MEDICINE

Early goal-directed therapy in the treatment of severe sepsis and septic shock

- Mortality in early treatment group - 30%
- Mortality in standard treatment group - 46%

50% increased mortality if given the same treatment late !

NEJM Volume 345:1368-1377 November 8, 2001 Number 19

Remember, when things get crazy.... simplify!

Cardiac output x Hb x % Sat O2

Further reading:

http://web.me.com/

johnvogel2

Questions?