NSOCM

CHRISTOPHER BJERKVIG

February 4, 2017

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"BLOOD FAR FORWARD"
BFF

Three Primary Research Modules

1. *Donor Performance and reinfusion - Donor safety research*
2. *Blood efficacy and safety- Blood Research*
3. *Training and educational requirements*

TRAUMA HEMOSTASIS & OXYGENATION RESEARCH
THOR
RDCR SYMPOSIUM SINCE 2011

RDCR
REMOTE DAMAGE CONTROL RESUSCITATION

ACKNOWLEDGEMENTS

Prof. Kevin Ward MD

- Department of Emergency Medicine, University of Michigan

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- Blood Far Forward / Helse-Bergen

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- US Army Institute of Surgical Research

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- Blood far forward / Helse-Bergen

Dr. Håkon Eliassen

- Blood far forward

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OUTLINE

Brief summary of history of DCR

Patophysiology of hemorrhagic shock and oxygen debt - implications on coagulopathy of trauma(blood failure) and outcome.

RDCR principles

Permissive hypotension in the presurgical and surgical phase – implications for oxygen debt and the management in the ICU

Strategies to improve oxygen delivery during field care/delayed evacuation

GOAL OF PREHOSPITAL CARE

REDUCE MORTALITY REDUCE MORBIDITY

FROM the time the enemy's missile strikes until the surgeon begins to repair the damage it has caused, every effort is directed toward a single aim, that of presenting to the surgeon a patient who will be as favorable an operative risk as possible. Several principles that are basic

Resuscitation and **anesthesia**. BEECHER HK. Anesthesiology. 1946

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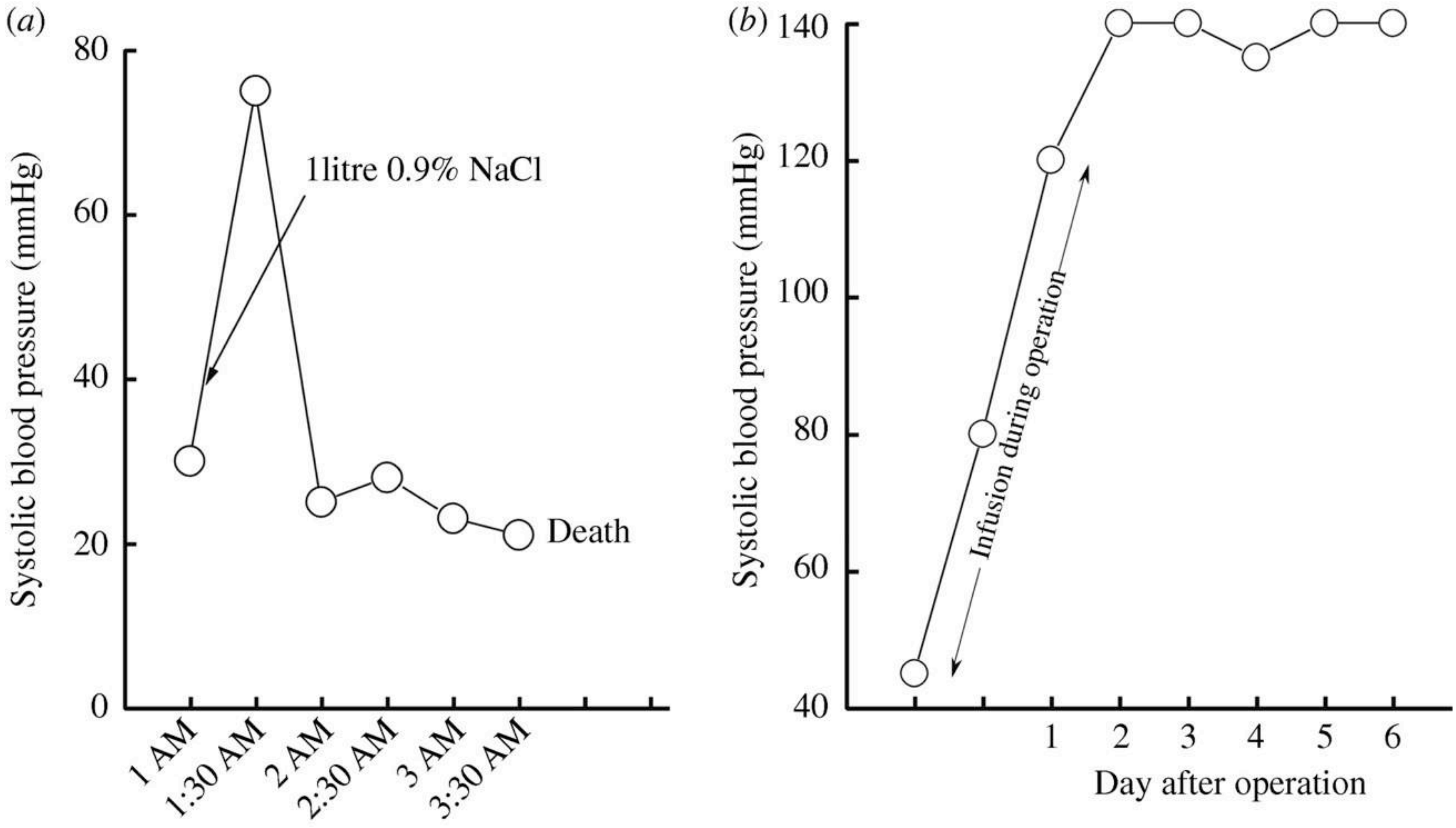
GORDON WATSON 1918:

Gordon Watson(1918), in a note attached to one of Robertson's papers *(20),* stated that there was no comparison between the results of transfusion, which were instantaneous and permanent**, and those secured by infusions of saline, which were "a flash in the pan" and followed by more serious collapse.**

EXPERIMENT 1918



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HK.BEECHER QUOTES 1946

Crystalloid solutions :

"These agents are primarily useful for the correction of dehydration. As "blood substitutes" they are not very effective,and are dangerous."

HK.BEECHER QUOTES 1946

"Curiously enough, a fact that is often not adequately appreciated is that plasma, lacking hemoglobin, is not, a satisfactory substitute for blood in the wounded man who is seriously bled-out. Plasma gives more time to get whole blood into the patient."

ANNALS OF SURGERY

Vol. 141 MARCH, 1955 No. 3

CLINICAL EXPERIENCES IN THE EARLY MANAGEMENT OF THE MOST SEVERELY INJURED BATTLE CASUALTIES*

CURTIS P. ARTZ, LIEUTENANT COLONEL, M. C., JOHN M. HOWARD, CAPTAIN, M. C., YOSHIO SAKO, CAPTAIN, M. C., ALVIN W. BRONWELL, CAPTAIN, M. C. AND THEODORE PRENTICE, CAPTAIN, M. C.

FT. SAM HOUSTON, TEXAS

FROM THE SURGICAL RESEARCH TEAM IN KOREA, ARMY MEDICAL SERVICE GRADUATE SCHOOL, WALTER REED ARMY MEDICAL CENTER WASHINGTON, D. C.

TABLE VII. *Most Severely Wounded—Admitted in Severe Shock; 33 Patients, 7 Deaths.* (Case Fatality Rate, 21 Per Cent)

No.	Type of Wound	Evac. Time (min.)	Admin. Blood Pressure	Preop. Blood (ml)	Blood Total 1st 24 hrs. (ml)	Remarks
1	Extrem.	110	70/30	2,000	2,500	Recovered
2	Extrem.	105	80/40	2,000	3,000	Recovered
3	Abdomen	180	70/40	2,500	3,000	Recovered
4	Extrem.	120	40/0	—	3,500	Recovered
5	Abdomen	60	66/0	2,000	3,500	Recovered
6	Extrem.	270	80/40	2,000	4,000	Recovered
7	Abdomen	185	60/30	2,500	4,000	Recovered
8	Extrem.	270	70/40	3,750	4,750	Recovered
9	Chest	—	60/0	2,500	3,500	Recovered
10	Abdomen	—	40/0	3,000	5,000	Recovered
11	Thor-abd.	150	80/40	3,000	5,000	Recovered
12	Abdomen	—	70/40	4,000	5,500	Recovered
13	Extrem.	120	70/40	3,500	6,000	Recovered
14	Extrem.	195	80/0	5,500	6,500	Recovered
15	Extrem.	45	70/30	3,000	7,000	Recovered
16	Extrem.	170	70/40	2,500	7,000	Recovered
17	Abdomen	130	70/0	4,000	9,000	Recovered
18	Abdomen	90	70/40	5,000	10,000	Recovered
19	Abdomen	90	74/52	3,500	11,500	Recovered
20	Extrem.	103	0/0	5,500	5,500	Recovered
21	Abdomen	180	0/0	4,000	6,000	Recovered
22	Extrem.	120	0/0	6,000	6,000	Recovered
23	Chest	190	0/0	4,000	7,000	Recovered
24	Abdomen	180	0/0	6,500	8,500	Recovered
25	Abdomen	—	0/0	2,500	11,000	Recovered
26	Chest	70	0/0	5,500	13,000	Recovered
27	Thor-abd.	205	0/0	4,000	8,000	Expired, unknown
28	Abdomen	105	0/0	5,500	9,000	Expired, uncontrolled hemorrhage
29	Extrem.	125	0/0	12,000	16,000	Expired, uncontrolled hemorrhage
30	Extrem.	330	80/60	2,500	6,000	Expired cardiac arrest
31	Extrem.	90	80/60	5,500	9,500	Expired, postoperative shock
32	Extrem.	85	40/0	5,500	11,500	Expired, undetermined
33	Abdomen	180	50/30	12,000	28,000	Expired, uncontrolled oozing
	Averages	150	——	4,400	7,600	

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HISTORY OF PREHOSPITAL SHOCK RESUSCITATION

WW I WW II Korea Vietnam OIF/OEF ?

50 years of Blood

40 years of Clear Fluids

Back to the future???

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WHAT HISTORY TELLS US ABOUT CRYSTALLOIDS

Ongoing discussion for a 100 years

In the INTERIN BETWEEN WARS always controversies what replacement fluid to choose.

In the post war conclusions, made up by the physicians who actually took the heat and did not sit in the warm reseach laboratories: SAME CONCLUSION EVERY POSTWAR UPDATE!!

BLOOD IS GOOD – CRYSTALLOIDS ARE BAD

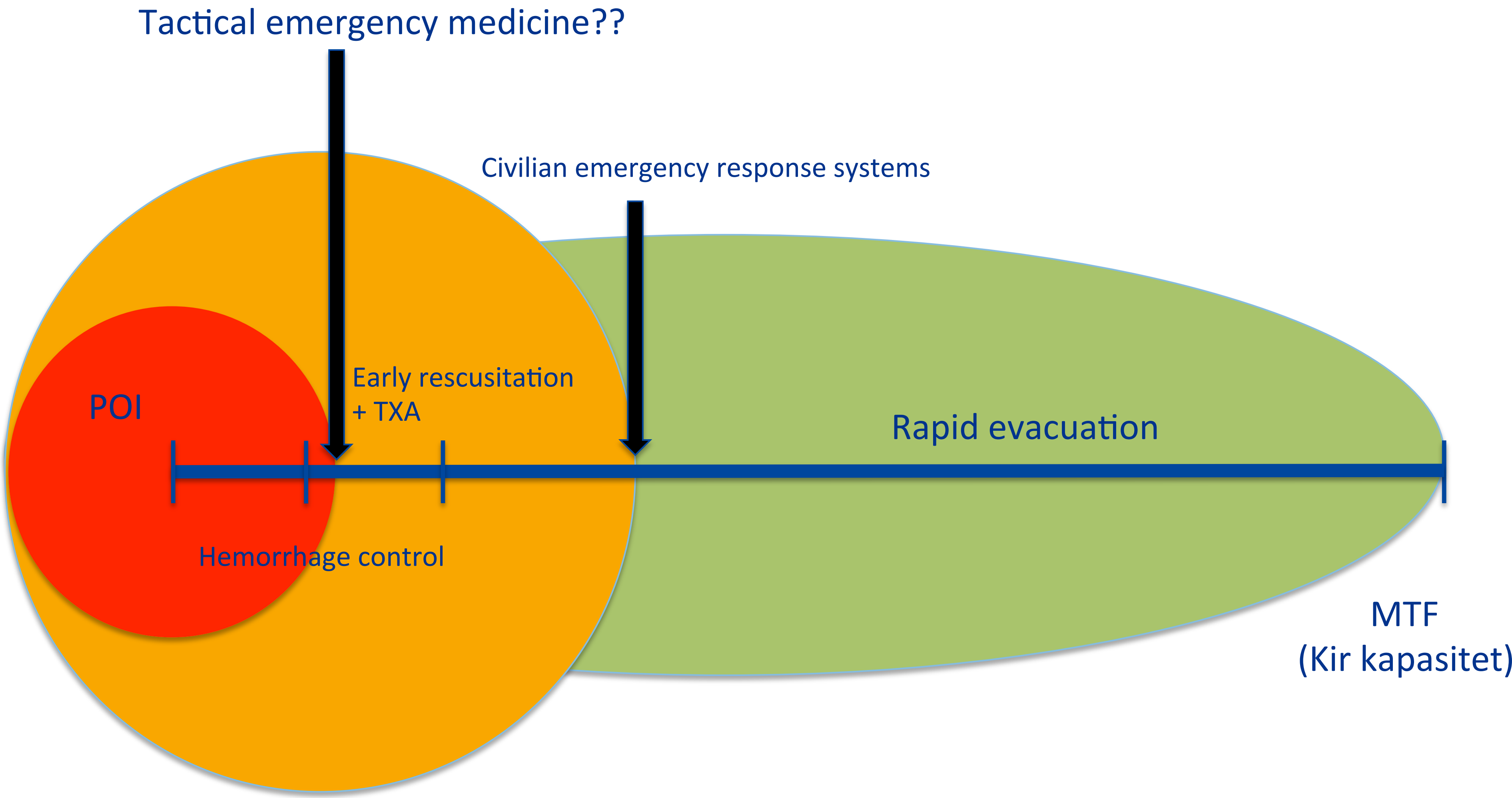
Fluid Resuscitation from Hemorrhagic Shock

"The historic role of crystalloid and colloid solutions in trauma resuscitation represents the triumph of hope and wishful thinking over physiology and experience."

LTC Andre Cap

J Trauma, 2015

There is an increasing awareness that fluid resuscitation for casualties in hemorrhagic shock is best accomplished with fluid that is identical to that lost by the casualty - whole blood.



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Shock is bad for you

Level of shock is correlated with outcome

Manikis, Panagiotis, et al. "Correlation of serial blood lactate levels to organ failure and mortality after trauma." *The American journal of emergency medicine* 13.6 (1995): 619-622.

Husain, Farah A., et al. "Serum lactate and base deficit as predictors of mortality and morbidity." *The American journal of surgery* 185.5 (2003): 485-491.

Floccard B, Rugeri L, Faure A, Saint Denis M, Boyle EM, Peguet O, et al. Early coagulopathy in trauma patients: an on-scene and hospital admission study. *Injury* 2012;43:26-32

Level of shock – correlated with level of coagulopathy and inflammation

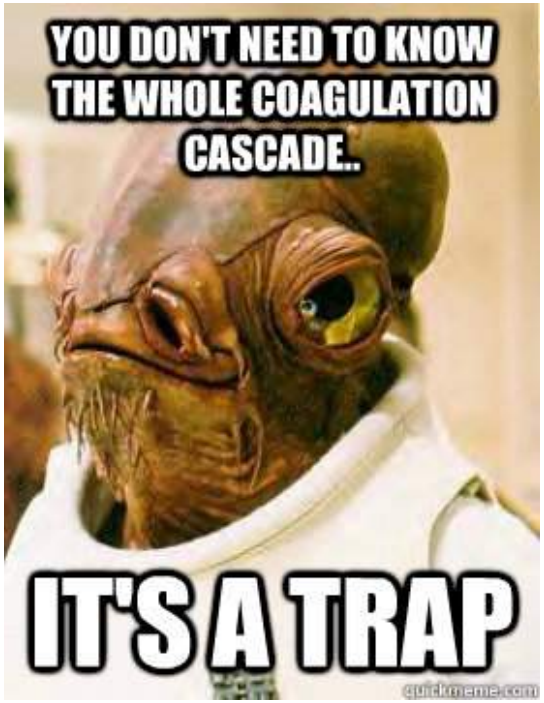
Macleod JBA, Lynn M, McKenney MG, et al. Early coagulopathy predicts mortality in trauma. J Trauma 2003; 55:39–44

Hess et al, J Trauma 2008 (ACOTS)

Brohi K, Singh J, Heron M, et al. Acute traumatic coagulopathy. J Trauma 2003; 54:1127–1130

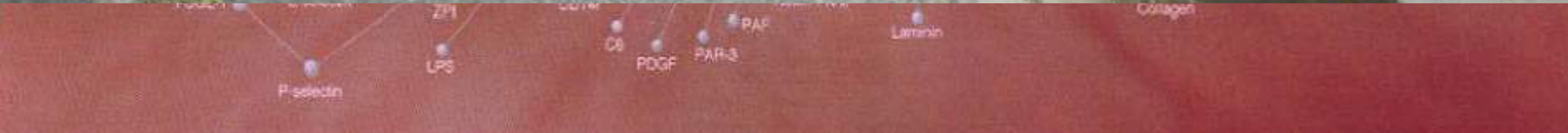
Maegele M, Lefering R, Yucel N, et al. Early coagulopathy in multiple injury: an analysis from the German Trauma Registry on 8724 patients. Injury 2007; 38:298 – 304

Hypoperfusion is probably the primary initiator of coagulopathy (ACoT)



Brohi K, Cohen MJ, Ganter MT, et al. Acute traumatic coagulopathy: initiated by hypoperfusion: modulated through the protein C pathway? Ann Surg 2007; 245:812–818

THE BIG PICTURE



FORWARD TO THE PAST

THOR

Prevention of further oxygen debt accumulation

Repayment of oxygen debt

Minimization of the time to oxygen debt resolution

Barbee, Robert Wayne, Penny S. Reynolds, and Kevin R. Ward. "Assessing shock resuscitation strategies by oxygen debt repayment." *Shock* 33.2 (2010): 113-122.

Definitions

- Shock:
  - *A a physiologic state where oxygen delivery (DO_2) is not sufficient to meet the metabolic requirements (VO_2) of the body.*

- Critical DO_2
  - *Level of DO_2 below which anaerobic metabolism begins and cellular function deteriorates*
  - *Lactate increases*

- Compensated Shock:
  - *A physiologic state where DO_2 is decreased but oxygen extraction increases to continue to meet VO_2 demands of the body.*

Oxygen requirement(VO2) beyond oxygen supply (DO2) organ failure

Rixen D, Siegel JH: Bench-to-bedside review: oxygen debt and its metabolic correlates as quantifiers of the severity of hemorrhagic and post-traumatic shock. Crit Care 9:441Y453, 2005.

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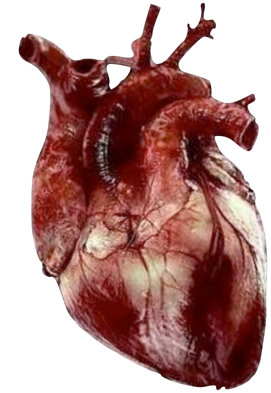
Definitions

- Oxygen deficit:
  - *The difference between the metabolic demand and supply at a certain time.*

- Oxygen debt:
  - *The magnitude and length of the oxygen deficit.*
  - *"The time spent below critical DO2"*

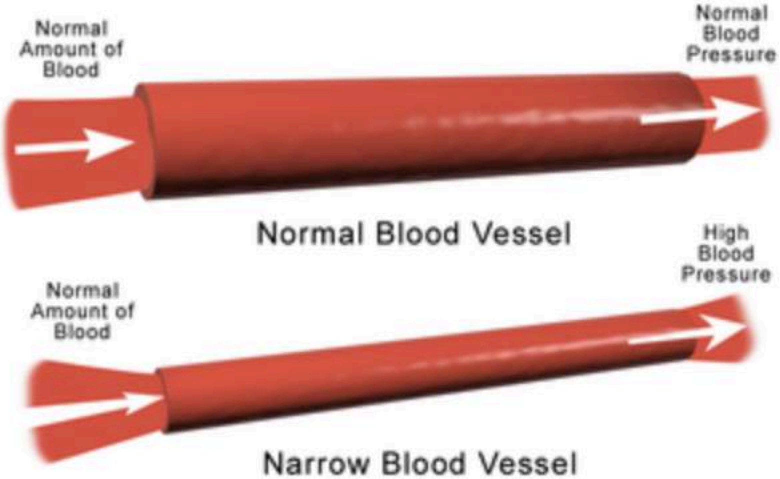
Ficks equation

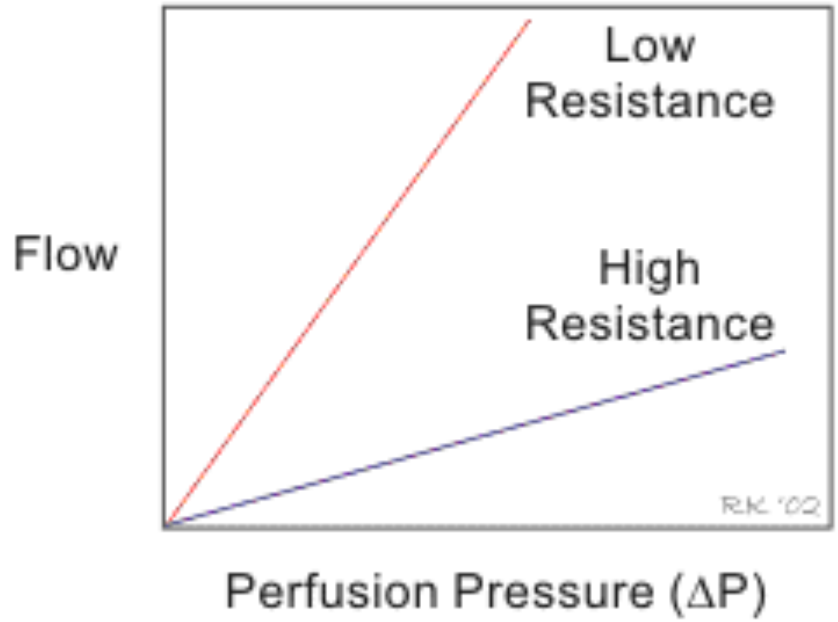


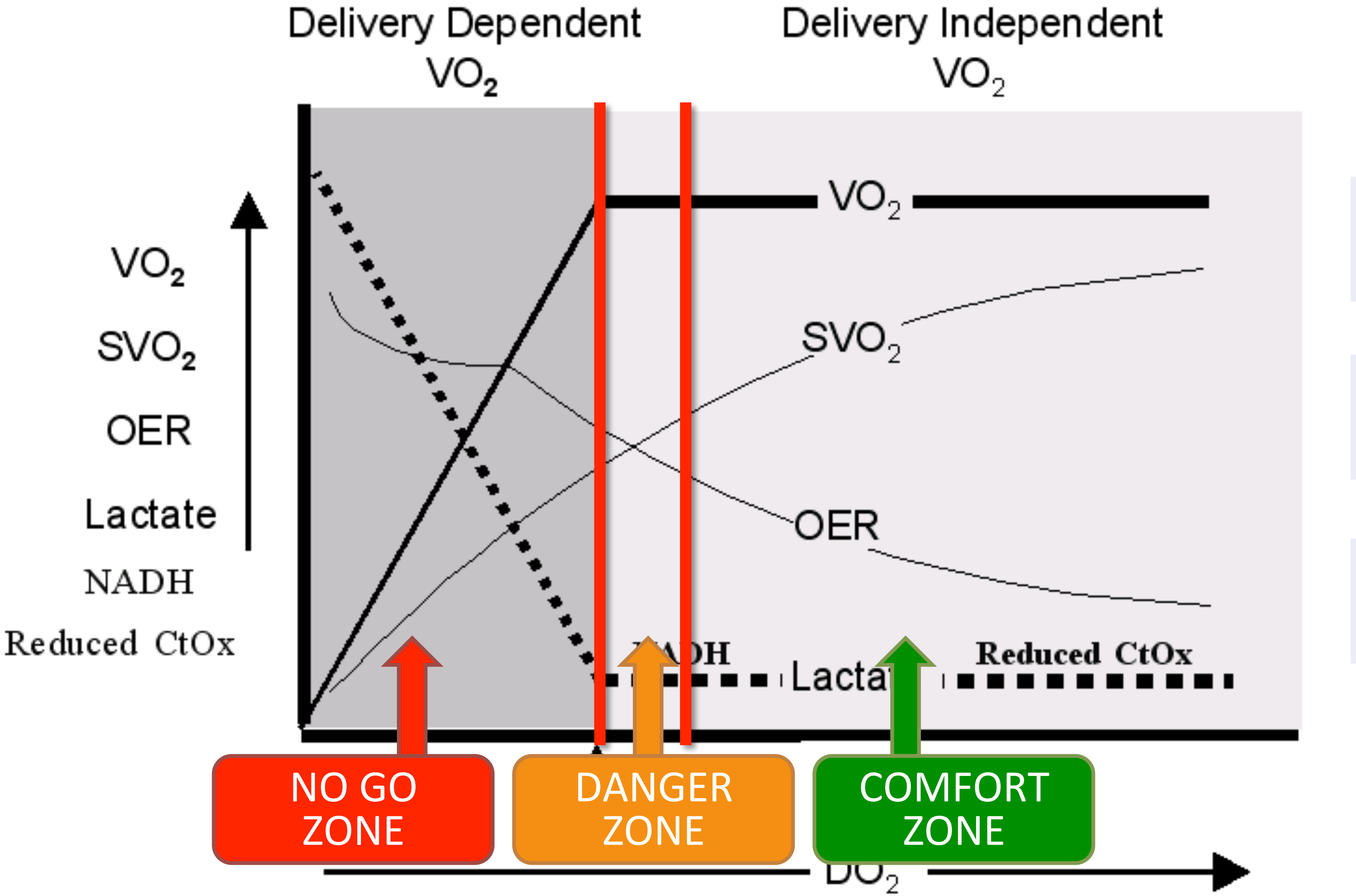
$$D0_2 = 1.34 \times Hgb \times Sa0_2 \times CO$$

Poiseuilles law

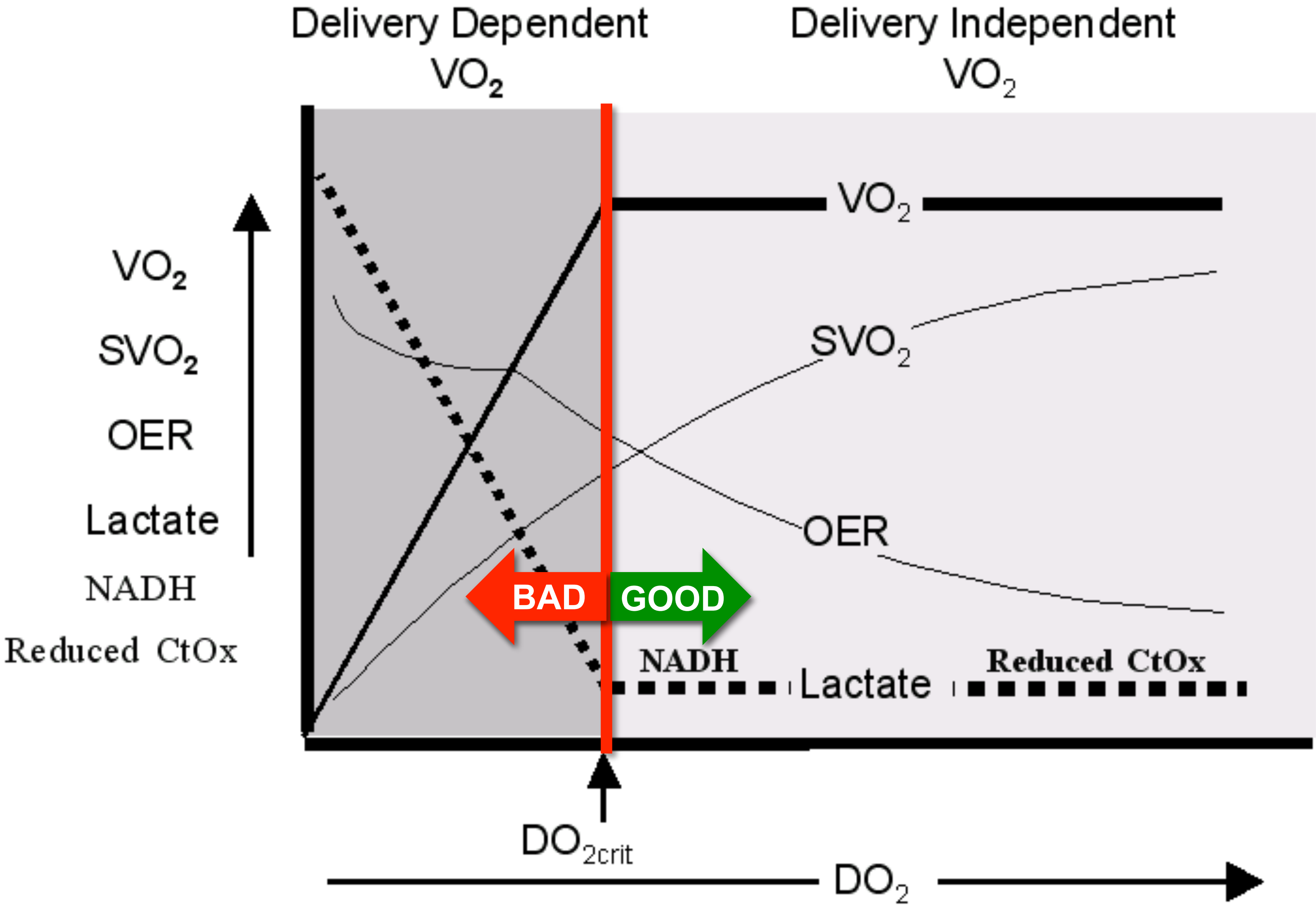
$$F = \frac{\Delta P}{R} = \frac{(P_A - P_V)}{R}$$



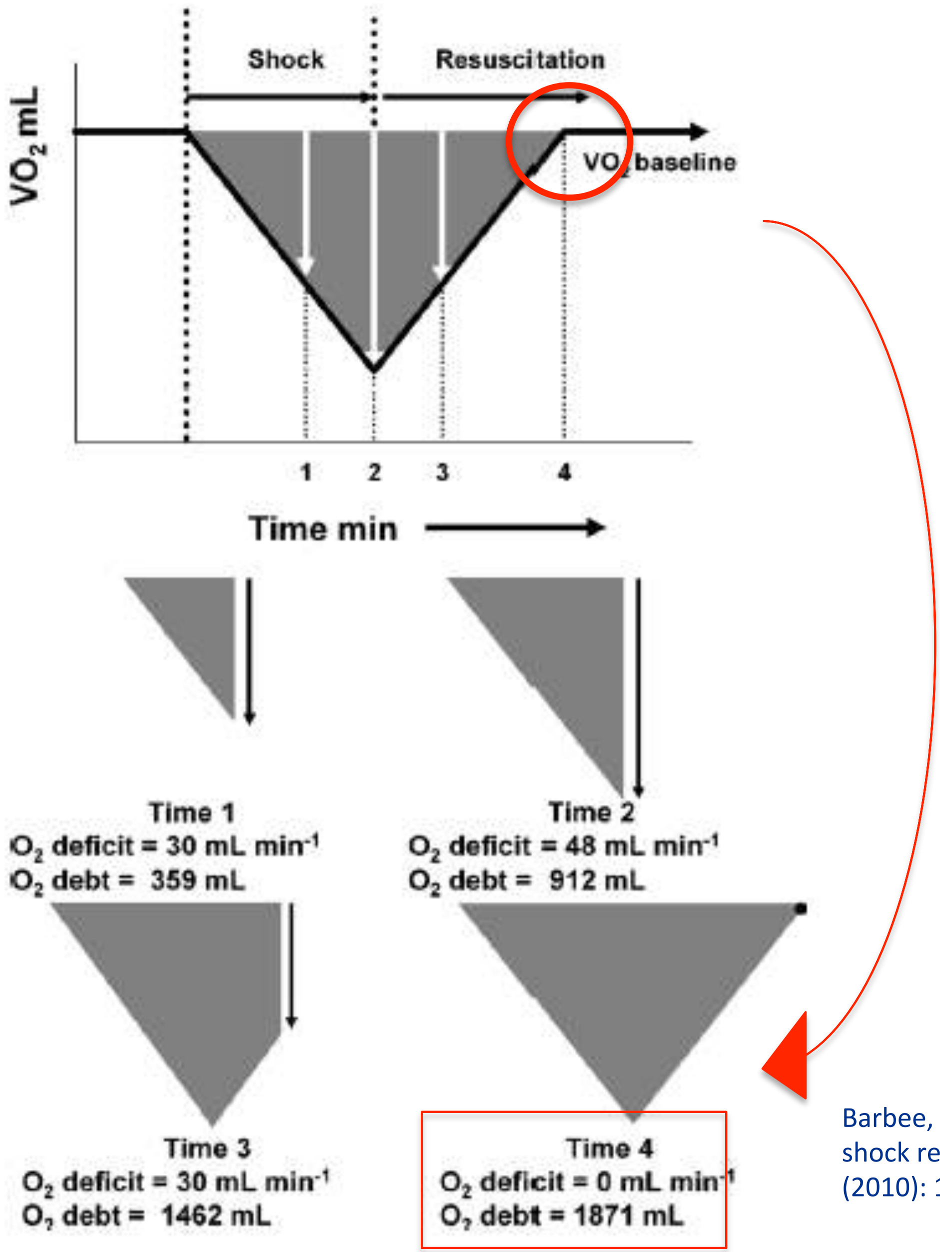




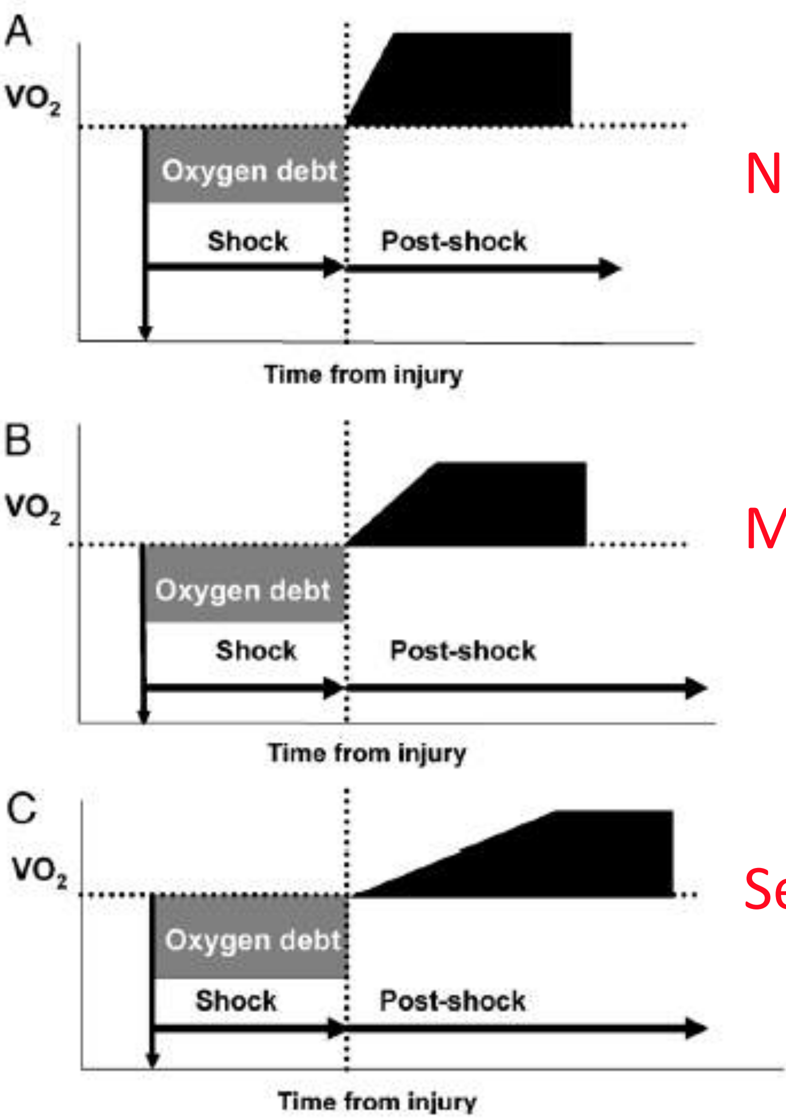
Delivery Dependent VO2
Delivery Independent VO2
VO2
SVO2
OER
Lactate
NADH
Reduced CtOx
VO2
SVO2
OER
NADH
Reduced CtOx
NO GO ZONE
DANGER ZONE
COMFORT ZONE
DO2



Delivery Dependent VO2
Delivery Independent VO2
VO2
SVO2
OER
Lactate
NADH
Reduced CtOx
VO2
SVO2
OER
BAD
GOOD
NADH
Lactate
Reduced CtOx
DO2crit
DO2



Barbee, Robert Wayne, Penny S. Reynolds, and Kevin R. Ward. "Assessing shock resuscitation strategies by oxygen debt repayment." *Shock* 33.2 (2010): 113-122.



No cellular damage

Bolus – Immediate 100% Repayment

Minimal/moderate cellular damage

Bolus – Immediate 64% Repayment

Severe organ injury,early death

Bolus – Immediate 28% Repayment

Colloid 5% Albumin

Siegel JH, Fabian M, Smith JA, Kingston EP, Steele KA, Wells MR: Oxygen debt criteria quantify the effectiveness of early partial resuscitation after hypovolemic hemorrhagic shock. J Trauma 54:862Y880, 2003

Barbee, Robert Wayne, Penny S. Reynolds, and Kevin R. Ward. "Assessing shock resuscitation strategies by oxygen debt repayment." *Shock* 33.2 (2010): 113-122.

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"TOO LITTLE, TOO LATE!"

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CRIT CARE MED. 1994 APR;22(4):633-9.

HEMODYNAMIC RESPONSES TO SHOCK IN YOUNG TRAUMA PATIENTS: NEED FOR INVASIVE MONITORING.

ABOU-KHALIL B[1], SCALEA TM, TROOSKIN SZ, HENRY SM, HITCHCOCK R

One of many clinical studies showing improved mortality/morbidity related to $D0_2/V0_2$ ratio.

Long list of publications supporting this ”fact”

Including multiple studies using different animal models

Table 3. Mean hemodynamic profiles of 39 patients

	At 1 Hr	At 8 Hrs	*p* Value (1 Hr vs. 8 Hrs)	At 24 Hrs	*p* Value (8 Hrs vs. 24 Hrs)
Temp (°F)	96 ± 0.42[a]	97.5 ± 0.3	.0001	99 ± 0.25	.03
MAP (mm Hg)	106 ± 3	103 ± 2.5	NS	103 ± 4.3	NS
HR (beats/min)	104 ± 3.7	101 ± 4	NS	96 ± 2.6	NS
CVP (mm Hg)	11 ± 0.85	11 ± 0.85	NS	11 ± 0.64	NS
PAOP (mm Hg)	12 ± 0.89	12 ± 0.84	NS	13 ± 0.76	NS
Hct (%)	37 ± 2.1	35 ± 1.5	NS	35 ± 1.2	NS
CI (L/min/m^2)	3.1 ± 0.19	4.5 ± 0.19	.001	5.4 ± 0.15	.01
SVRI (dyne·sec/cm^5·m^2)	3102 ± 94.1	1990 ± 58.6	.001	1433 ± 0.15	.015
PVRI (dyne·sec/cm^5·m^2)	370 ± 7	190 ± 7.6	.001	138 ± 9	.01
$\dot{D}o_2I$ (mL/min/m^2)	496 ± 34.9	732 ± 38.2	.001	993 ± 46.4	.001
$\dot{V}o_2I$ (mL/min/m^2)	128 ± 7.1	183 ± 7.9	.001	236 ± 10.2	.001
Lactate (mmol/L)	5.1 ± 0.56	3.4 ± 0.31	.04	2.2 ± 0.22	.001
$S\bar{v}o_2$ (%)	69 ± 8.2	74 ± 4.2	.03	79 ± 3.1	.5

Table 5. Hemodynamic data of survivors vs. nonsurvivors in 39 patients

	At 1 Hr			At 24 Hrs		
	Survivor	Nonsurvivor	*p* Value	Survivor	Nonsurvivor	*p* Value
MAP (mm Hg)	106 ± 3.6[a]	105 ± 4.5	NS	102 ± 2.8	101 ± 3.5	NS
HR (beats/min)	104 ± 8.3	105 ± 7.2	NS	104 ± 9.1	105 ± 11.1	NS
CVP (mm Hg)	12 ± 1	11 ± 1.4	NS	13 ± 0.83	12 ± 1.4	NS
PAOP (mm Hg)	11 ± 0.9	13 ± 0.99	NS	11 ± 0.7	13 ± 1.7	NS
Hct (%)	38 ± 2.3	36 ± 3.1	NS	34 ± 2.1	35 ± 1.2	NS
CI ($L/min/m^2$)	3.2 ± 0.18	3 ± 0.62	NS	5.7 ± 0.15	5.2 ± 0.46	NS
SVRI ($dyne \cdot sec/cm^5 \cdot m^2$)	3010 ± 266	3202 ± 308	NS	1531 ± 53.9	1358 ± 58.1	NS
PVRI ($dyne \cdot sec/cm^5 \cdot m^2$)	301 ± 18.4	532 ± 36.1	.001	105 ± 14.3	165 ± 12.2	.02
$\dot{D}o_2I$ ($mL/min/m^2$)	519 ± 55.1	428 ± 80.1	.02	1098 ± 76.1	895 ± 78.2	.02
$\dot{V}o_2I$ ($mL/min/m^2$)	129 ± 8.8	127 ± 10	NS	278 ± 14.1	168 ± 20.1	NS
Lactate (mg/dL)						
(mmol/L)	4.1 ± 0.62	7.7 ± 1.2	.001	1.9 ± 0.19	4.2 ± 0.72	.001
$S\bar{v}o_2$ (%)	73 ± 3.3	63 ± 4.1	.03	81 ± 4.2	78 ± 3.1	NS

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DAMAGE CONTROL RESUSCITATION

TEMPORARY HEMORRHAGE CONTROL

PERMISSIVE HYPOTENSION

HEMOSTATIC RESUSCITATION

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DAMAGE CONTROL SURGERY

(DAMAGE CONTROL RADIOLOGICAL INTERVENTION)

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RESTORING ORGAN PERFUSION

PRESURGICAL MANAGEMENT
PERMISSIV HYPOTENSJON

"PRESERVING COAGULATION, REDUCING BLEEDING WHILE SACRIFISING PERFUSION"

Not a treatment

Necessary evil??

Evidence????

Bicknell WH, Wall MJ, Pepe PE, Martin RR, Ginger VF, Allen MK, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. N Engl J Med 1994;331:1105-9

Turner J, Nicholl J, Webber L, Cox H, Dixon S, Yates D. A randomised controlled trial of prehospital intravenous fluid replacement therapy in serious trauma. Health Technology Assessment 2000;4:1-57.

Dutton RP, Mackenzie CF, Scalae TM. Hypotensive resuscitation during active haemorrhage: impact on hospital mortality. J Trauma 2002;52:1141-6.

SAFE Study Investigators; Australian and New Zealand Intensive Care Society Clinical Trials Group; Australian Red Cross Blood Service; George Institute for International Health, Myburgh J, Cooper DJ, et al. Saline or albumin for fluid resuscitation in patients with traumatic brain injury. N Engl J Med 2007;357:874-84

WHAT ABOUT DELAYED EVACUATION?

HOW LONG IN THE LOW-FLOW STATE?? EVIDENCE?

Garner, Jeff, et al. "Prolonged permissive hypotensive resuscitation is associated with poor outcome in primary blast injury with controlled hemorrhage." *Annals of surgery* 251.6 (2010): 1131-1139.

- 30% Bloodloss – SBP 80mmHg – Mean survival - 2 h

Doran, Catherine M., et al. "Targeted resuscitation improves coagulation and outcome." *Journal of Trauma and Acute Care Surgery* 72.4 (2012): 835-843.

- 35% Bloodloss – SBP 80mmHg vs 110mmHg – Mean survival hypotensive group - 3 h
- Significantly shorter survival in the hypotensive group

Skarda DE, Mulier KE, George ME, Beilman GJ. Eight hours of hypotensive versus normotensive resuscitation in a porcine model of controlled hemorrhagic shock. Acad Emerg Med 2008;15:845– 52.

- 35% Bloodloss SBP 65 vs 80 vs 90mmHg
  - Increased mortality and persistent BD and low StO2

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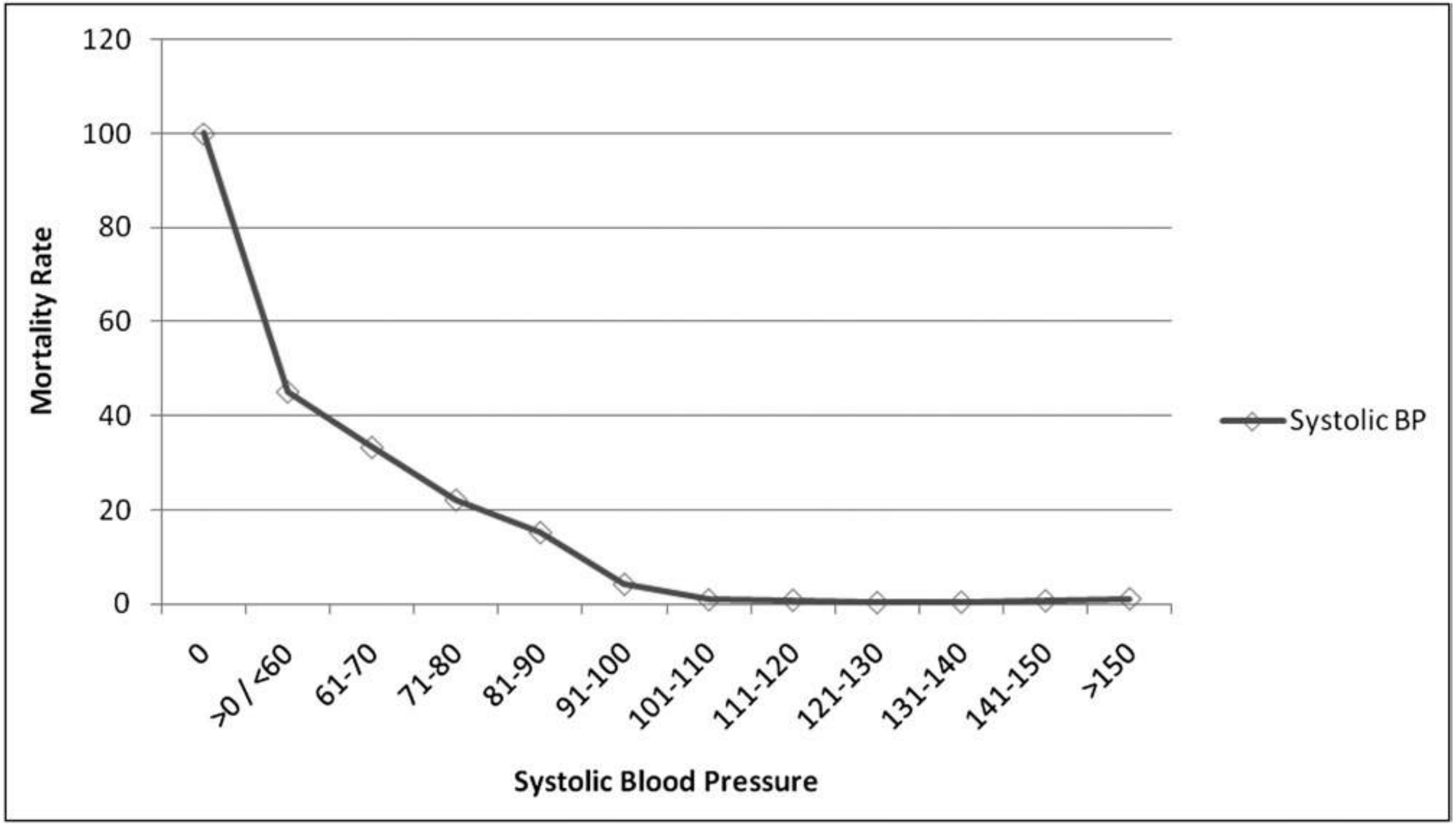
WHAT TARGETS?

HYPOTENSION IS 100 MM HG ON THE BATTLEFIELD
BRIAN J. EASTRIDGE, M.D.*, JOSE SALINAS, PH.D., CHARLES E. WADE, PH.D., LORNE H. BLACKBOURNE, M.D.



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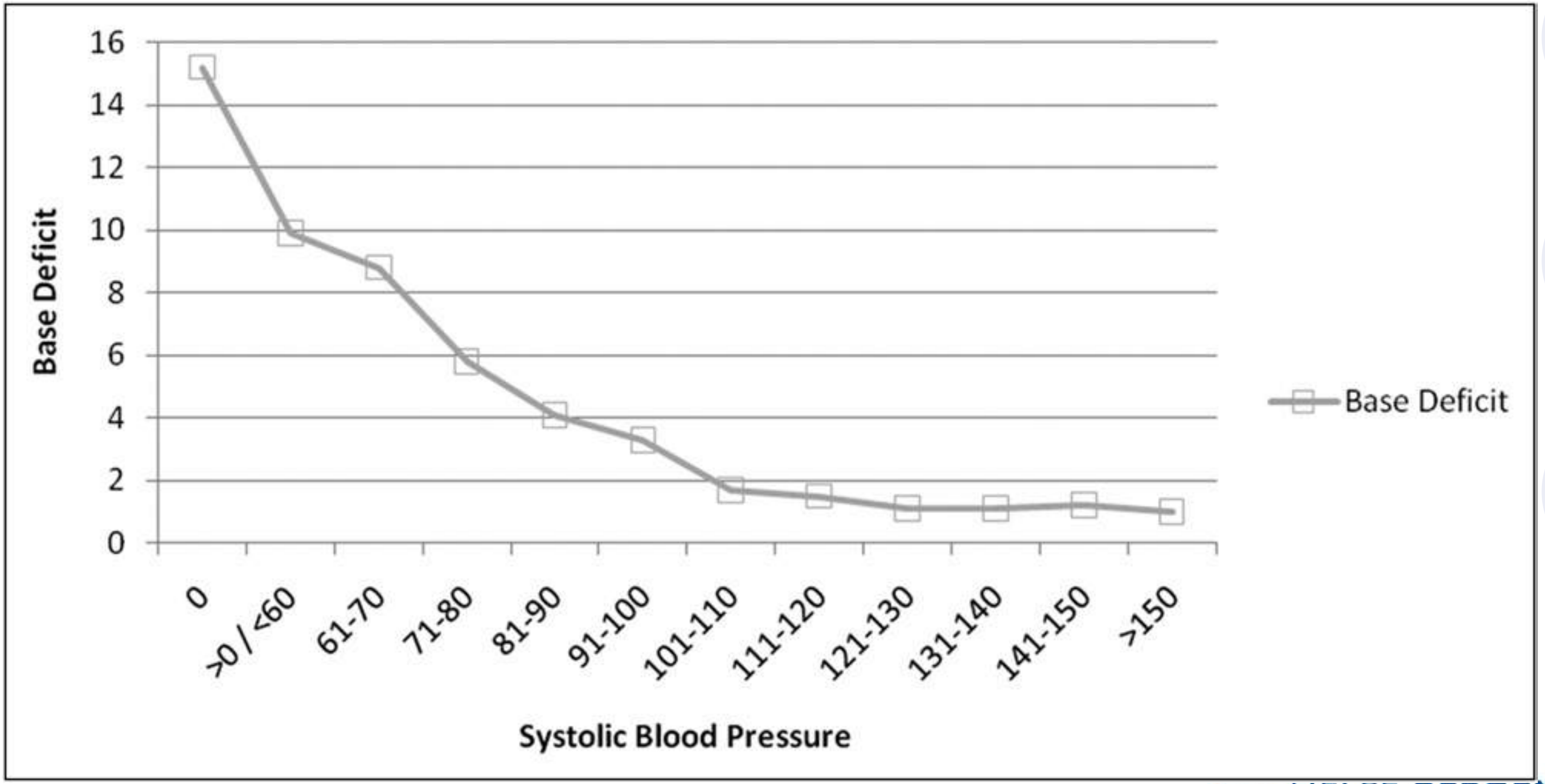
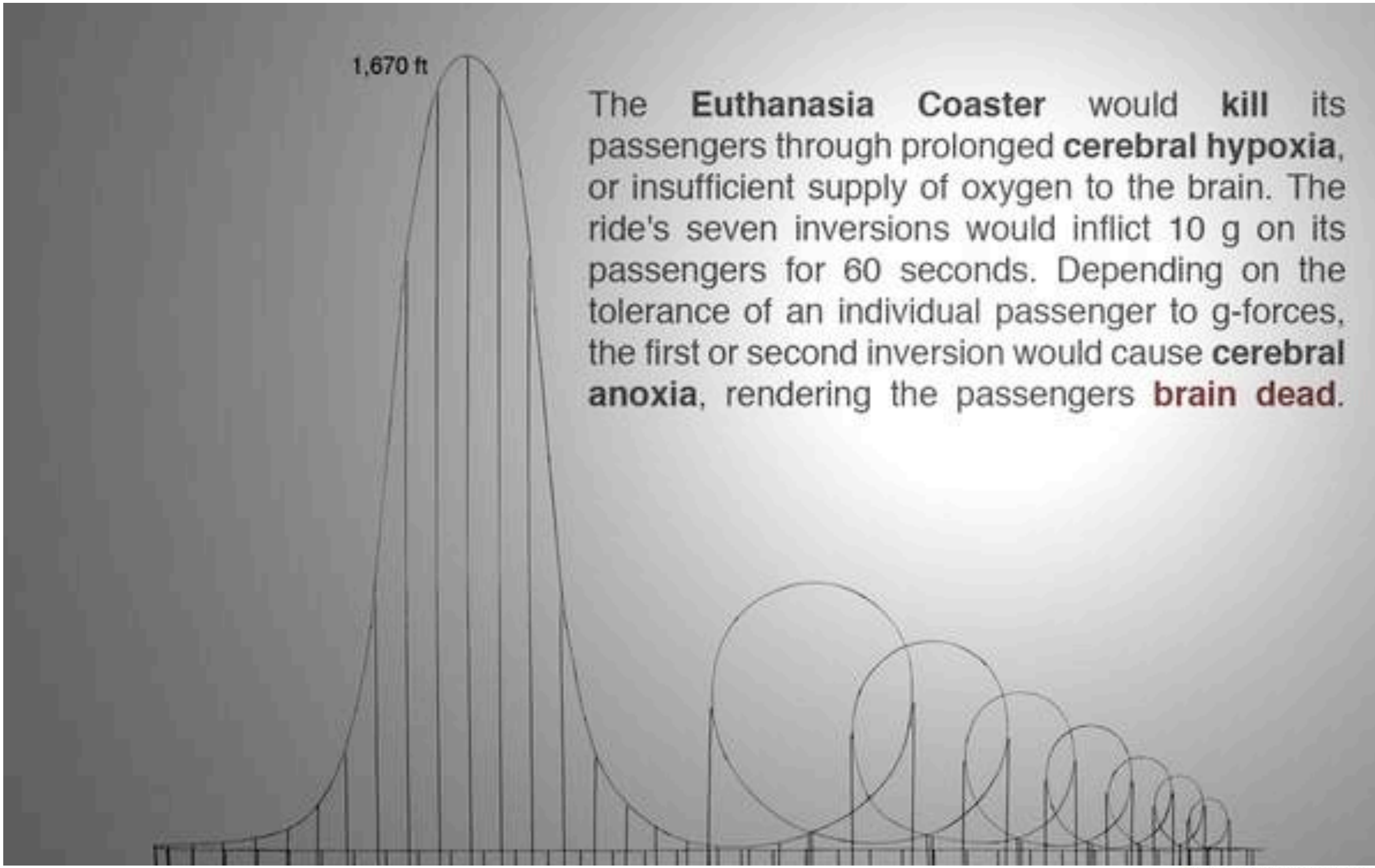
HYPOTENSION IS 100 MM HG ON THE BATTLEFIELD

BRIAN J. EASTRIDGE, M.D.*, JOSE SALINAS, PH.D., CHARLES E. WADE, PH.D.,
LORNE H. BLACKBOURNE, M.D.



PROLONGED PERMISSIVE HYPOTENSION WITH SALINE? – THE EUTHANASIA COASTER



PERMISSIVE HYPOTENSION

$$D0_2 = 1.34 \text{ X HGB X } SA0_2 \text{ X CO}$$

Ideal Resuscitation Fluid

	Volume	Hemostatic	O2 Carrying Capacity
Crystalloid	Y	N	N
Colloid	Y	N	N
Plasma	Y	Y	N
1:1:1	Y	Y	Y
Whole Blood	Y	Y	Y

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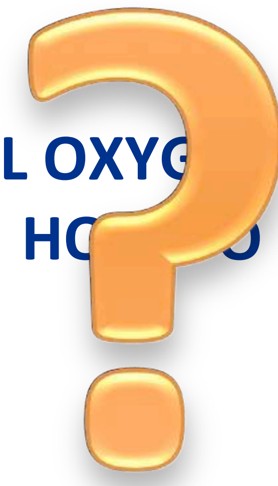
HEMOSTATIC RESUSCITATION

NEITHER HEMOSTATIC NOR RESUSCITATIVE

Khan, Sirat, et al. "Hemostatic resuscitation is neither hemostatic nor resuscitative in trauma hemorrhage." *Journal of Trauma and Acute Care Surgery* 76.3 (2014): 561-568.

- 106 study patients receiving at least 4 U of PRBC
  - 27 received 8 U to 11 U of PRBC
  - 31 received more than 12 U of PRBC
  - Average admission lactate was 6.2 mEq/L
  - Patients with high lactate (≥5 mEq/L) on admission did not clear lactate until hemorrhage control was achieved.
  - On admission, 43% of the patients were coagulopathic
  - There was no improvement in any ROTEM parameter during ongoing bleeding.

PREHOSPITAL OXYG DEBT REPAYMENT,
HO O DO IT?



Identifying the patient

- Vital signs?
- Systolic blood pressure?
  - Surrogate for cellular perfusion?
  - Undertriage 0-5%
  - Overtriage 15-50%
  - Lacks sensitivity/specificity for predicting patient outcomes and the need for resuscitative care
  - MECHANISM OF INJURY!!!

Vandromme, Marianne J., et al. "Lactate is a better predictor than systolic blood pressure for determining blood requirement and mortality: could prehospital measures improve trauma triage?." *Journal of the American College of Surgeons* 210.5 (2010): 861-867.

McGee S, Abernethy WB 3rd, Simel DL. The rational clinical examination. Is this patient hypovolemic? *JAMA*. 1999;281(11):1022–1029.

Brasel KJ, Guse C, Gentilello LM, Nirula R. Heart rate: is it truly a vital sign? *J Trauma*. 2007;62(4):812–817.

Bulger EM, Jurkovich GJ, Nathens AB, Copass MK, Hanson S, Cooper C, Liu PY, Neff M, Awan AB, Warner K, Maier RV. Hypertonic resuscitation of hypovolemic shock after blunt trauma: a randomized controlled trial. *Arch Surg*. 2008;143(2):139–148; discussion 149.

Newgard CD, Rudser K, Hedges JR, Kerby JD, Stiell IG, Davis DP, Morrison LJ, Bulger E, Terndrup T, Minei JP, et al. A critical assessment of the out-of-hospital trauma triage guidelines for physiologic abnormality. *J Trauma*. 2010;68(2):452–462.

Point of care lactate

- Elevated lactate is is predictive of poor outcomes in the in-hospital setting

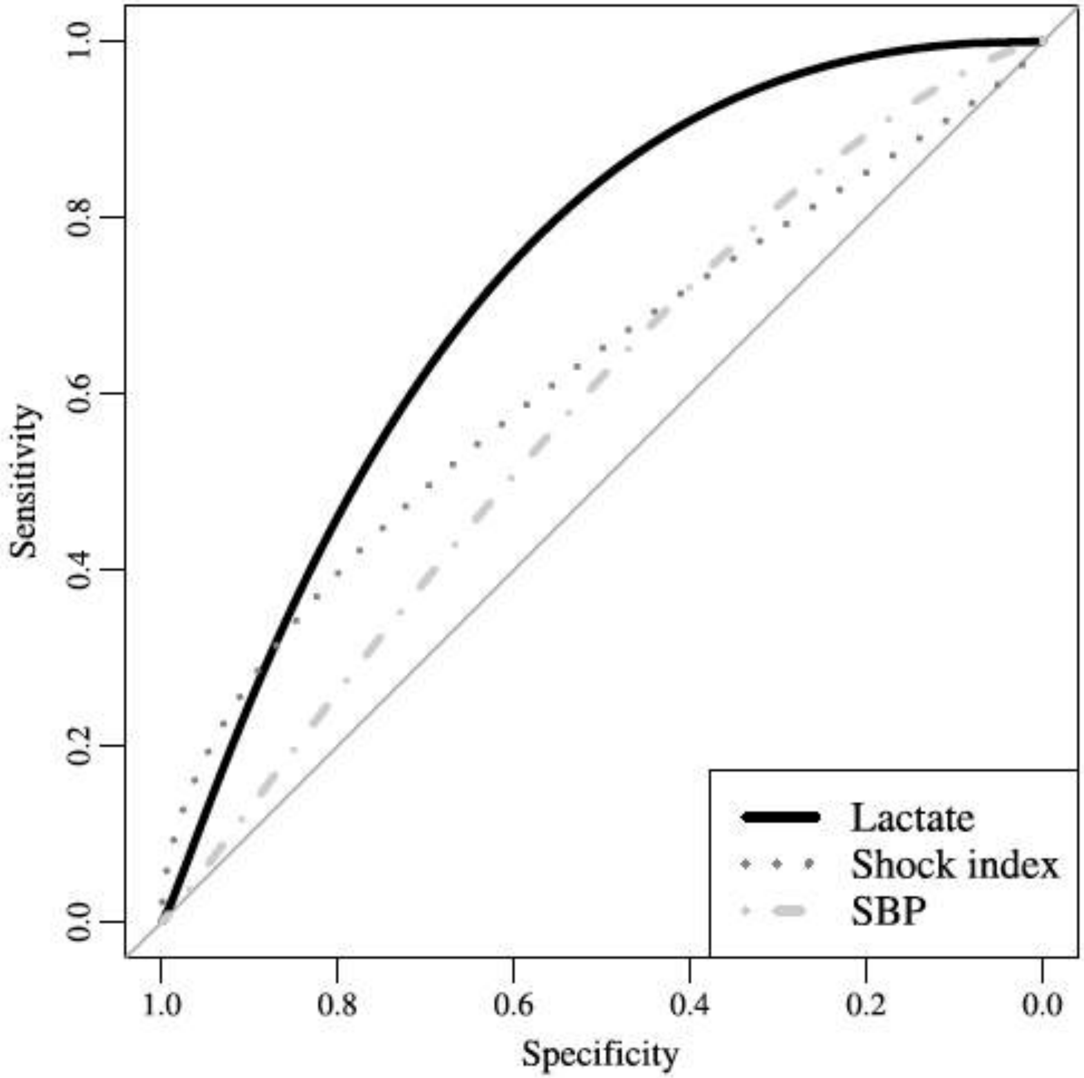
- P-LAC is superior to other early surrogates for hypoperfusion (SBP and shock index) in predicting the need for RC in trauma patients with
  70 mm Hg < SBP < 100 mm Hg

- Trends associated with the effectiveness of resuscitation, even with normal vital signs

Guyette, Francis X., et al. "A comparison of prehospital lactate and systolic blood pressure for predicting the need for resuscitative care in trauma transported by ground." *Journal of Trauma and Acute Care Surgery* 78.3 (2015): 600-606.

Sensitivity/Specificity

SBP >70
SBP<100



Guyette, Francis X., et al.

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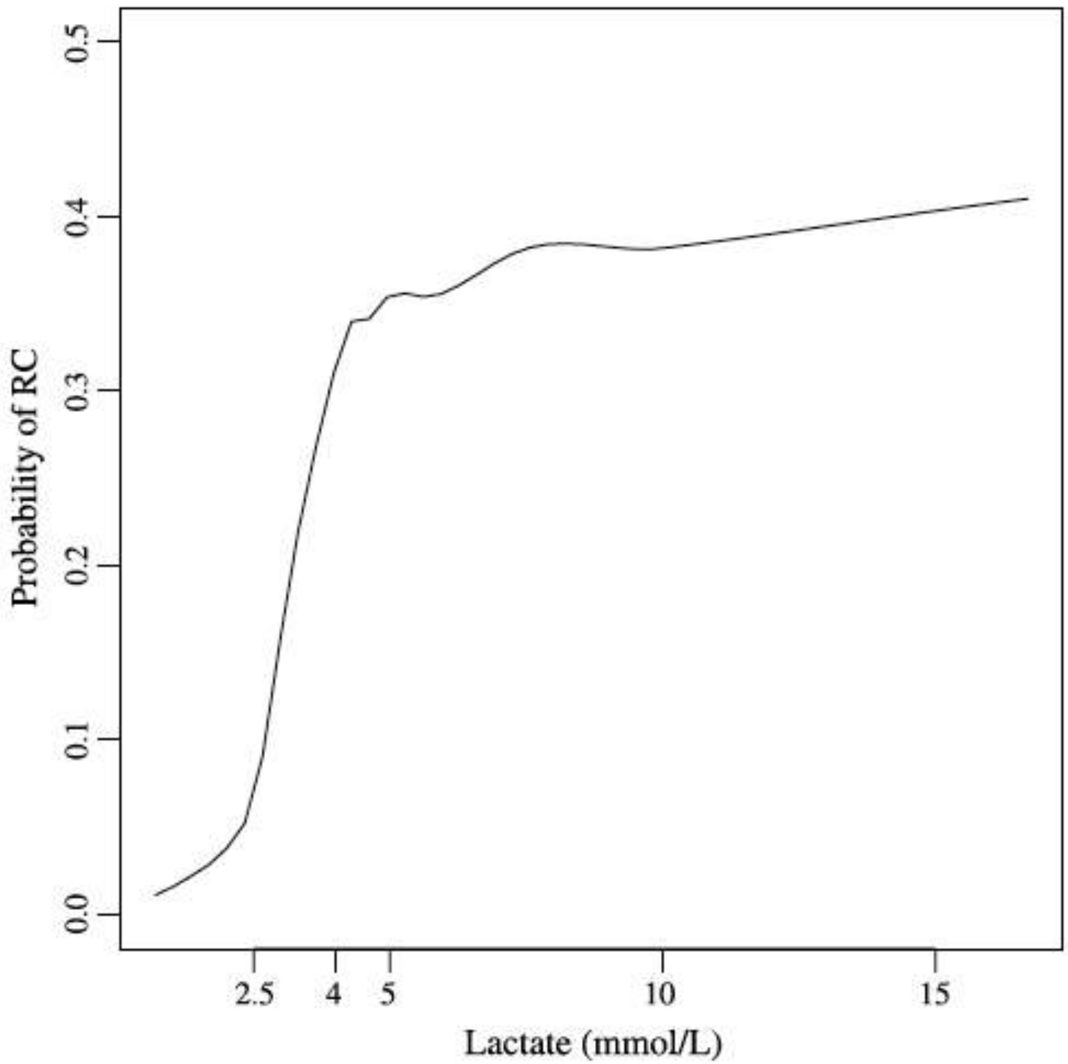
Probability of resuscitative care



Guyette, Francis X., et al.

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The detrimental effects of positive pressure ventilation during low-flow states

- Ventilatory requirements during low flow states is limited
- Positive pressure ventilation impairs perfusion

"Botched attempt is correct. But can anyone suggest a more family-friendly way of describing what happened?"

Pepe, Paul E., Lynn P. Roppolo, and Raymond L. Fowler. "The detrimental effects of ventilation during low-blood-flow states." *Current opinion in critical care* 11.3 (2005): 212-218.

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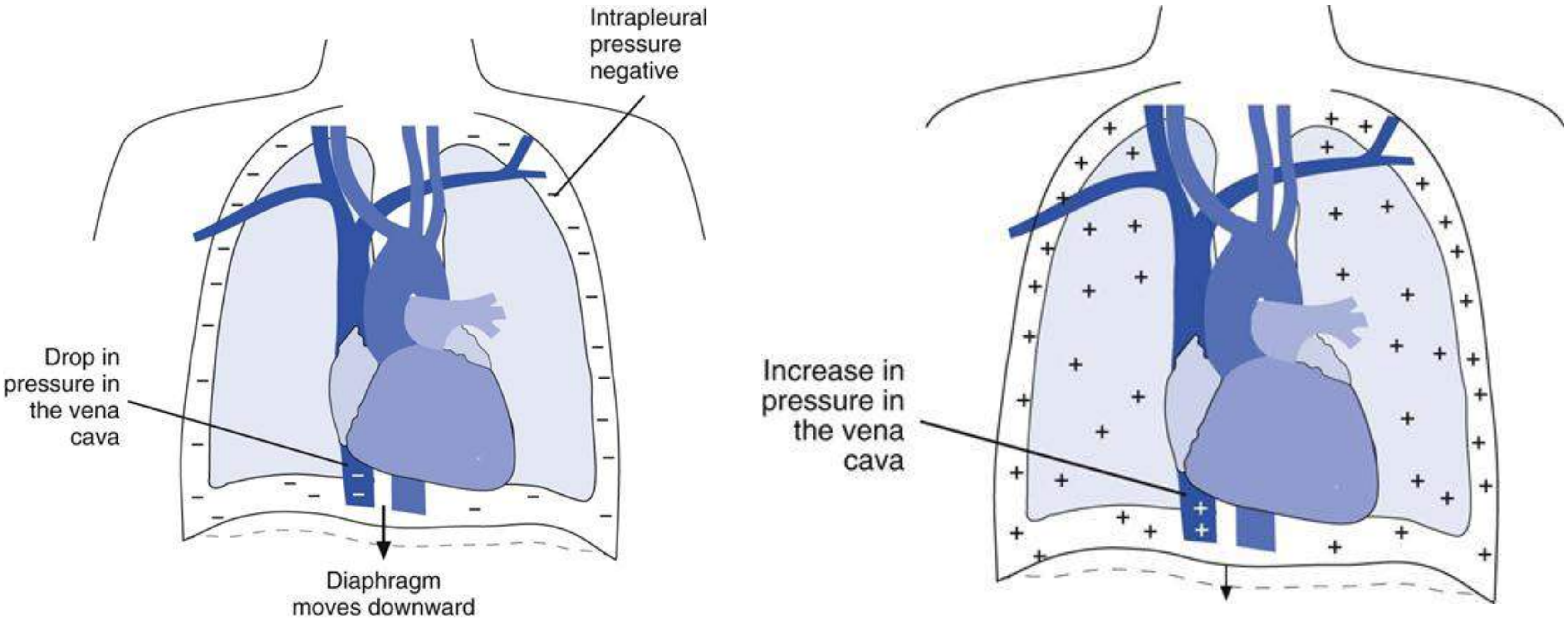
Positive pressure ventilation



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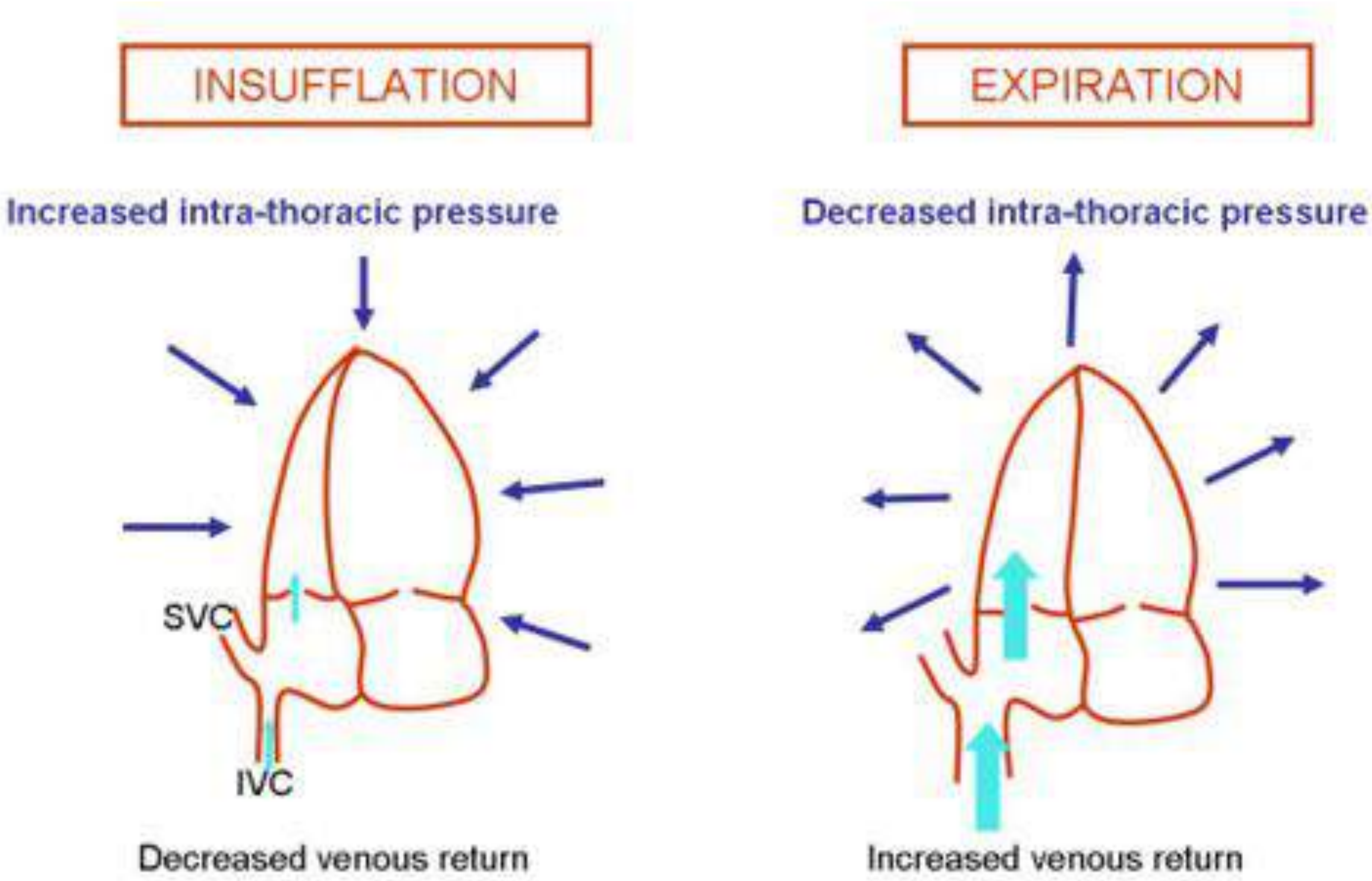
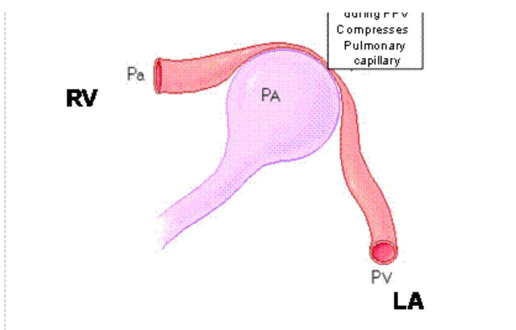
Positive pressure ventilation





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Spontaneus breathing

What fluid?

WHY IS 1:1:1 THERAPY PROBABLY INFERIOR TO WHOLE BLOOD?

DILUTION

Standard Amounts of Anti-coagulants and Additives in Reconstituted Whole Blood vs Whole Blood

Component Therapy per Unit:

6 x RBC	6 x 120 ml = 720ml
6 x FFP	6 x 50 ml = 300ml
1 x aPLT	1 x 35 ml = 35ml

Total =1055ml

Whole Blood per Unit:

6 x 63ml = 378ml

Total: 378ml

3 times the volume of anticoagulant and additives in 1:1:1 compared to whole blood

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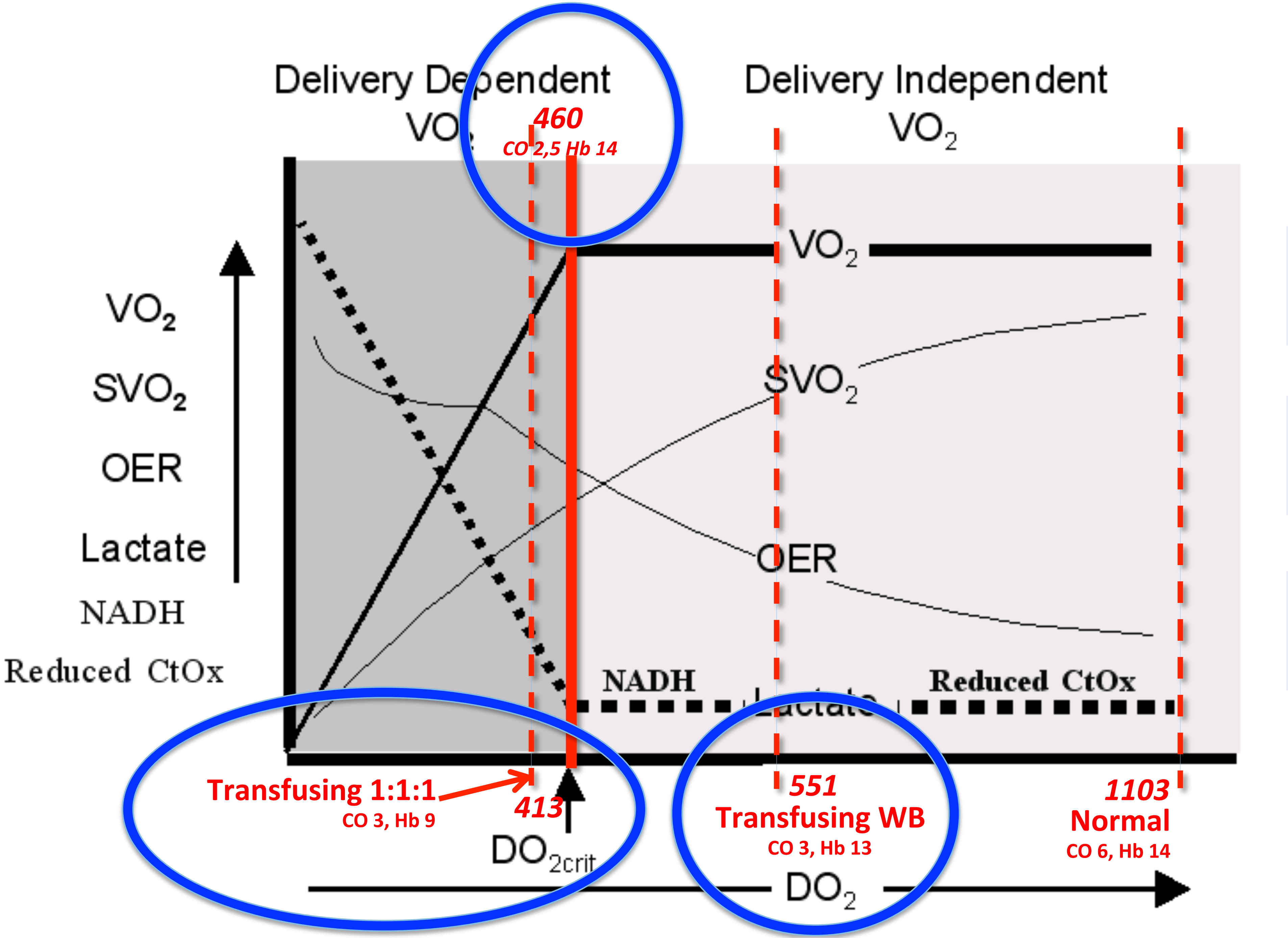
WHOLE BLOOD VS RECONSTITUATED WHOLE BLOOD (1:1:1)

- **CO 2-3 L/min vs. 6 L/min in healthy 80 kg Soldier**
- **1:1:1 gives Hgb 9g/L (DO2 = 413ml/min)**
- **WB gives Hgb 13/L (DO2 = 597ml/min)**
- ***Normal DO2 (CO = 6, Sat = 98%, Hgb 13) = 1103***
- ***Critical DO2 in healthy volunteers (CO = 6, Sat = 98%, Hgb 5) = 378***

Vallet et al. *Critical Care* 2010.

Cardenas et al. *J Trauma* 2014



Delivery Dependent
VO2
460
CO 2,5 Hb 14
Delivery Independent
VO2
VO2
SVO2
OER
Lactate
NADH
Reduced CtOx
VO2
SVO2
OER
NADH
Lactate
Reduced CtOx
Transfusing 1:1:1
CO 3, Hb 9
413
DO2crit
551
Transfusing WB
CO 3, Hb 13
1103
Normal
CO 6, Hb 14
DO2

EFFICACY

Warm fresh whole blood

Short term stored cold whole blood

Better RBC´s??

- "Storage lesion"
- NO mediated vasoconstriction

Cold stored platelets – better?

Spinella, Philip C., and Allan Doctor. "Role of transfused red blood cells for shock and coagulopathy within remote damage control resuscitation." *Shock* 41 (2014): 30-34.

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E-1-3

BEST TREATMENT FOR HEMORRHAGE/ SHOCK/ATC?

What we are doing now that is associated with improved outcomes?

Aggressive hemorrhage control
- Hemostatic dressings, tourniquets

TXA

Early resuscitation that delivers ***functionality of WB*** (WB or 1:1:1)
- Increasing use of plt & cryo (1:1:1:1)
- Reduced RBC age
- ROTEM-guided DCR?
- Permissive hypotension?

Reduced crystalloid/colloid

Minimize time to surgery

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KEY POINTS

Oxygen Debt - important predictor of death and organ failure and is directly linked to the coagulopathy of trauma

Major emphasis in the field is to prevent further accumulation of oxygen debt

Oxygen Debt must be repaid to a certain level over a certain period of time to reduce mortality and organ injury

Oxygen debt is mirrored by level of lactate and length of time it is elevated

Clearance of lactate is associated with repayment of oxygen debt, point of care lactate might be helpful in triage and as a monitor during resuscitation prehospitally

KEY POINTS

Positive pressure ventilation may be detrimental during permissive hypotension.

Whole blood may be superior to component therapy in permissive hemostatic resuscitation

Listen to the medics – implement only what is doable – and what helps the patient.

Brohi K, Cohen MJ, Ganter MT, et al. Acute traumatic coagulopathy: initiated by hypoperfusion: modulated through the protein C pathway? Ann Surg 2007; 245:812–818

Hess et al, J Trauma 2008 (ACOTS)

Manikis, Panagiotis, et al. "Correlation of serial blood lactate levels to organ failure and mortality after trauma." *The American journal of emergency medicine* 13.6 (1995): 619-622.

Husain, Farah A., et al. "Serum lactate and base deficit as predictors of mortality and morbidity." *The American journal of surgery* 185.5 (2003): 485-491.

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Hess et al, J Trauma 2008 (ACOTS)

Brohi K, Singh J, Heron M, et al. Acute traumatic coagulopathy. J Trauma 2003; 54:1127–1130

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Manikis P, Jankowski S, Zhang H, Kahn RJ, Vincent JL. Correlation of serial blood lactate levels to organ failure and mortality after trauma. Am J Emerg Med. 1995;13(6):619Y622

Barbee, Robert Wayne, Penny S. Reynolds, and Kevin R. Ward. "Assessing shock resuscitation strategies by oxygen debt repayment." *Shock* 33.2 (2010): 113-122.

Rixen D, Siegel JH: Bench-to-bedside review: oxygen debt and its metabolic correlates as quantifiers of the severity of hemorrhagic and post-traumatic shock. Crit Care 9:441Y453, 2005.

Bicknell WH, Wall MJ, Pepe PE, Martin RR, Ginger VF, Allen MK, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. N Engl J Med 1994;331:1105-9

Turner J, Nicholl J, Webber L, Cox H, Dixon S, Yates D. A randomised controlled trial of prehospital intravenous fluid replacement therapy in serious trauma. Health Technology Assessment 2000;4:1-57.

Dutton RP, Mackenzie CF, Scalae TM. Hypotensive resuscitation during active haemorrhage: impact on hospital mortality. J Trauma 2002;52:1141-6.

Vandromme, Marianne J., et al. "Lactate is a better predictor than systolic blood pressure for determining blood requirement and mortality: could prehospital measures improve trauma triage?." *Journal of the American College of Surgeons* 210.5 (2010): 861-867.

Guyette, Francis X., et al. "A comparison of prehospital lactate and systolic blood pressure for predicting the need for resuscitative care in trauma transported by ground." *Journal of Trauma and Acute Care Surgery* 78.3 (2015): 600-606.

HYPOTHERMIA

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Simplicity

THE MEDIC: NEW GEAR??

Duty Position	Average Fighting Load (lbs)	Average FL % Body Weight	Average Approach March Load (lbs)	Average AML % Body Weight	Average Emergency Approach March Load (lbs)	Average EAML % Body Weight
Combat Medic	54.53 lbs	31.08%	91.72 lbs	51.58%	117.95 lbs	69.88%

Hemoglobin levels matter?

1996: FIS (International ski federation) -decision to take pre-race Hgb measurements and exclude men with Hgb>18,5 g/l and women with Hgb>16,5 g/l from participation in the race