2020-06-04 (Thu.)
대한흉부외과학회 전공의 연수교육

Monitoring at ICU and Cardiovascular Management

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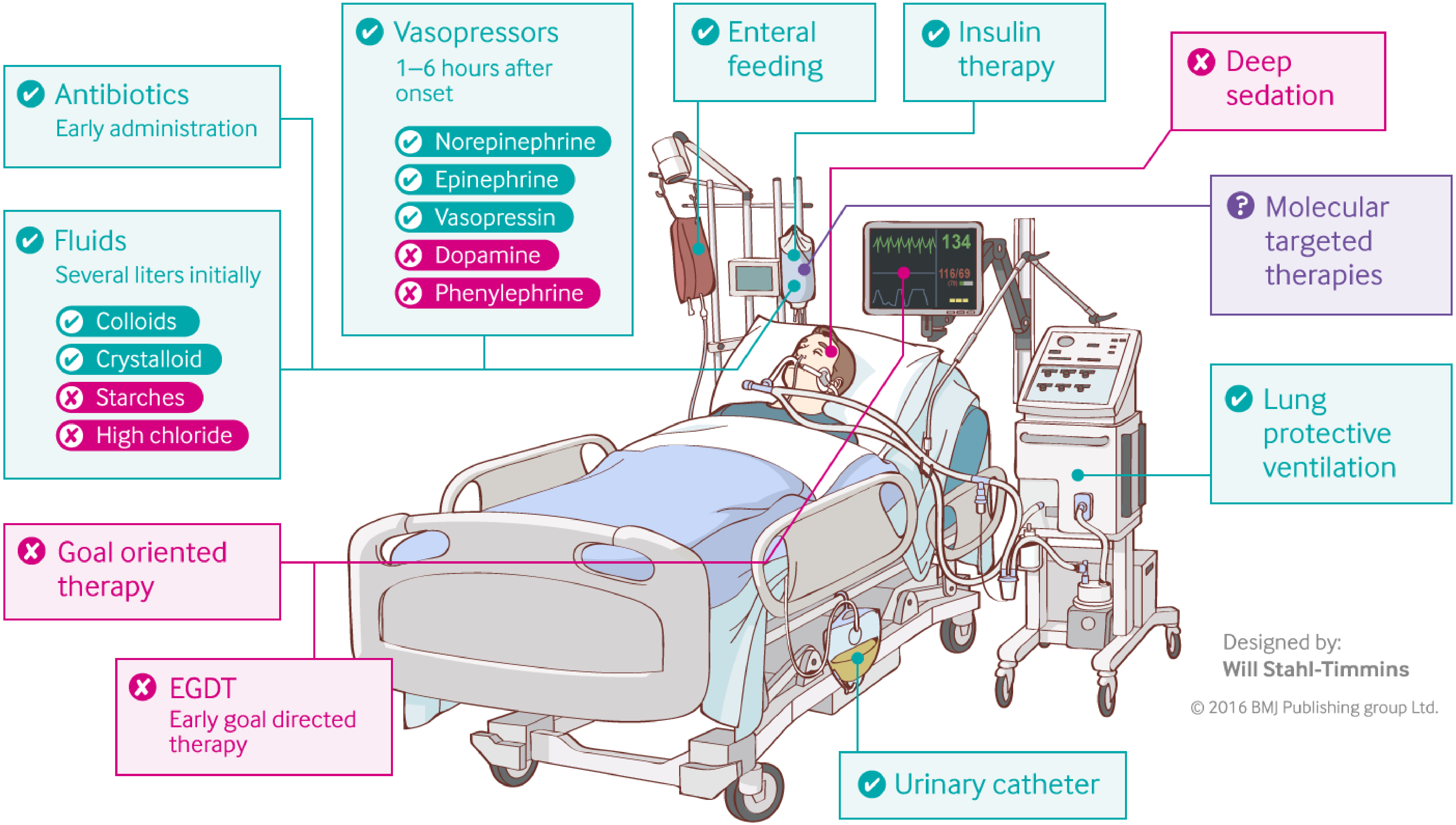
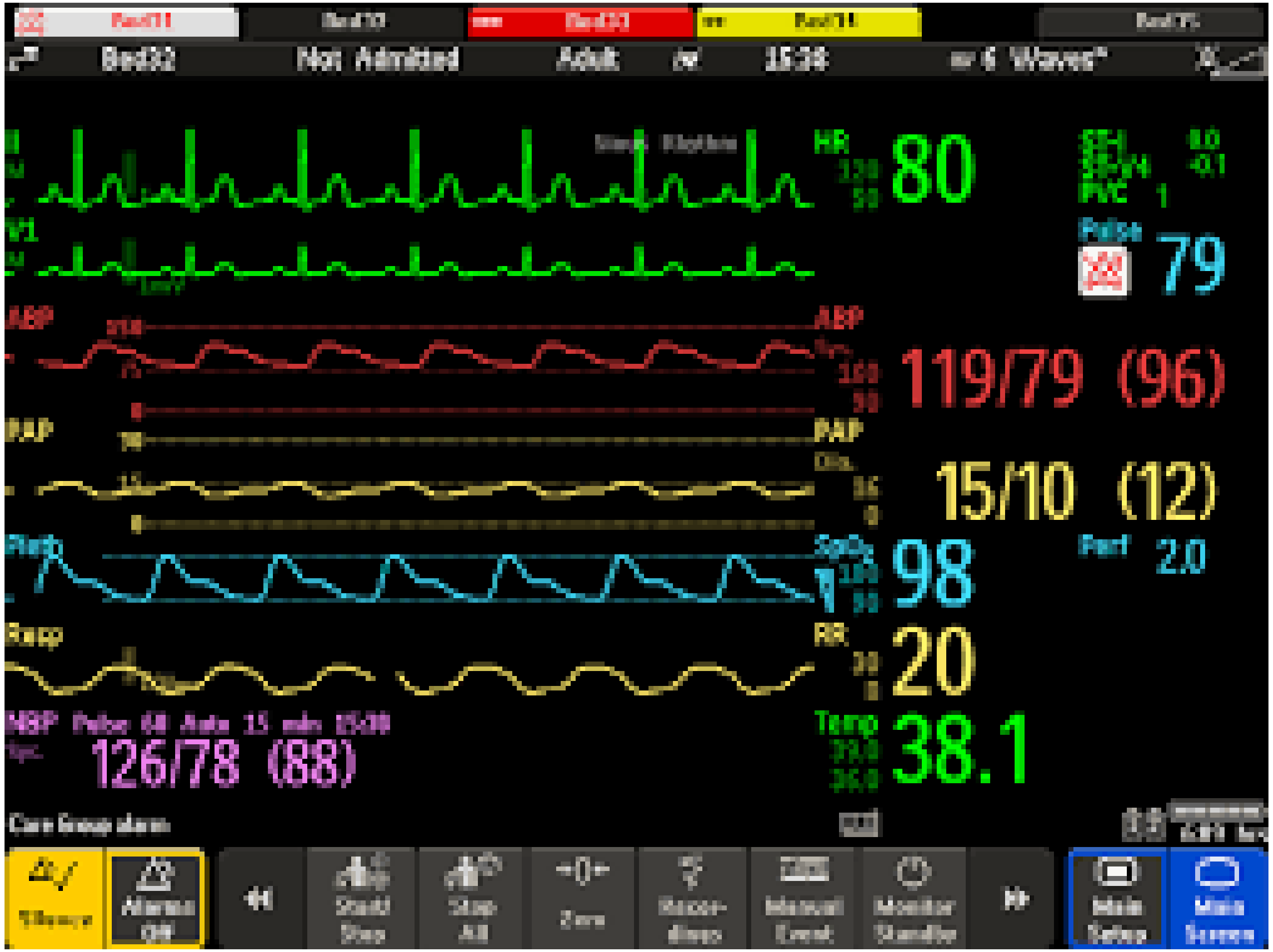
Chonnam National University Hospital and Medical School

INTRODUCTION

Treating sepsis: the latest evidence



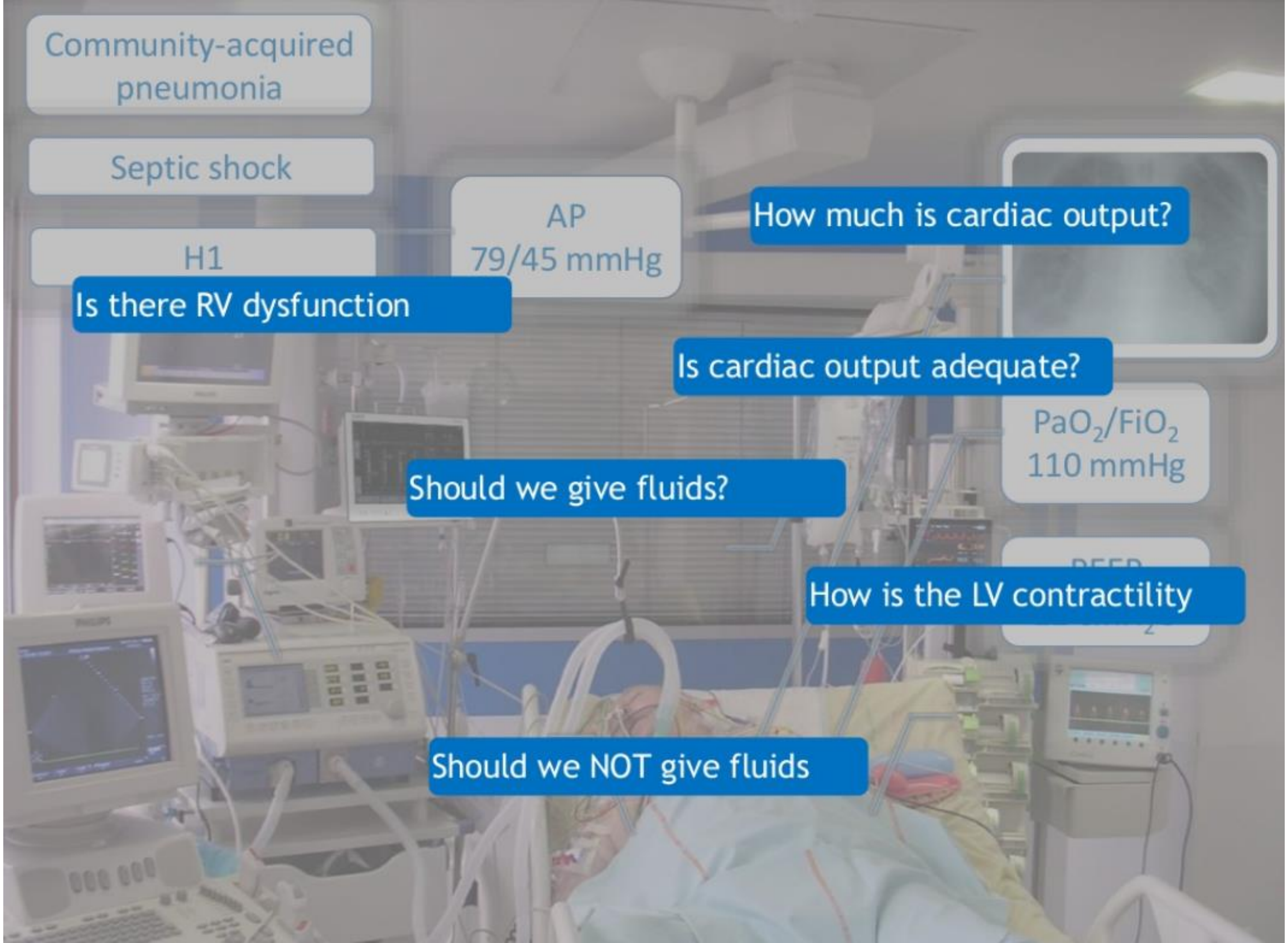
Designed by:
Will Stahl-Timmins



Bed32
Not Admitted
Adult
15:38
HR
80
79
ABP
119/79 (96)
PAP
15/10 (12)
98
Perf
2.0
RR
20
Temp
38.1
NBP
126/78 (88)
Monitor Standby
Main Setup
Main Screen

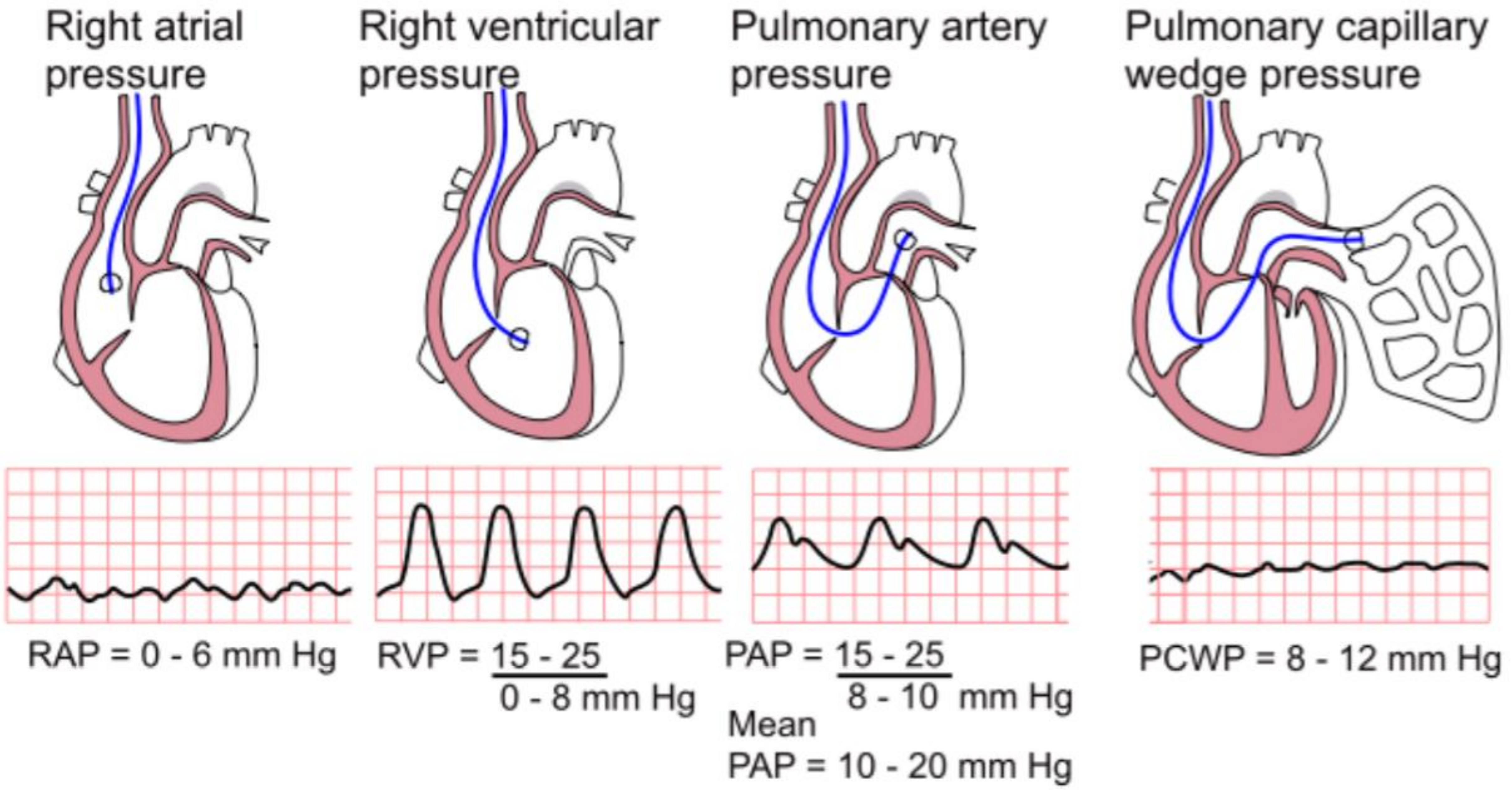

152
86
152
0.6
134/82 (98)
38/11 (24)
(8)
18
7:59

Not Admitted
Adult
18 May 19:50
HR
108
Pulse
108
PVC
2
ST-I
ST-II
ST-III
ST-aVR
ST-aVL
ST-aVF
ST-V
ST-MCL
ABP
148/74
(93)
Ao
133/74
(94)
PAP
34/24
(28)
Pleth
SpO₂
100
CVP
(16)
Resp
RR
14


Community-acquired pneumonia
Septic shock
H1
AP 79/45 mmHg
How much is cardiac output?
Is there RV dysfunction
Is cardiac output adequate?
PaO_2/FiO_2 110 mmHg
Should we give fluids?
How is the LV contractility
Should we NOT give fluids

- Central venous and pulmonary artery catheters (PAC) are invasive tools that have traditionally been used for hemodynamic monitoring in patients who present with shock.
- However, these tools have drawbacks and inaccuracies.
- Thus, several, less invasive, novel technologies are available or being investigated for use to assess parameters such as cardiac output, intravascular volume status, responsiveness to intravenous fluid administration, and tissue perfusion.
- They can potentially be used in the emergency department, intensive care unit, and operating room when caring for patients with shock or hypovolemia.

GENERAL PRINCIPLES


Right atrial pressure
Right ventricular pressure
Pulmonary artery pressure
Pulmonary capillary wedge pressure
RAP = 0 - 6 mm Hg
RVP = 15 - 25 / 0 - 8 mm Hg
PAP = 15 - 25 / 8 - 10 mm Hg
Mean PAP = 10 - 20 mm Hg
PCWP = 8 - 12 mm Hg

- Central venous and pulmonary artery catheterization (PAC), the traditional tools used for hemodynamic monitoring of patients who present with shock, are invasive and frequently inaccurate.

CVP and PAC monitoring suffer from the following inadequacies:

1. **Inconsistent prediction of fluid responsiveness**

2. **Complications associated with invasiveness**

3. **Difficult data interpretation**

Inconsistent prediction of fluid responsiveness

1. Both CVP and pulmonary alveolar occlusion pressure have been shown to have poor predictive value for predicting fluid responsiveness (arbitrarily defined as an increase of at least 15 percent in cardiac output [CO] in response to a 500 mL bolus fluid challenge, as measured by PAC).
2. Furthermore, CVP is affected by a number of other physiologic derangements, including valvular regurgitation, right ventricular dysfunction, pulmonary hypertension, and variation in intrathoracic pressure with respiration.

Complications associated with invasiveness

1. CVCs and PACs require central venous access and have been associated with a number of complications, including arrhythmias, injury to vascular or cardiac structures, catheter-associated bloodstream infection, pneumothorax, and venous thromboembolism.

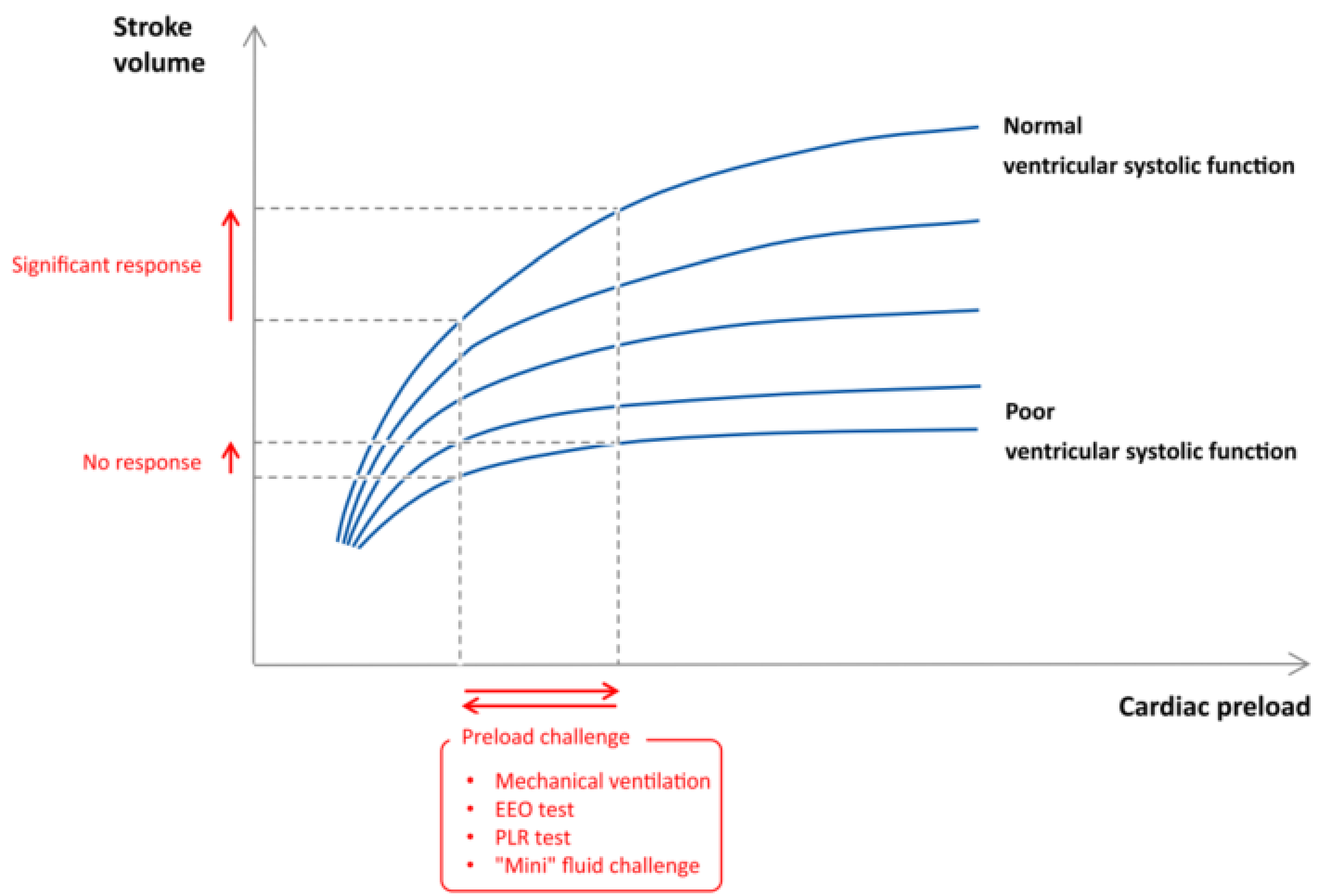


Fig. 1 Frank–Starling relationship. The slope of the Frank–Starling curve depends on the ventricular systolic function. Then, one given level of cardiac preload does not help in predicting fluid responsiveness. By contrast, dynamic tests include a preload challenge (either spontaneous, induced by mechanical ventilation or provoked, by passive leg raising, end-expiratory occlusion or fluid infusion). Observing the resulting effects on stroke volume allows for the detection of preload responsiveness. *EEO* end-expiratory occlusion, *PLR* passive leg raising

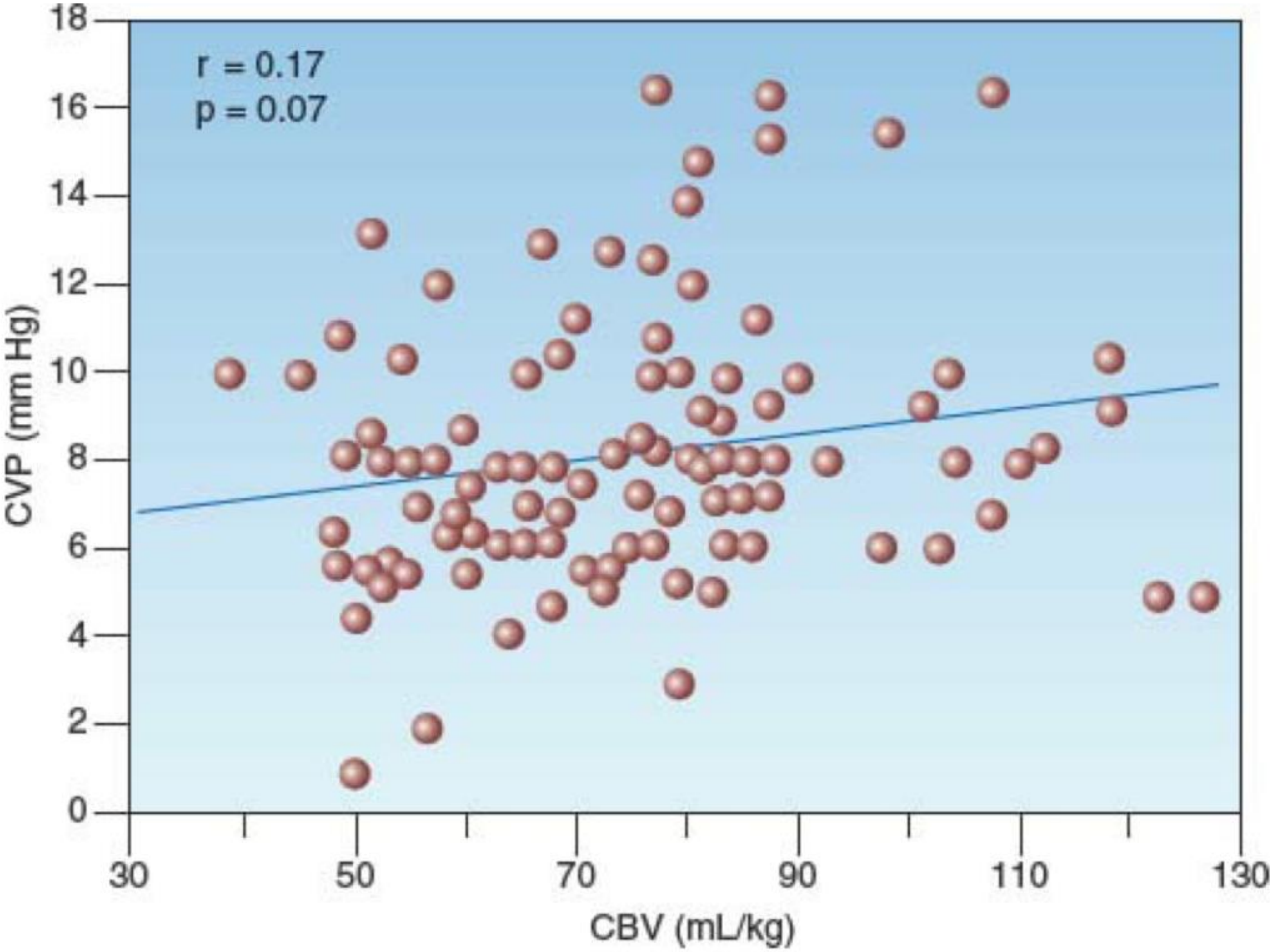
Monnet et al. Ann. Intensive Care (2016) 6:111

Table 1 Summary of methods predicting preload responsiveness with diagnostic threshold and limitations

Method	Threshold	Main limitations
Pulse pressure/stroke volume variations [22]	12%	Cannot be used in case of spontaneous breathing, cardiac arrhythmias, low tidal volume/ lung compliance
Inferior vena cava diameter variations [44]	12%	Cannot be used in case of spontaneous breathing, low tidal volume/lung compliance
Superior vena caval diameter variations [44]	36%*	Requires performing transesophageal Doppler Cannot be used in case of spontaneous breathing, low tidal volume/lung compliance
Passive leg raising [55]	10%	Requires a direct measurement of cardiac output
End-expiratory occlusion test [75]	5%	Cannot be used in non-intubated patients Cannot be used in patients who interrupt a 15-s respiratory hold
"Mini"-fluid challenge (100 mL) [84]	6%**	Requires a precise technique for measuring cardiac output
"Conventional" fluid challenge (500 mL) [81]	15%	Requires a direct measurement of cardiac output Induces fluid overload if repeated

* Thresholds from 12 to 40% have been reported

** 10% is more compatible with echography precision. Citations indicate the most important reference regarding the test



Monnet, et al. Prediction of fluid responsiveness: an update.
Ann Intensive Care. 2016 Dec;6(1):111. Epub 2016 Nov 17.

Indications

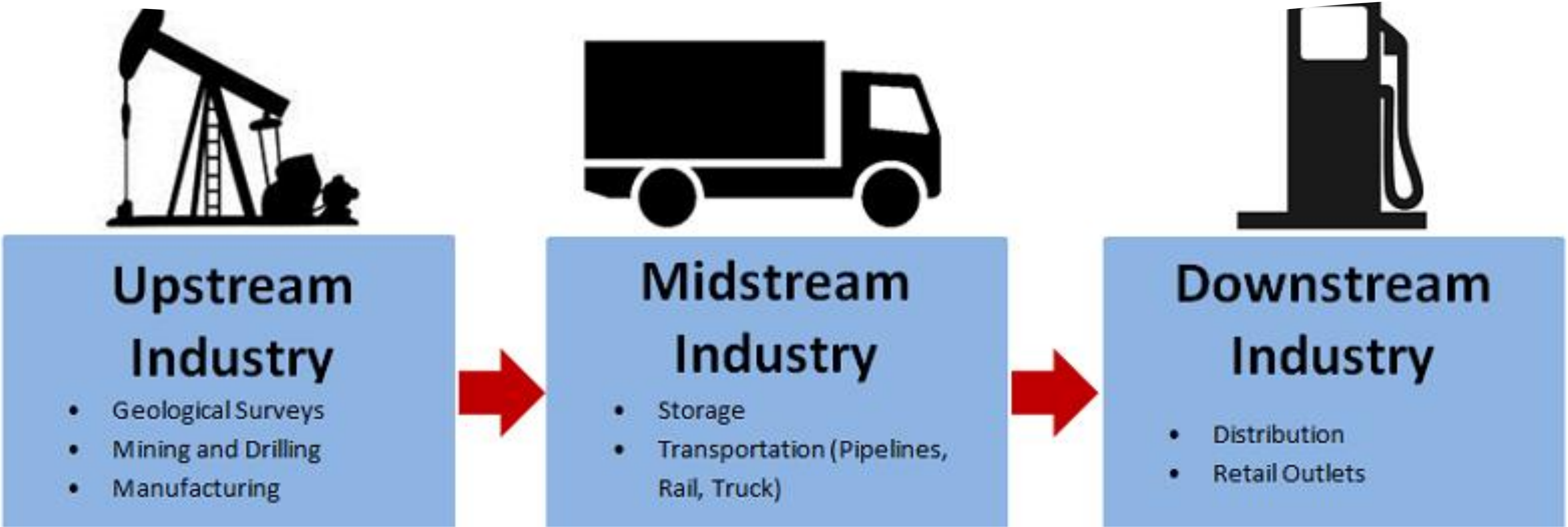
- A plethora of techniques aimed at overcoming the deficiencies associated with standard hemodynamic monitoring tools have been developed, many of which use complex imaging technology and computer algorithms to estimate the following:

1. **Fluid responsiveness and volume status**
   (see 'Volume tolerance and fluid responsiveness' below)
2. **Cardiac output**
   (see 'Cardiac output' below)
3. **Tissue perfusion**
   (see 'Measurement of tissue oxygen saturation' below and 'Measurement of microcirculatory blood flow' below and 'Tissue perfusion' below)

- While no large randomized trials of resuscitation guided by noninvasive hemodynamic monitors have been conducted, a systematic review of 13 trials enrolling over 1600 subjects found that such practice was associated with reduced mortality, ICU length of stay, and duration of mechanical ventilation.
- A sub-analysis of the ANDROMEDA-SHOCK trial suggests that assessment of fluid responsiveness was possible in 80 percent of patients.
- Fluid responsive patients received lower fluid volumes, exhibited less positive fluid balances, and received more vasopressors, but had no difference in mortality or organ failure.
- These findings will likely only increase the interest in use of these tools in critically ill patients.

Physiologic principles

- Upstream versus downstream monitors
- A greater understanding of tissue and cellular hypoxia as a cardinal feature of shock has led to the concept of "upstream" and "downstream" indicators of organ perfusion [11].



Physiologic principles: Upstream

- "Upstream" ("macro") markers assess flow and pressure in the heart, vena cava, pulmonary artery, and aorta and are the traditional variables that have been used to assess the hemodynamic status of critically ill patients.
- The majority of existing hemodynamic monitors are upstream monitors.

Physiologic principles: Downstream

- Shock with end-organ dysfunction occurs at the capillary and tissue levels [12].
- Tools have been developed that follow alterations in tissue oxygenation and microvascular blood flow.
- These techniques are known as the "downstream" (or "micro") markers of resuscitation.

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 APRIL 24, 2014 VOL. 370 NO. 17

High versus Low Blood-Pressure Target in Patients with Septic Shock

Pierre Asfar, M.D., Ph.D., Ferhat Meziani, M.D., Ph.D., Jean-François Hamel, M.D., Fabien Grelon, M.D., Bruno Megarbane, M.D., Ph.D., Nadia Anguel, M.D., Jean-Paul Mira, M.D., Ph.D., Pierre-François Dequin, M.D., Ph.D., Soizic Gergaud, M.D., Nicolas Weiss, M.D., Ph.D., François Legay, M.D., Yves Le Tulzo, M.D., Ph.D., Marie Conrad, M.D., René Robert, M.D., Ph.D., Frédéric Gonzalez, M.D., Christophe Guitton, M.D., Ph.D., Fabienne Tamion, M.D., Ph.D., Jean-Marie Tonnelier, M.D., Pierre Guezennec, M.D., Thierry Van Der Linden, M.D., Antoine Vieillard-Baron, M.D., Ph.D., Eric Mariotte, M.D., Gaël Pradel, M.D., Olivier Lesieur, M.D., Jean-Damien Ricard, M.D., Ph.D., Fabien Hervé, M.D., Damien du Cheyron, M.D., Ph.D., Claude Guerin, M.D., Ph.D., Alain Mercat, M.D., Ph.D., Jean-Louis Teboul, M.D., Ph.D., and Peter Radermacher, M.D., Ph.D., for the SEPSISPAM Investigators*

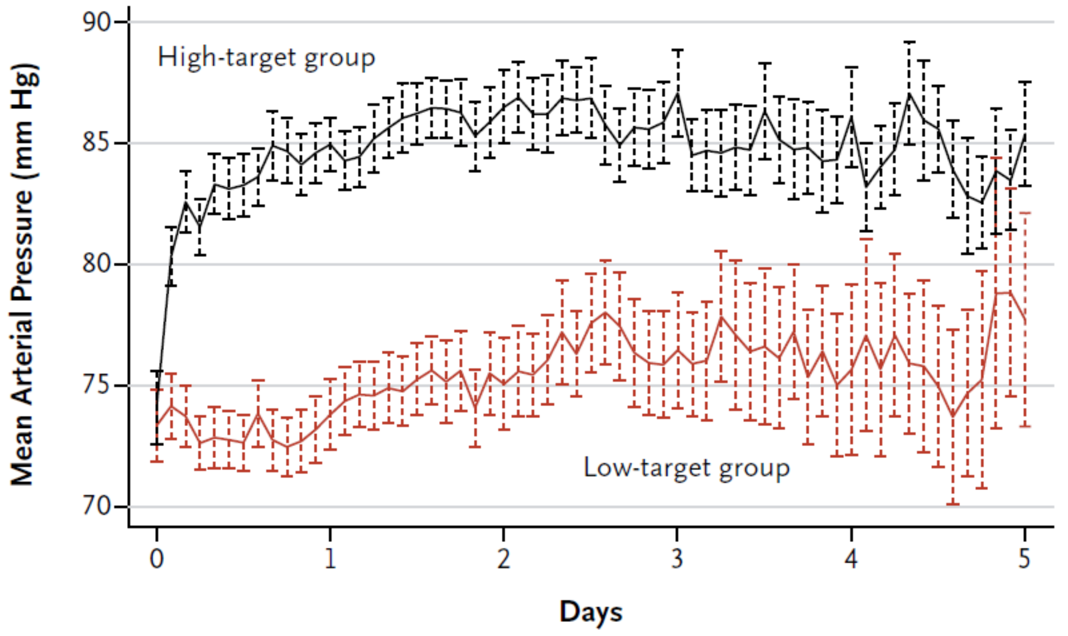
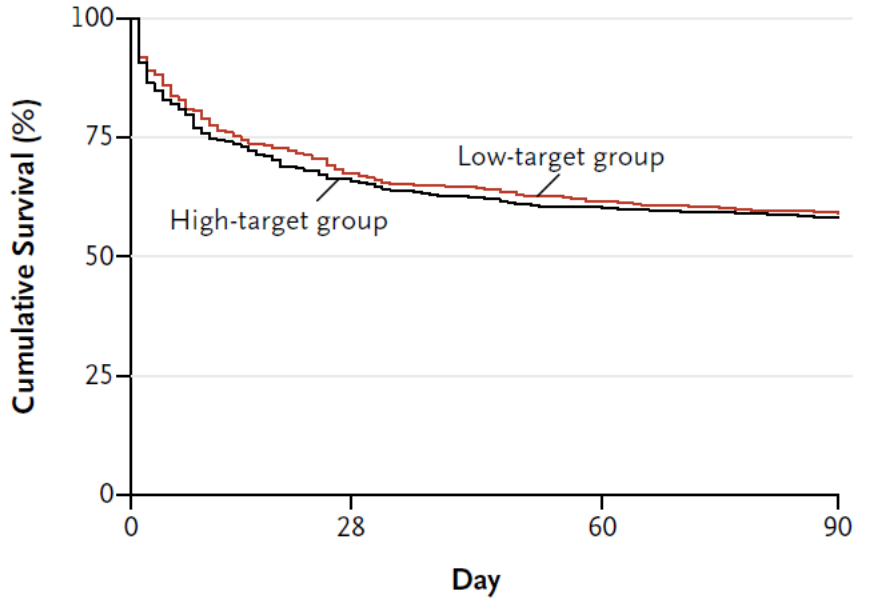


Figure 2. Mean Arterial Pressure during the 5-Day Study Period.

Mean arterial pressures were significantly lower in the low-target group than in the high-target group during the 5 protocol-specified days (P=0.02 by repeated-measures regression analysis), although the values exceeded the target values of 80 to 85 mm Hg in the high-target group and 65 to 70 mm Hg in the low-target group. The I bars represent 95% confidence intervals.



No. at Risk				
Low target	379	256	233	225
High target	375	249	227	219

Figure 3. Kaplan–Meier Curves for Cumulative Survival.

Data for the survival analysis, which was performed in the intention-to treat population, were censored at 90 days. There was no significant difference in survival between the high-target group and the low-target group (P=0.57 at 28 days; P=0.74 at 90 days).

ASAIO Journal 2019

Adult Circulatory Support

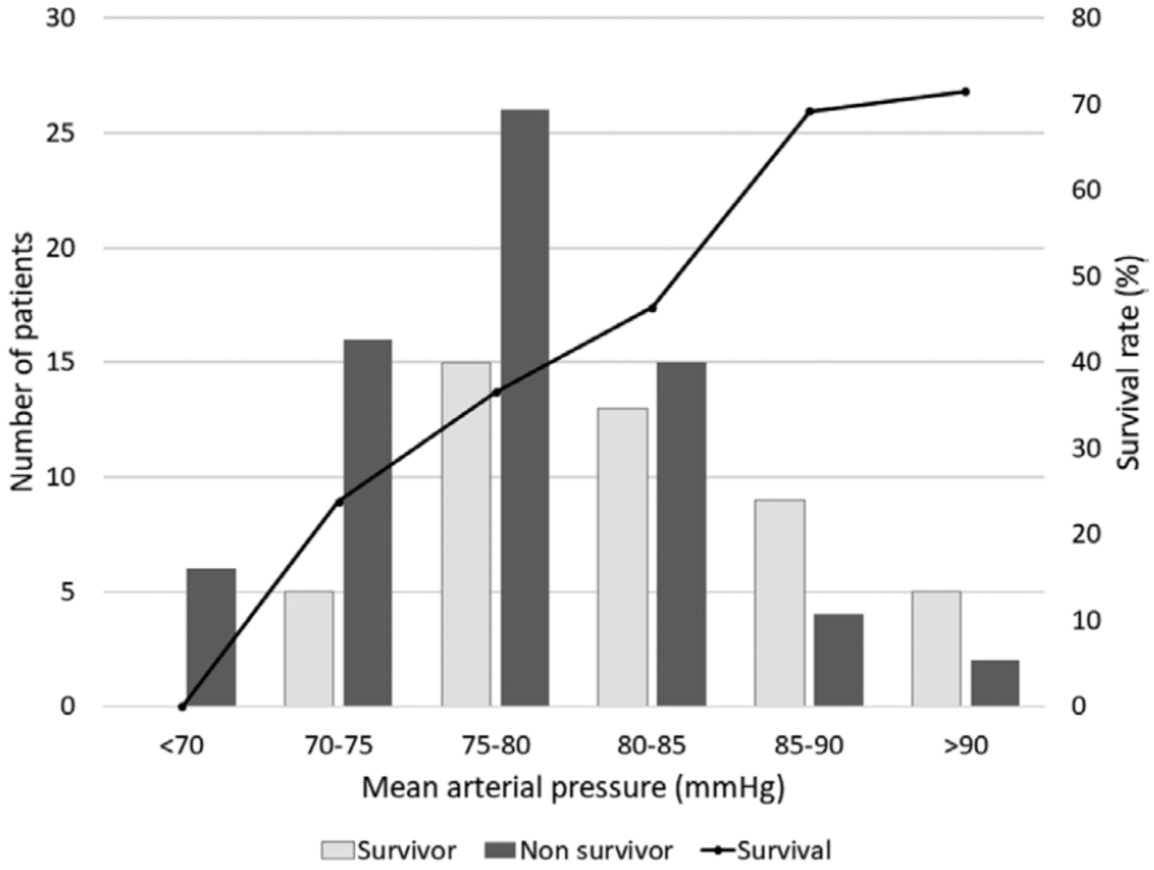
What Is the Optimal Blood Pressure on Veno-Arterial Extracorporeal Membrane Oxygenation? Impact of Mean Arterial Pressure on Survival

DAIZO TANAKA, SHOGO SHIMADA, MEGAN MULLIN, KRISTIN KREITLER, NICHOLAS CAVAROCCHI, AND HITOSHI HIROSE

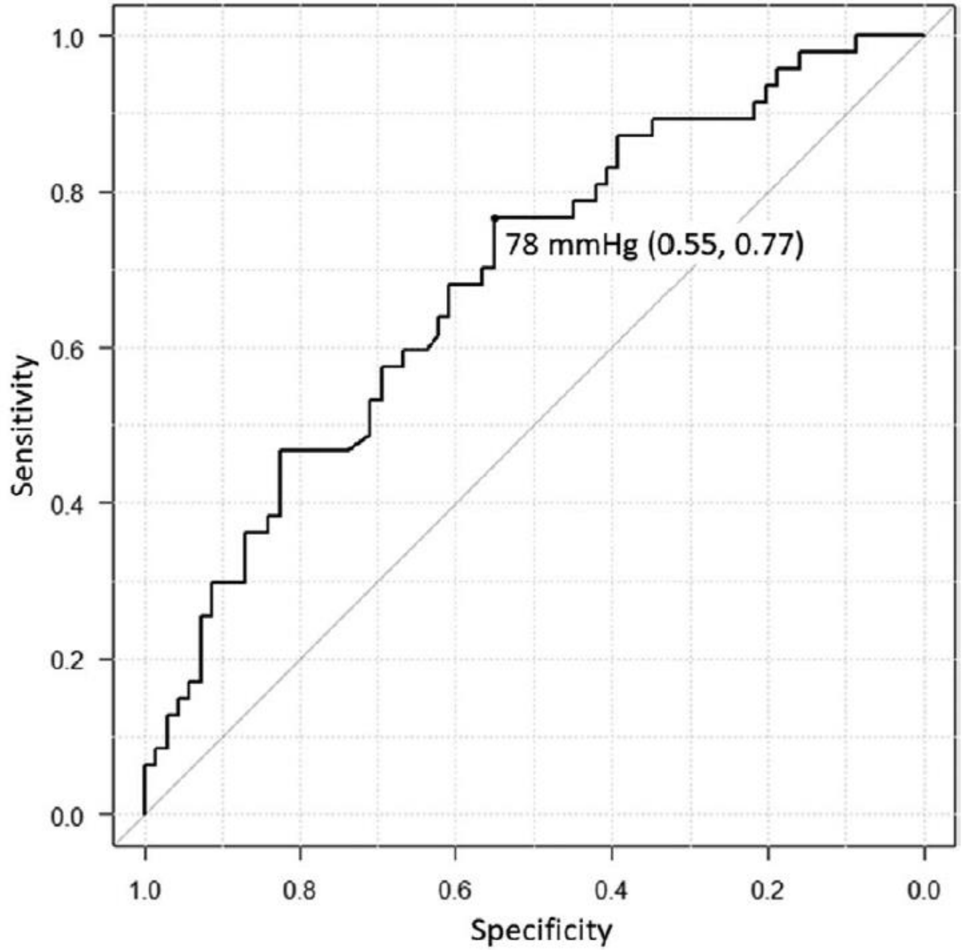
- 116 patients with VA ECMO (2010.9 – 2016.3)
- Mean MAP: significantly higher in survivors
- (82 ± 5.6 vs. 78 ± 5.5 mm Hg, $p = 0.0003$).
- There was a positive association between MAP and survival.
- Higher MAP: not affect the probability of strokes or bleeding complications,
- Higher MAP: a lower incidence of kidney injury ($p = 0.007$).

ASAIO Journal 2019; 65:336–341.

Thomas Jefferson University, Philadelphia, Pennsylvania



Number of patients
Survival rate (%)
30
25
20
15
10
5
0
80
70
60
50
40
30
20
10
0
<70
70-75
75-80
80-85
85-90
>90
Mean arterial pressure (mmHg)
Survivor
Non survivor
Survival



Sensitivity
1.0
0.8
0.6
0.4
0.2
0.0
78 mmHg (0.55, 0.77)
1.0
0.8
0.6
0.4
0.2
0.0
Specificity

VOLUME TOLERANCE AND FLUID RESPONSIVENESS

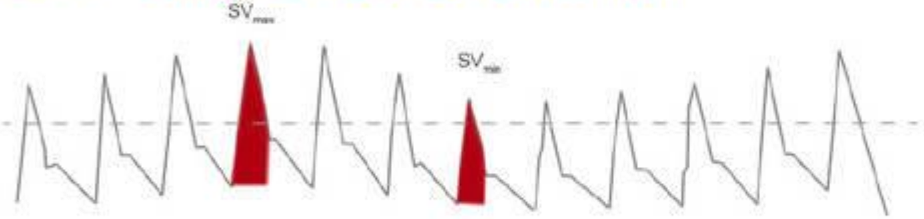
Pulse contour analysis (fluid responsiveness)

1. Pulse pressure variation (PPV)
2. Stroke volume variation (SVV)
3. Oximetric waveform variation

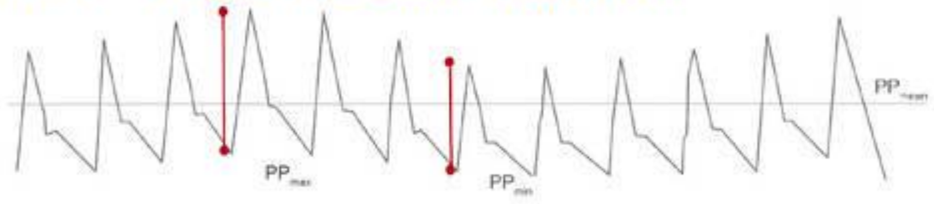
Pulse pressure variation (PPV)

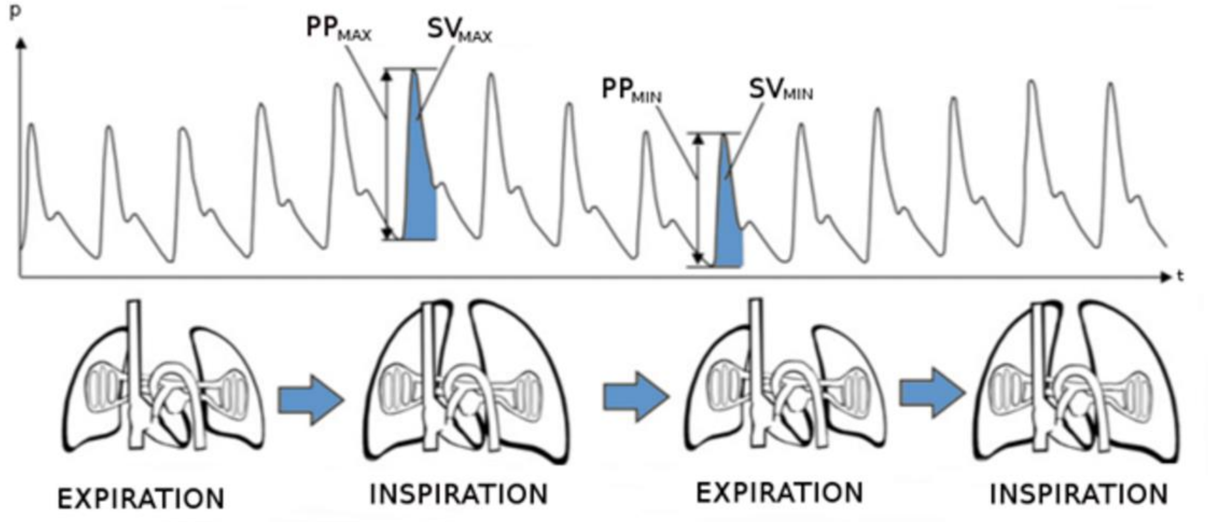
- Numerous studies have demonstrated that a PPV of at least 13 to 15 percent is strongly associated with volume responsiveness.
- As an example, one systematic review of 29 studies reported a higher area under the receiver operating characteristic curve (AUROC) for PPV compared with CVP (0.94 versus 0.55) as an indicator of fluid responsiveness (sensitivity and specificity were 0.88 each).

SVV - Stroke Volume Variation

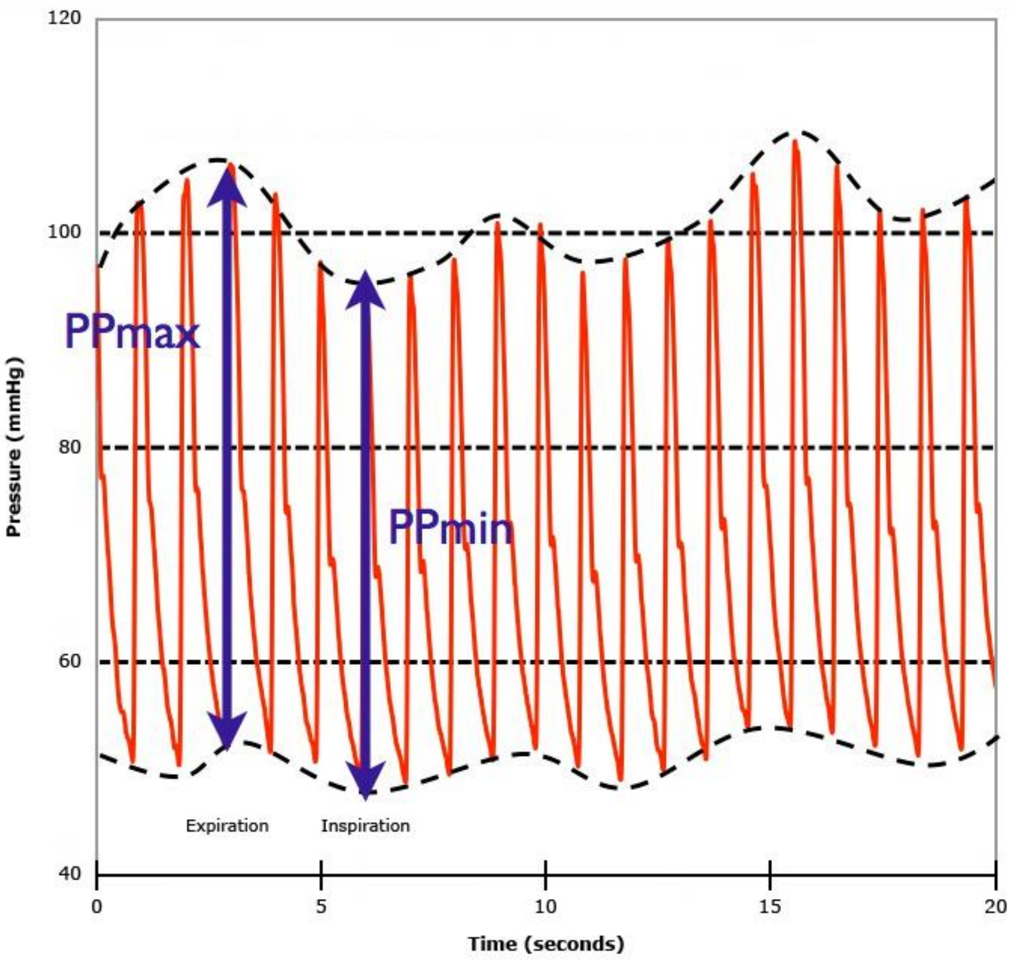


PPV - Pulse Pressure Variation





Calculating pulse pressure variation



Pulse pressure variation (PPV). Pulse pressure is the difference between systolic and diastolic blood pressure. The phases of respiration, denoted by positive (expiration) and negative (inspiration) deflections, reflect those for patients on mechanical ventilation (these would be different if the patient was spontaneously breathing and can vary depending upon the mode of ventilation). PPV can be calculated as follows: PPV = 100 × (PPmax − PPmin) / ([PPmax + PPmin] / 2).

PPmax: maximum pulse pressure; PPmin: minimum pulse pressure.

Reproduced from: ProfBondi. Available at: https://commons.wikimedia.org/wiki/File:Pulse_pressure_variation.jpg (accessed on August 10, 2016).

UpToDate®

Conditions where pulse pressure and stroke volume variations are less reliable

- Spontaneous breathing
- Cardiac arrhythmias
- Low Vt/low lung compliance
- Open chest
- Increased intra-abdominal pressure
- Very high respiratory rate (HR/RR < 3.6)
- Right heart failure*

BJA

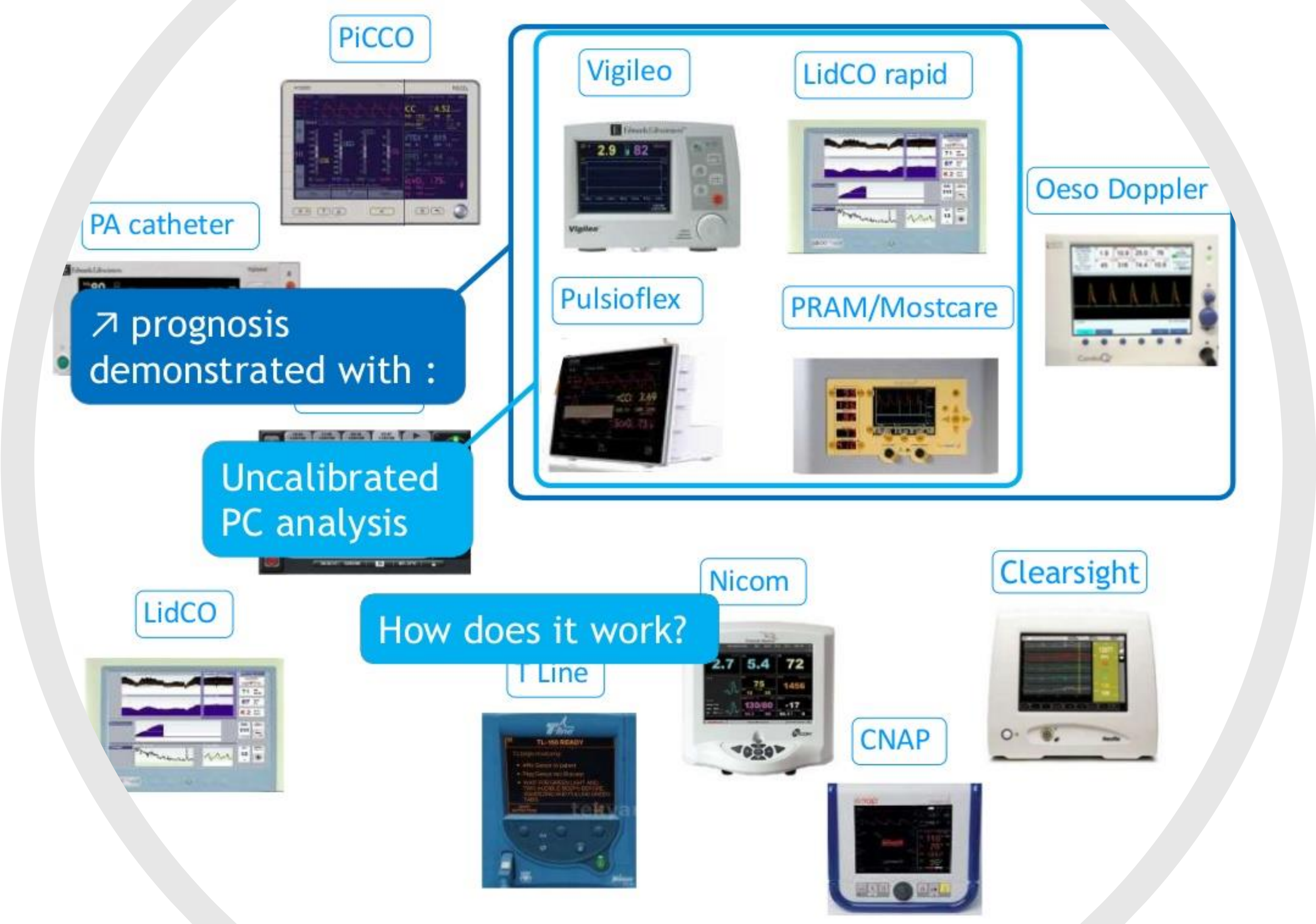
British Journal of Anaesthesia, 118 (3): 298–310 (2017)

doi: 10.1093/bja/aew461
Review Article

REVIEW ARTICLE

Accuracy and precision of non-invasive cardiac output monitoring devices in perioperative medicine: a systematic review and meta-analysis†

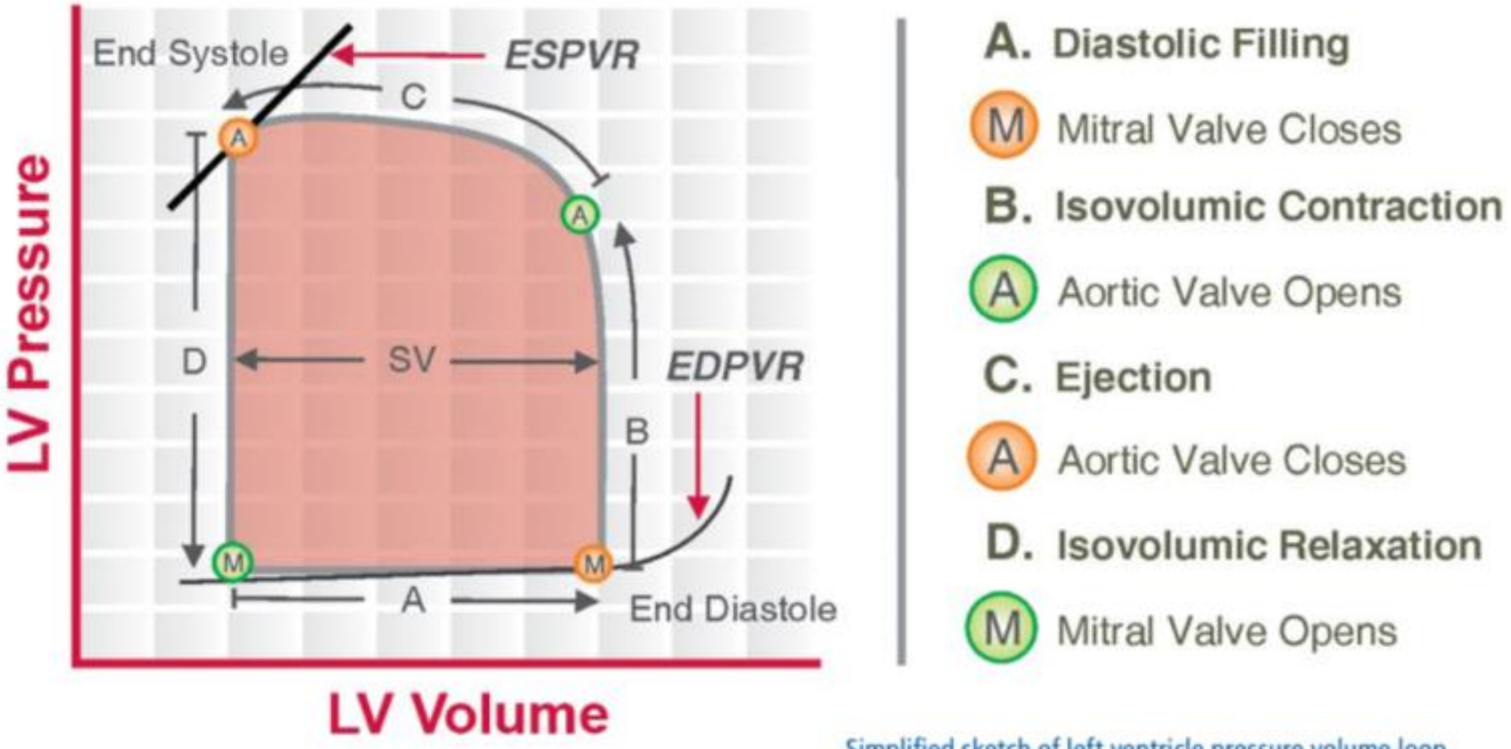
A. Joosten[1,*], O. Desebbe[2], K. Suehiro[3], L. S.-L. Murphy[4], M. Essiet[5], B. Alexander[6], M.-O. Fischer[7,8], L. Barvais[1], L. Van Obbergh[1], D. Maucort-Boulch[9] and M. Cannesson[10]


PiCCO
PA catheter
↗ prognosis demonstrated with :
Vigileo
LidCO rapid
Pulsioflex
PRAM/Mostcare
Oeso Doppler
Uncalibrated PC analysis
LidCO
How does it work?
T Line
Nicom
CNAP
Clearsight

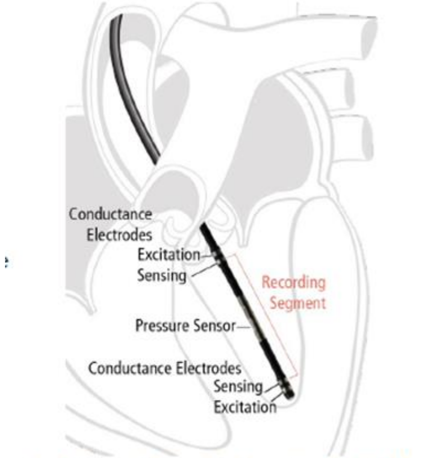
Editor's key points

- Advances in non-invasive cardiac output technologies offer simpler perioperative monitoring, but their accuracy is questioned.
- This meta-analysis found modest agreement and inadequate percentage error for most technologies.
- Novel non-invasive cardiac output technologies are typically developed in relatively healthy populations; their internal algorithms may thus be inappropriate to major surgery or critical illness.
- Percentage error and trending are important variables in the evaluation of non-invasive cardiac output technologies.

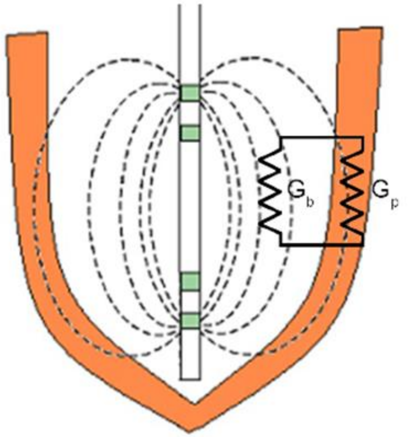
TISSUE PERFUSION



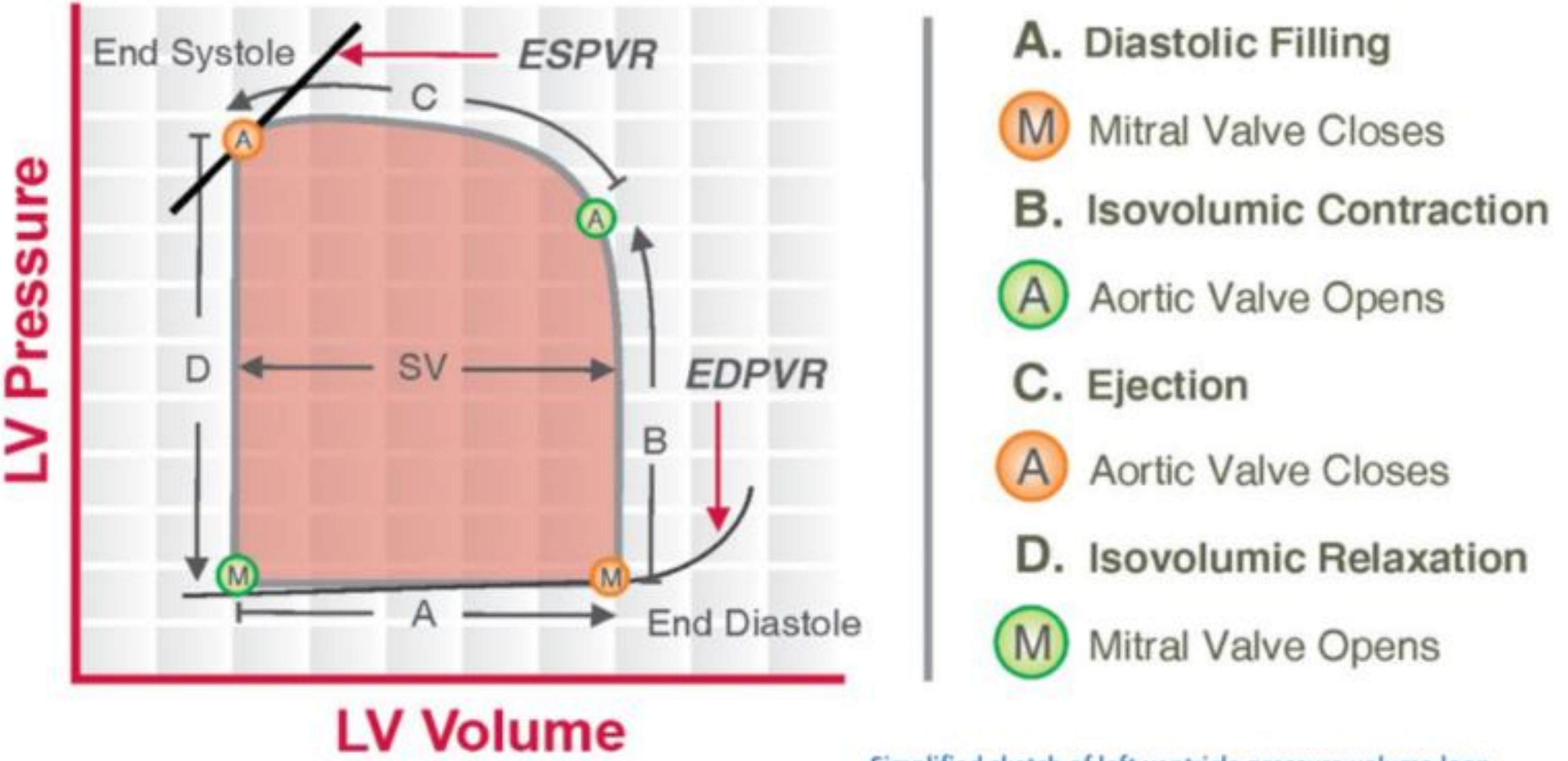
Simplified sketch of left ventricle pressure volume loop



Conductance excitation electrodes create an electric field while sensing electrodes measure the voltage change, which allows for the calculation of resistance and conductance.

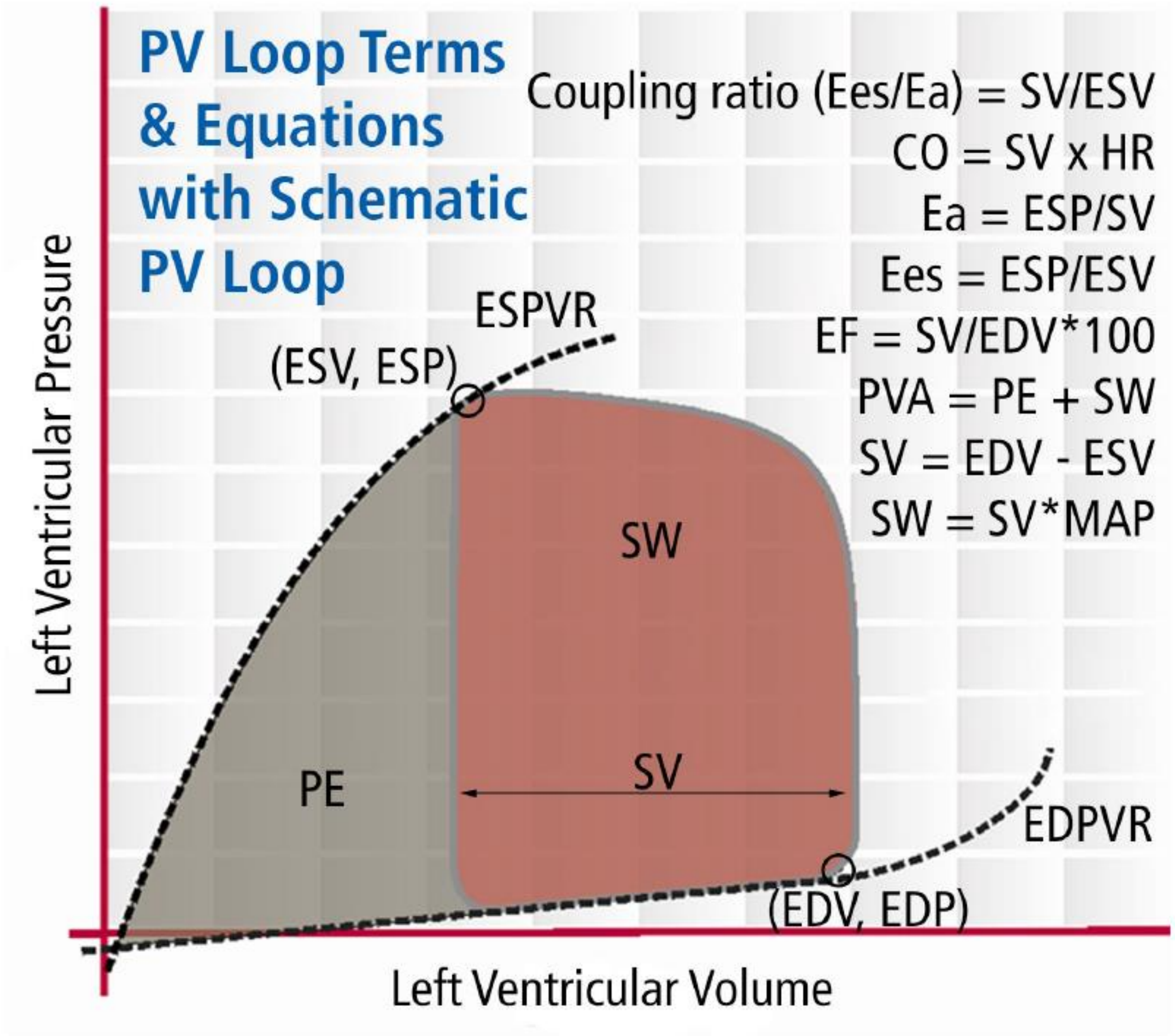


Conductance uses a circuit model where both blood (G_b) and cardiac muscle (G_m) are conductive and measured together as a single conductance value (G_x) and phase components are ignored.



Simplified sketch of left ventricle pressure volume loop

Basics of Pressure-Volume Loop


PV Loop Terms
& Equations
with Schematic
PV Loop
Coupling ratio (Ees/Ea) = SV/ESV
CO = SV x HR
Ea = ESP/SV
Ees = ESP/ESV
EF = SV/EDV*100
PVA = PE + SW
SV = EDV - ESV
SW = SV*MAP
ESPVR
(ESV, ESP)
SW
PE
SV
EDPVR
(EDV, EDP)
Left Ventricular Pressure
Left Ventricular Volume

Definition of Shock

- Shock is defined as a state of cellular and tissue hypoxia due to reduced oxygen delivery, increased oxygen consumption, inadequate oxygen utilization, or a combination of the three.
- "Undifferentiated shock" refers to the situation where shock is recognized but the cause is unclear.

Classifications of Shock

- Four types of shock are recognized. However, many patients have a combination of more than one of the forms of shock listed below (table 1):

1. Distributive shock: septic shock, SIRS (ex.pancreatitis), neurogenic shock, anaphylactic shock, toxin-related shock, and endocrine shock (ex. adrenal crisis).
2. Cardiogenic shock: cardiomyopathic (ex. AMI), arrhythmia (ex. sustained VT/Vf), mechanical abnormality (ex. acute valvular rupture).
3. Hypovolemic shock: hemorrhagic (ex. trauma) or non-hemorrhagic fluid losses (ex. diarrhea).
4. Obstructive shock: pulmonary vascular related (ex. pulmonary embolism) or due to a mechanical cause of reduced preload (ex. tension pneumothorax, pericardial tamponade).

Hemodynamic profiles of shock on pulmonary artery catheter in adults

Physiologic variable	Preload	Pump function	Afterload	Tissue perfusion
Clinical measurement	**Pulmonary capillary wedge pressure**	**Cardiac output***	**Systemic vascular resistance**	**Mixed venous oxyhemoglobin saturation¶**
Hypovolemic	↔ (early) or ↓ (late)	↔ (early) or ↓ (late)	↑	>65% (early) or <65% (late)
Cardiogenic	↑	↓	↑	<65%
Distributive	↔ (early) or ↓ (late)	↑ or ↓ (occasionally)	↓	>65%
Obstructive				
PE, PH, tension pneumothorax	↔ (early) or ↓ (late)	↔ (early) or ↓ (late)	↑	>65%
Pericardial tamponade[Δ]	↑	↓	↑	<65%

PE: pulmonary embolus; PH: pulmonary hypertension; PAC: pulmonary artery catheter.
* Cardiac output is generally measured using the cardiac index.
¶ Mixed venous oxyhemoglobin saturation cutoff measured on PAC is 65%, but on triple lumen catheter is 70%.
Δ Equalization of right atrial, right ventricular end-diastolic and pulmonary artery wedge pressures is classic in pericardial tamponade and distinguishes it from primary cardiogenic shock.

- In compensated shock, macro-circulatory measures such as arterial pressure and cardiac output (CO) may be normal in the face of markedly abnormal oxygen delivery and utilization.
- Devices have been developed to measure indices of shock at the tissue level.

Measurement of tissue oxygen saturation (StO2)

- StO2 measurement using near-infrared spectroscopy (NIRS) has been proposed as a downstream hemodynamic monitoring tool to survey the micro-circulation and assess the balance of oxygen delivery and consumption at the tissue level.
- StO2 is measured transcutaneously using NIRS via a number of commercially available devices that measure tissue absorbance values in a defined range of wavelengths.
- StO2 with VOT has been shown to predict outcome and organ dysfunction in patients with sepsis and congestive heart failure in two small studies, and preliminary studies have demonstrated its usefulness in trauma patients.

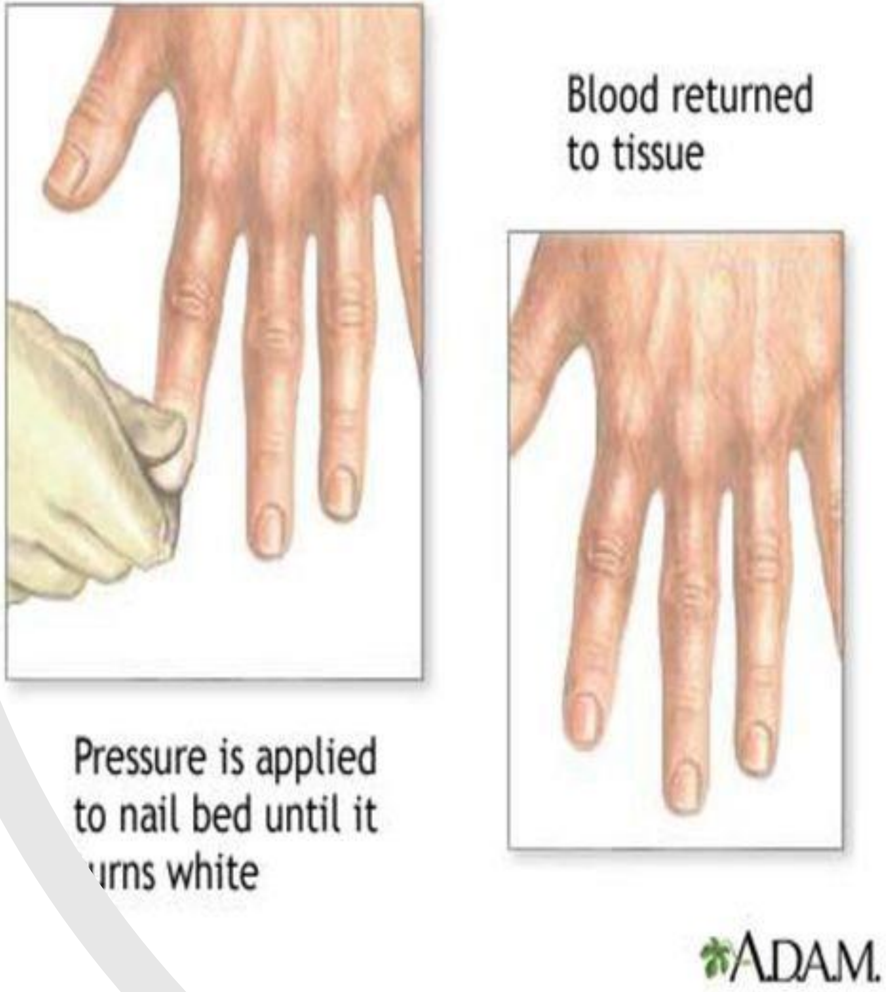
Measurement of tissue oxygen saturation (StO2)

- However, the value of StO2 value is limited because StO2 remains within normal range until shock is quite advanced.
- The addition of a dynamic ischemic challenge such as the vascular occlusion test (VOT; application of a tourniquet or sphygmomanometer above systolic arterial pressure for brief, defined intervals) may improve the predictive ability of StO2 to identify tissue hypoperfusion.

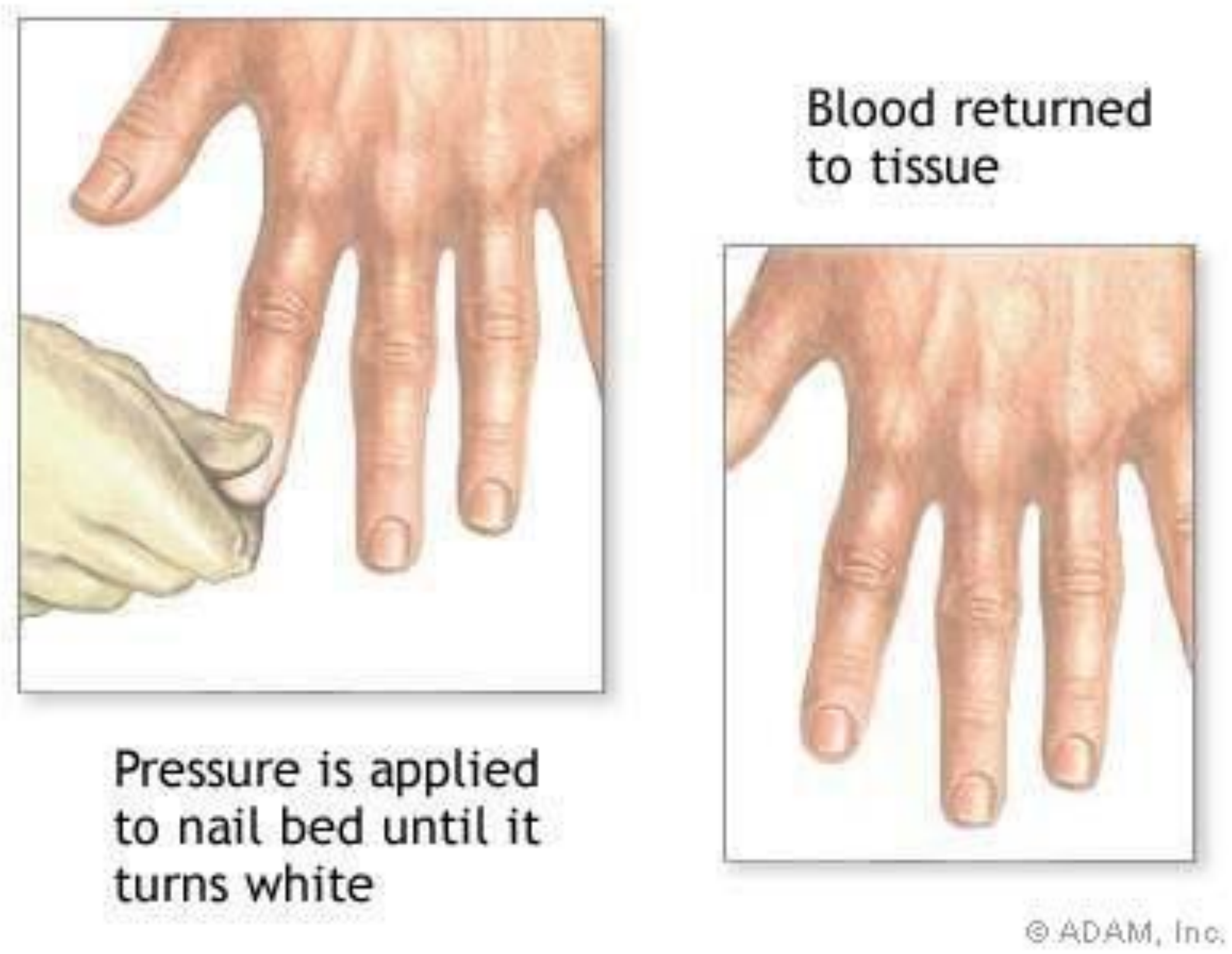
Measurement of microcirculatory blood flow

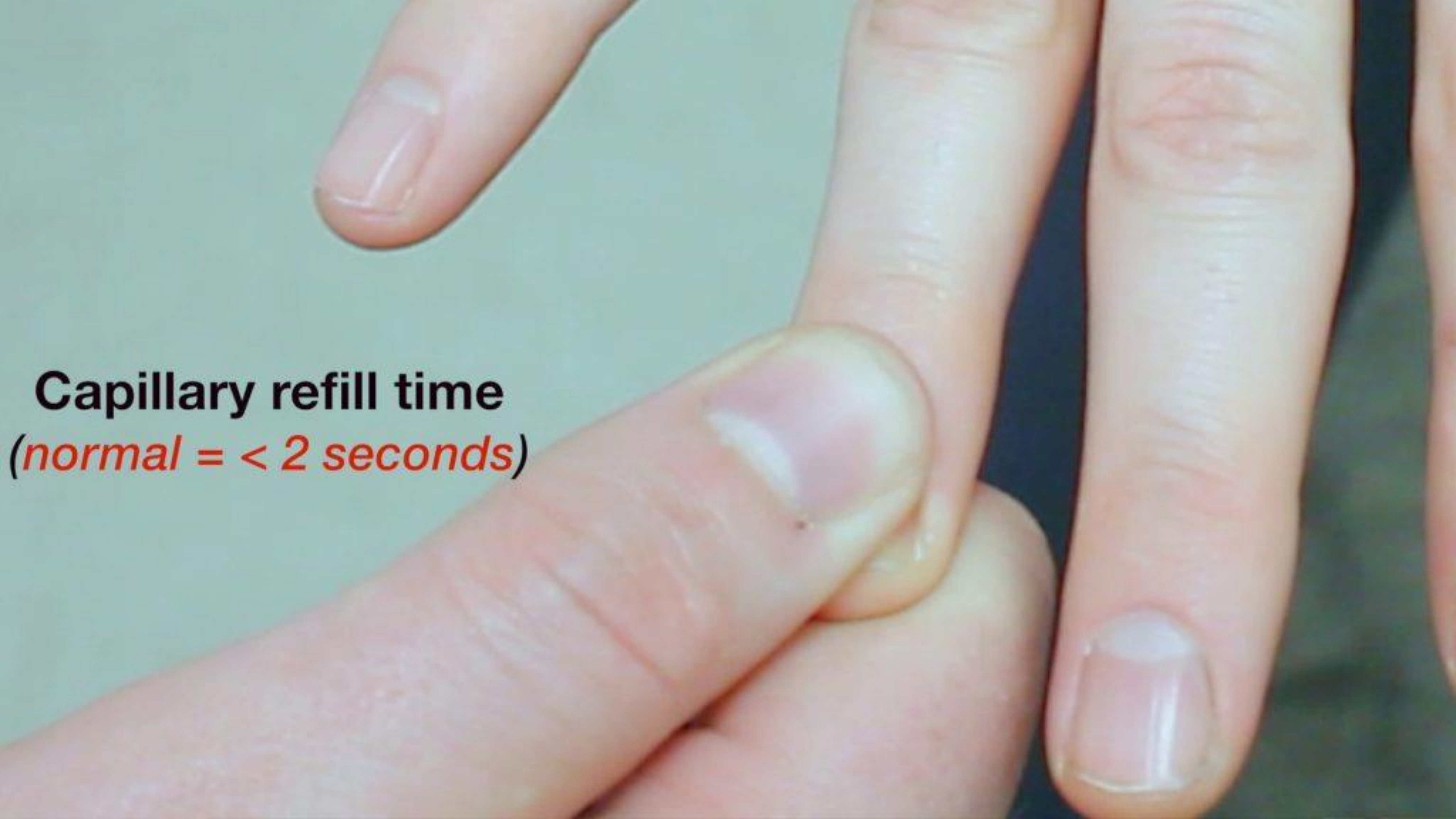
- There is considerable interest in shock-induced microcirculatory dysfunction, most notably in the case of sepsis.
- The sublingual mucosa is the preferred means to evaluate the microcirculation in critically ill patients because it shares embryological origin with the splanchnic circulation and can be easily accessed at the bedside.
- Imaging of the sublingual microvasculature is typically obtained using advanced microscopy techniques, such as sidestream dark field imaging, or by near-infrared spectroscopy (NIRS).
- Early studies demonstrated alterations in microvascular flow in patients with sepsis and cardiogenic shock.
- Multiple subsequent studies have demonstrated that alterations in sublingual microcirculatory blood flow are associated with poor outcome among patients with septic shock.

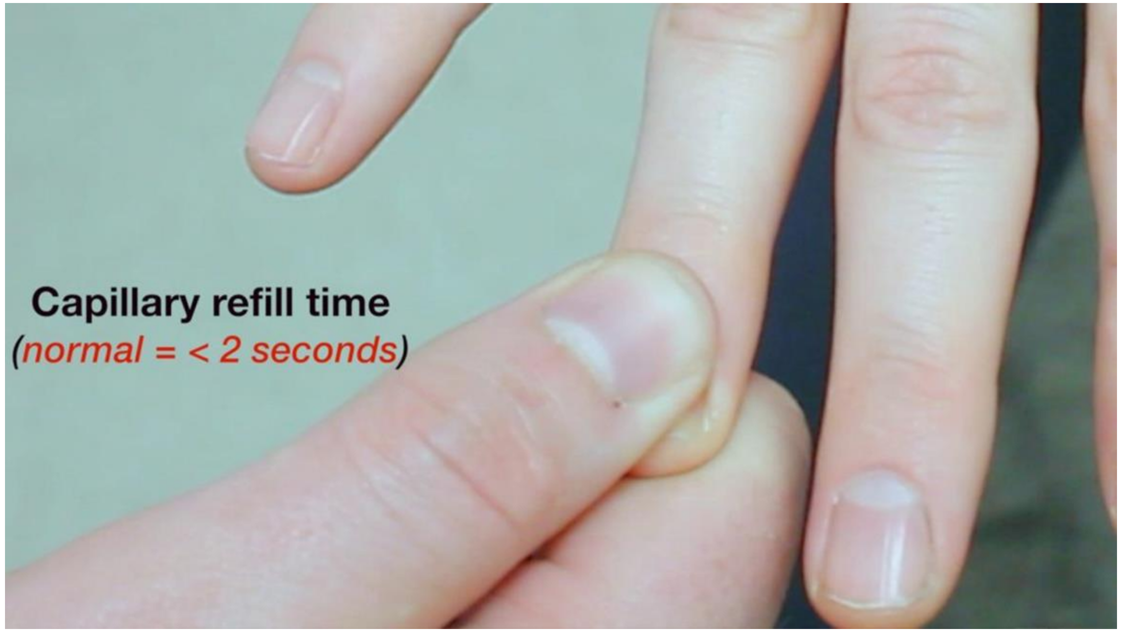
Fingernails
Nail Blanch Test

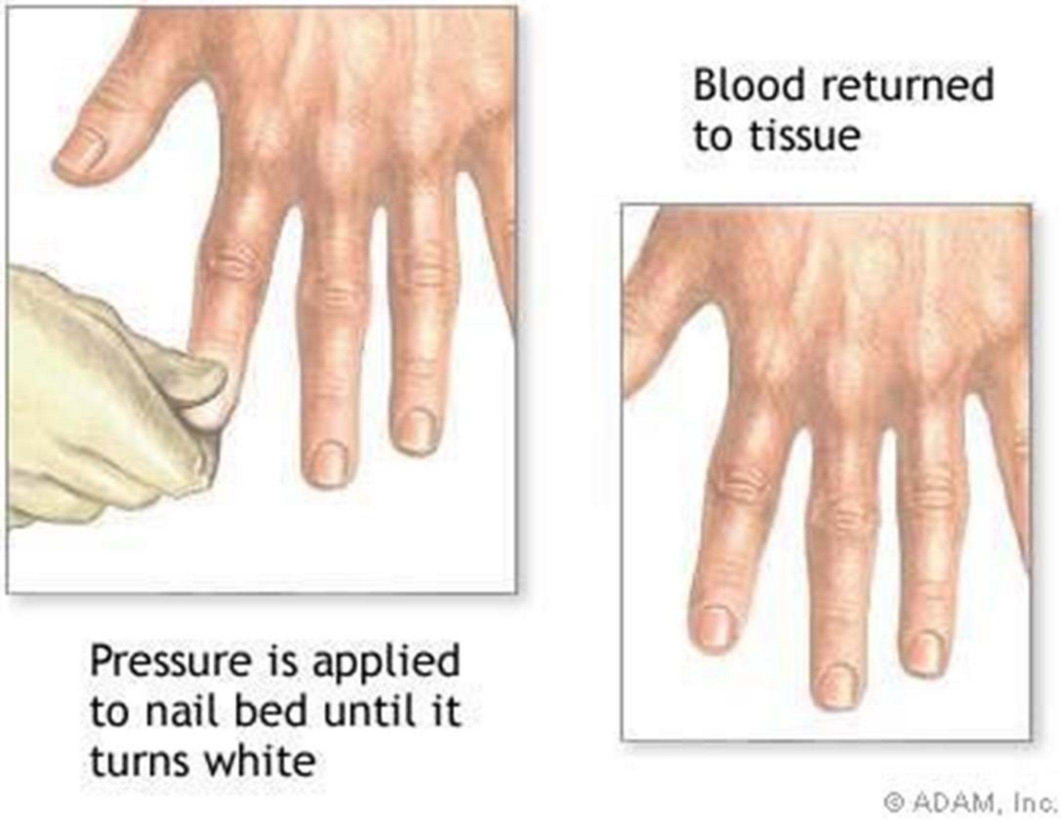


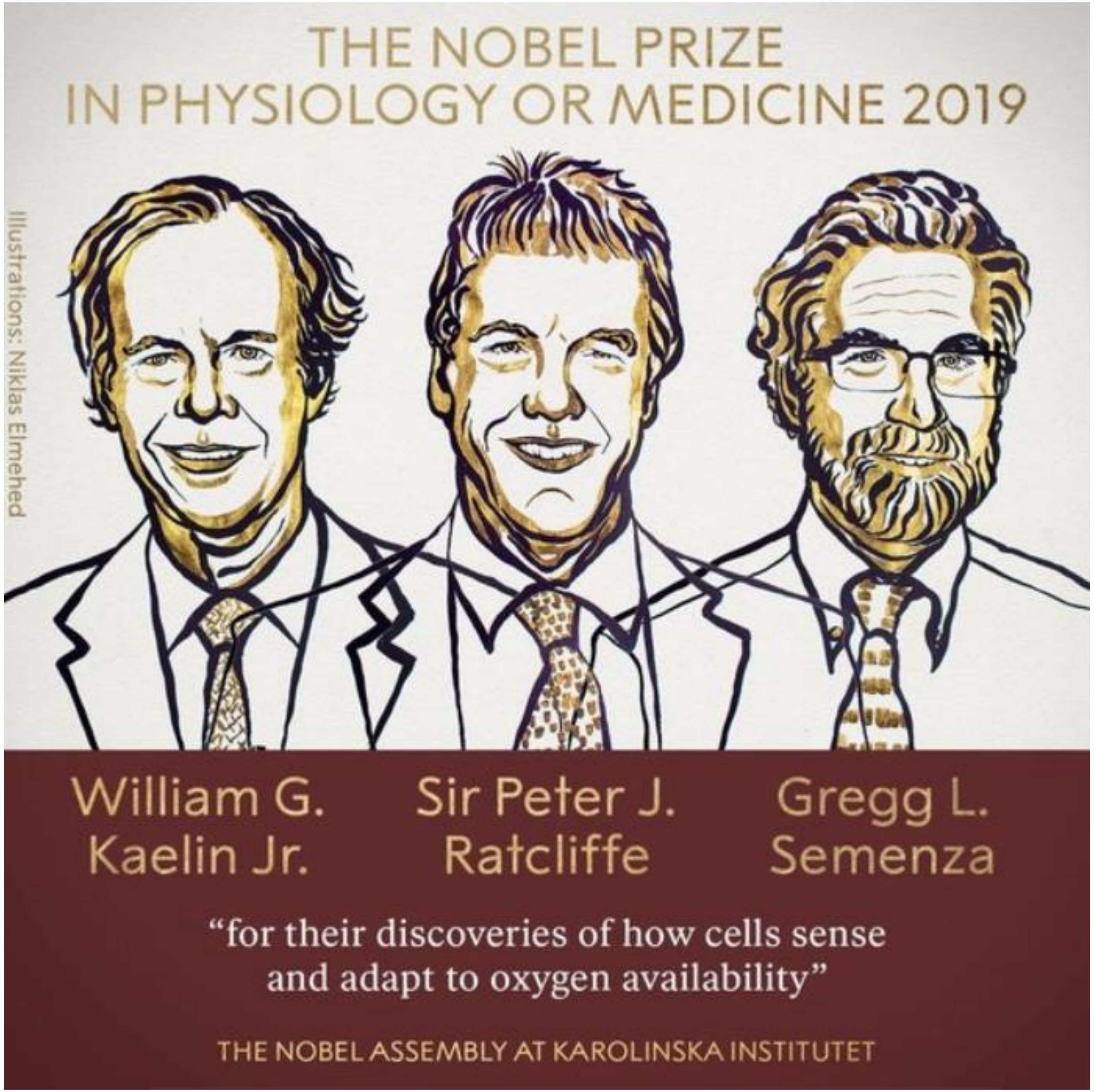
capillary refill time of nail plate <3 seconds

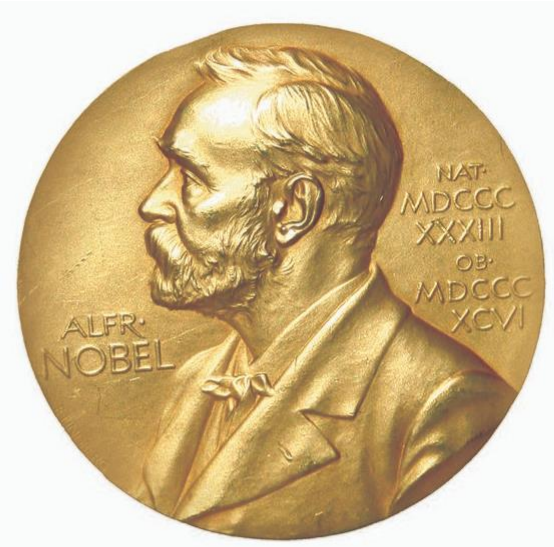

Pressure is applied to nail bed until it turns white
Blood returned to tissue
© ADAM, Inc.


Capillary refill time
(normal = < 2 seconds)


Capillary refill time
(normal = < 2 seconds)


Blood returned to tissue
Pressure is applied to nail bed until it turns white
© ADAM, Inc.


THE NOBEL PRIZE
IN PHYSIOLOGY OR MEDICINE 2019
Illustrations: Niklas Elmehed
William G.
Kaelin Jr.
Sir Peter J.
Ratcliffe
Gregg L.
Semenza
“for their discoveries of how cells sense
and adapt to oxygen availability”
THE NOBEL ASSEMBLY AT KAROLINSKA INSTITUTET


NAT·
MDCCC
XXXIII
OB·
MDCCC
XCVI
ALFR·
NOBEL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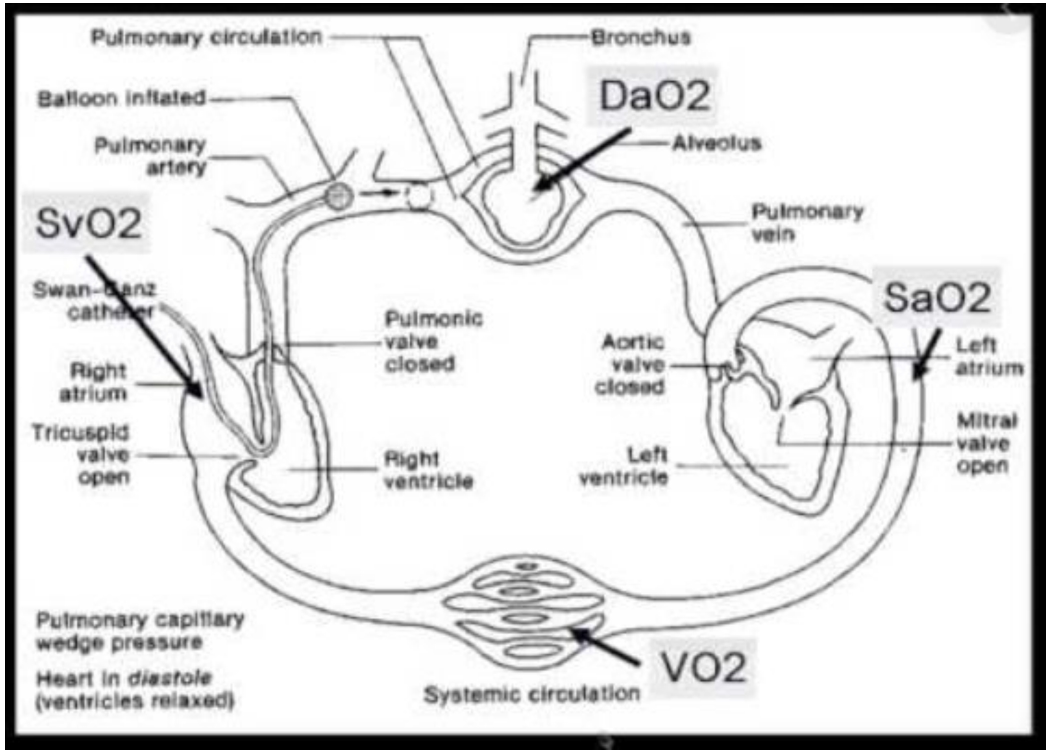
#nobelprize
THE NOBEL PRIZE



- SaO2: arterial saturation
- SvO2: mixed venous saturation

- CaO2: arterial oxygen contents
- DaO2: oxygen delivery (supply)

DO_2 (cc/min)
=Cardiac output (L/min)×arterial CO_2 (cc/dL)×10

CO_2 (cc/dL)
=Hemoglobin bound O_2+dissolved O_2
=(Hemoglobin [g/dL]×saturation [%]×1.36 cc/g)+(pO_2 [mmHg]×0.0031 cc/mmHg/dL)

DO2: CO / Hgb / SaO2

- DaO_2: oxygen delivery (CO, Hgb, SaO_2)
- CaO_2: oxygen contents (Hgb bound oxygen + dissolved oxygen)
- VO_2 : oxygen consumption in tissue (tissue metabolism)
- SvO_2 : mixed venous oxygen saturation
  (not utilized oxygen, measured in pulmonary artery)

- DO_2 / VO_2 ratio = 4 ~ 5 (normal condition)

- $SvO_2 = DO_2 - VO_2$ = 60 ~ 80 (%) (normal condition)

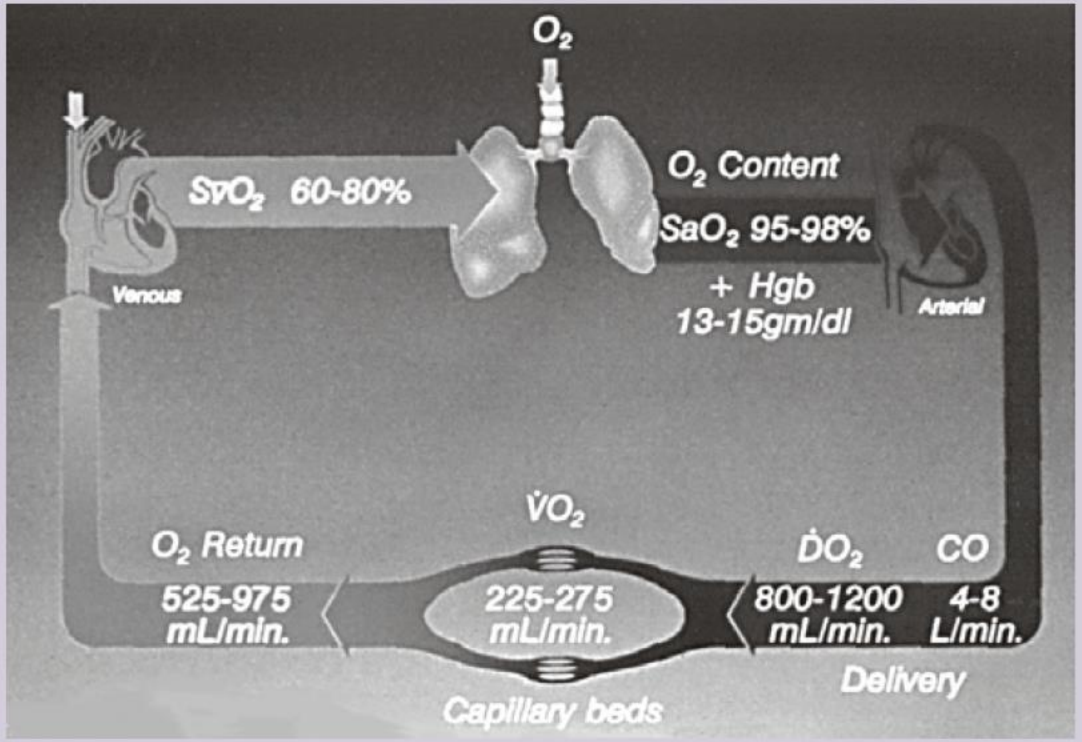


Figure 2 Cardiopulmonary system including the normal values of tissue oxygenation parameters. Mixed venous oxygen saturation (Svo_2) reflects the adequacy of oxygen delivery (Do_2) in meeting oxygen demand. As shown, cardiac output (CO), hemoglobin (Hgb), and arterial oxygen saturation (Sao_2) make up delivery. Oxygen consumption (Vo_2) is a reflection of oxygen demand.

Increase SvO2 (DaO2↑, VO2↓)

Decrease in oxygen consumption	Use of analgesics and anesthetics Neuromuscular blockade or use of paralytics Use of β-antagonists Hypothermia Hypothyroidism Sepsis (dysoxia, shunting) Cyanide poisoning Sleep or rest
Increase in oxygen saturation	Increase in fraction of inspired oxygen or hyperoxia Intracardiac shunt or arteriovenous fistula Severe mitral valve regurgitation Distal migration of a pulmonary artery catheter
Increase in cardiac output	Optimal preload Use of inotropic agents Use of mechanical-assist devices

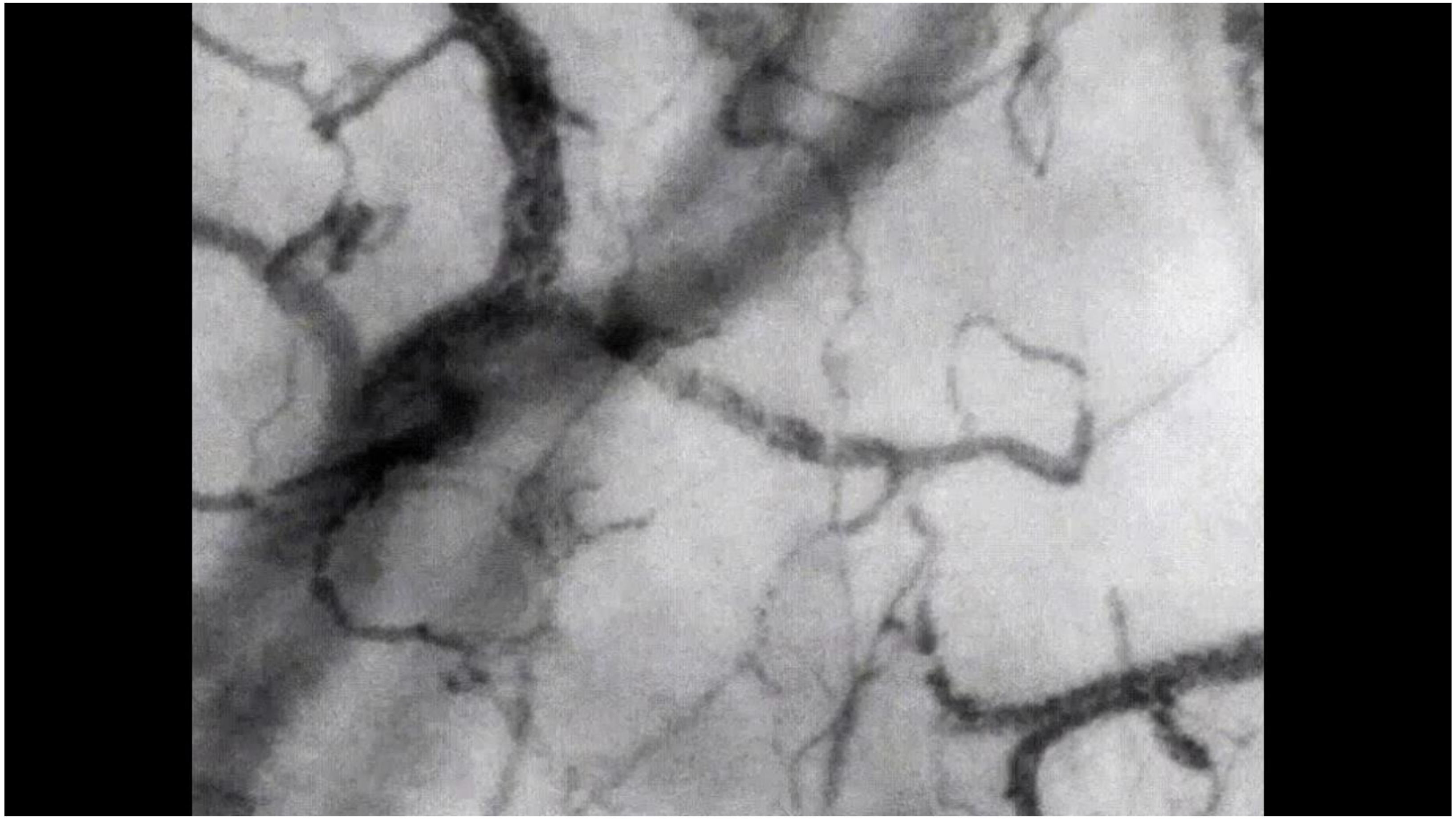
Decrease SvO2 (DaO2↓, VO2↑)

Decrease in cardiac output	Hypovolemia or cardiac tamponade Shock Myocardial infarction Arrhythmias Increases in positive end-expiratory pressure
Decrease in oxygen saturation	Pulmonary edema Adult respiratory distress syndrome Decrease in inspired oxygen
Decrease in hemoglobin level	Anemia Hemorrhage Dysfunctional hemoglobin
Increase in oxygen consumption	Pain Anxiety or fear Agitation or restlessness Hyperthermia or burns Tachycardia Shivering Activity (positioning, suctioning)

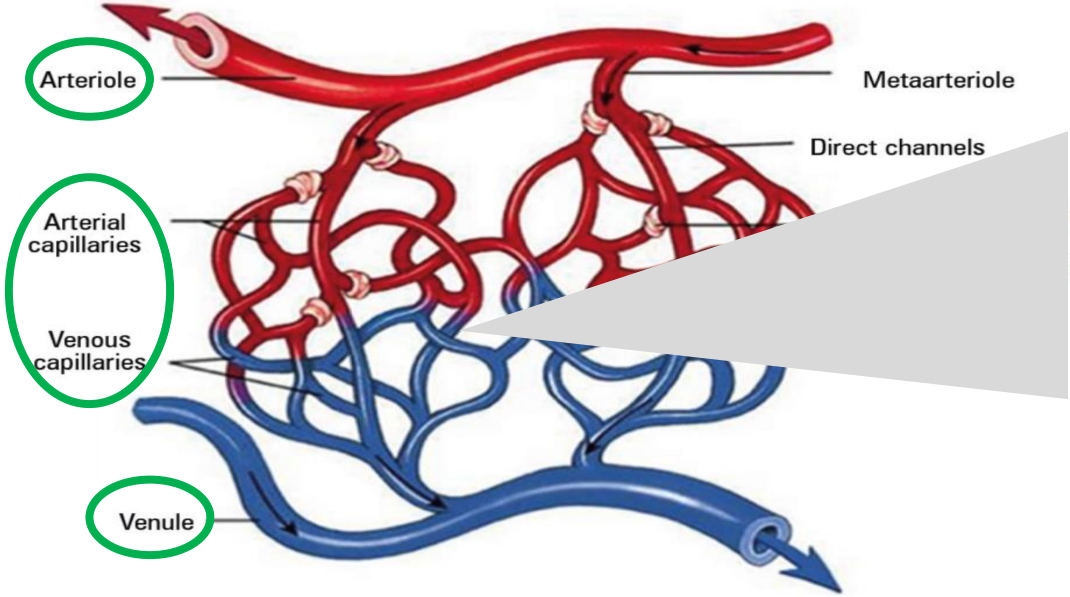
- If DO2 is severely decreased, there is insufficient oxygen to meet metabolic demands, anaerobic metabolism occurs, and, finally, lactic acidosis and shock occur.

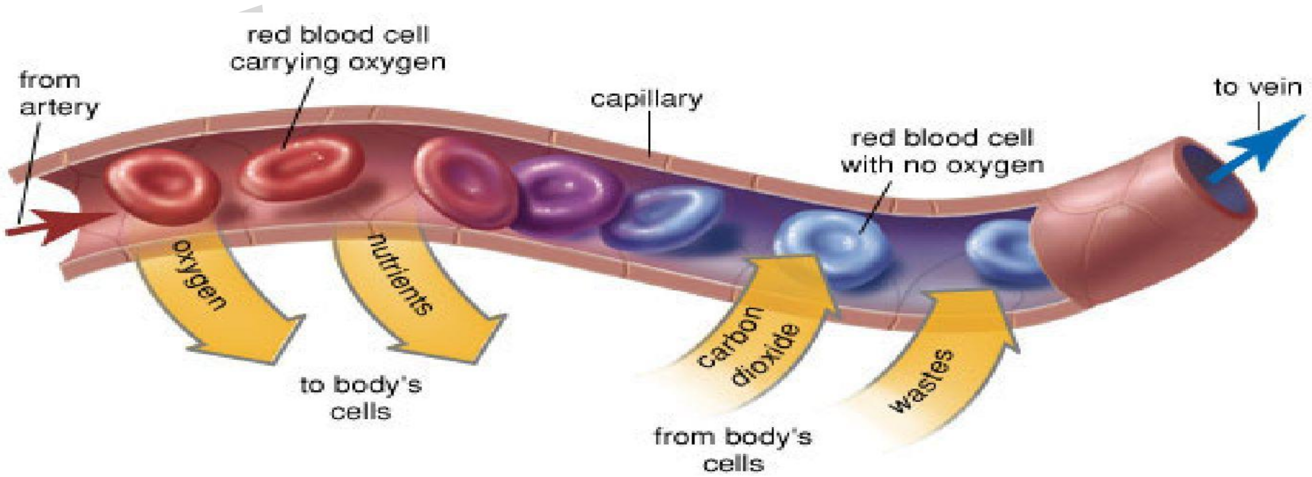
- Since SvO2 reflects this ratio accurately, it is one of the most important considerations when monitoring and managing critically ill patients.

- VA ECMO can be an option for the treatment of various types of shock because it can increase CO2 and systemic blood flow and eventually increase DO2.
- Hence, the goal of VA ECMO is as follows: to restore organ blood flow and adequate tissue oxygenation while awaiting recovery.



Tissue Perfusion



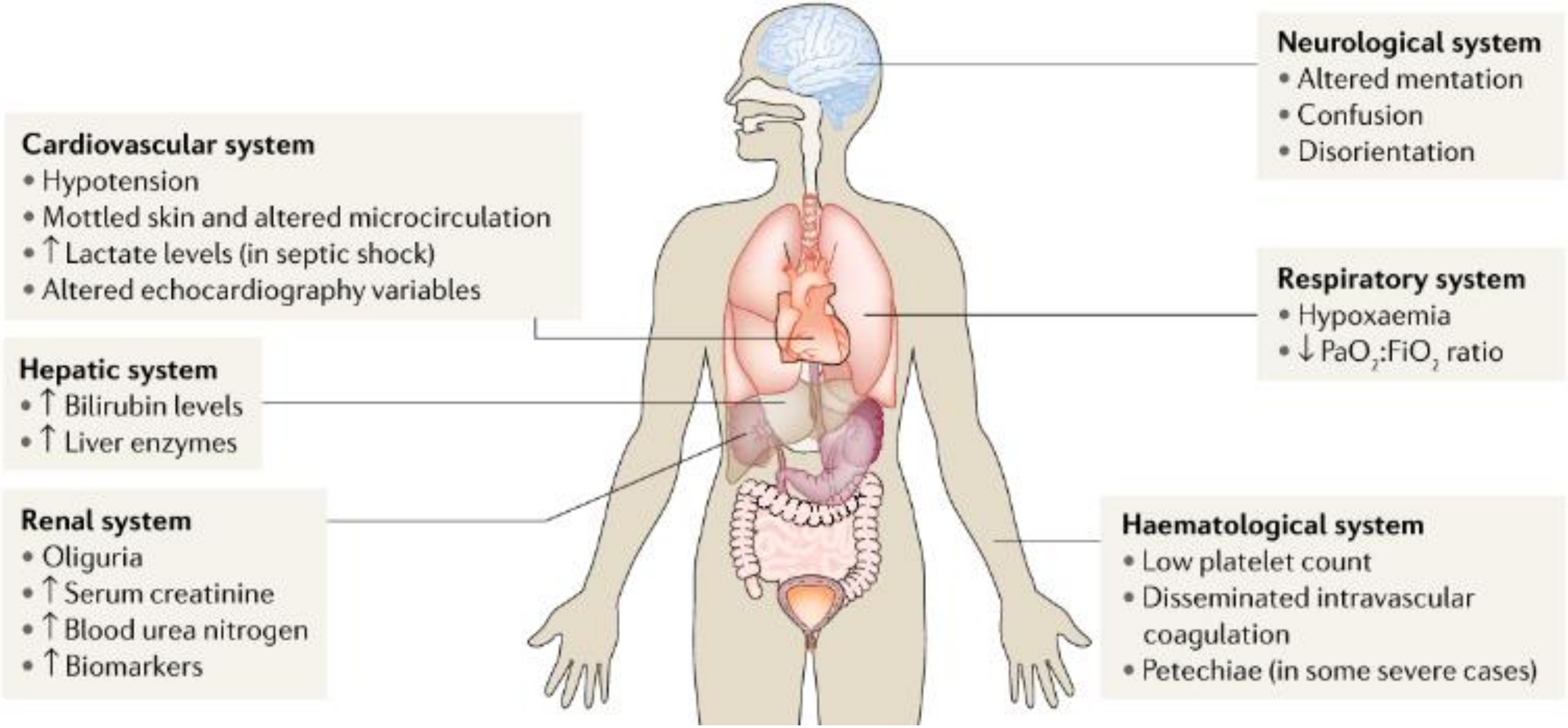


Microflow ↓

Organ failure

Microcirculatory dysfunction

- transudation of fluids in the perivascular region → tissue pressure↑
  → alters viscosity within the vessel lumen
  ⇒ **microcirculatory alterations** (in or around the organs)



Evaluation of microcirculation

Table 1. Selected modalities to investigate the microcirculation in cardiogenic shock

Assessment of the microcirculation	Advantages	Disadvantages
Indirect methods		
Blood pressure	Monitored in every CS patient, no costs	Questionable correlation to organ perfusion
Central venous pressure	Available in most patients	Only one of various variants determining organ microcirculation
Capillary refill	Easy available, no costs	Influenced by extremity perfusion, interobserver and intraobserver variability
Mottling score	Easy available and reproducible	Comparable low correlation to organ microcirculation
Serum lactate	Easy available	Influenced by other parameters and conditions, not on-line with delayed response
Various serum parameters	Sensitive and specific markers available for different organs in research contexts	Not available within a reasonable time frame
(Contrast) Ultrasound/ Echocardiography	Good organ resolution	Moderate correlation to organ failure
(Contrast) MRI	Good organ resolution	Not applicable in CS patients
Gas tomography	Reflects organ metabolism	Direct or indirect organ access necessary, low correlation to organ failure
Direct methods		
Capillaroscopy (nail-fold)	Good reproducibility under standardized conditions	Limited availability, low correlation to organ perfusion, dependent on body temperature
Intravitalmicroscopy [SDF (imaging), IDF (imaging)]	Good reproducibility, good correlation to organ failure, outcome prediction validated, on-line available	Limited availability

CS, cardiogenic shock; IDF, incident dark-field; SDF, sidestream dark-field.

ASAIO Journal 2017 Case Reports

Ejection Fraction May Not Reflect Contractility: Example in Veno-Arterial Extracorporeal Membrane Oxygenation for Heart Failure

Philippe Morimont,* Bernard Lambermont,* Julien Guiot,* Vincent Tchana Sato,* Christophe Clotuche,* Jonathan Goffoy,* and Jean-Olivier Defraigne‡

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Critical Care

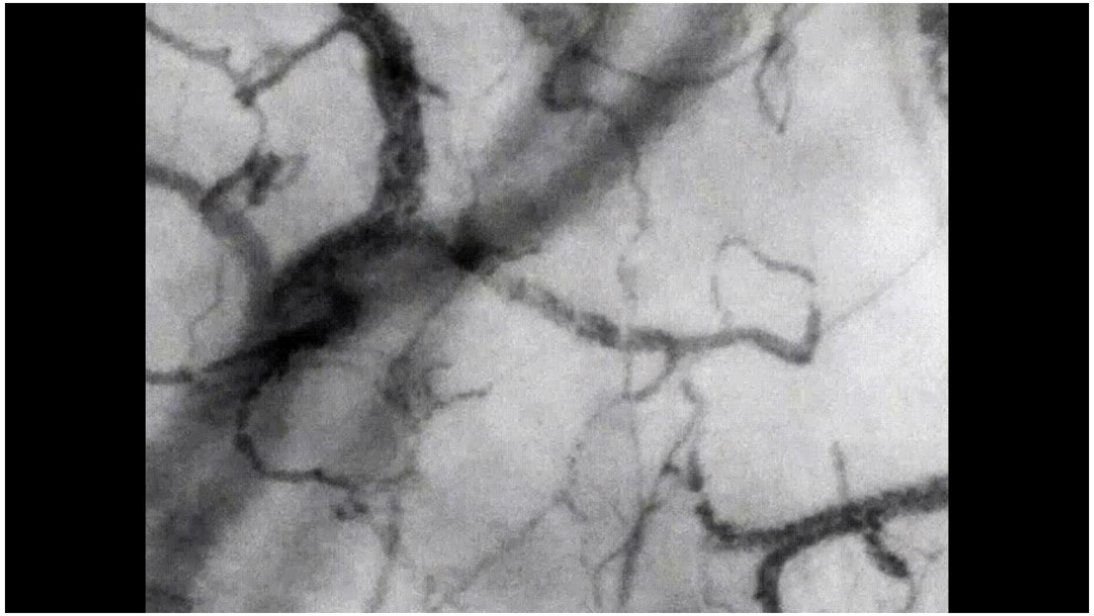
RESEARCH Open Access

Functional evaluation of sublingual microcirculation indicates successful weaning from VA-ECMO in cardiogenic shock

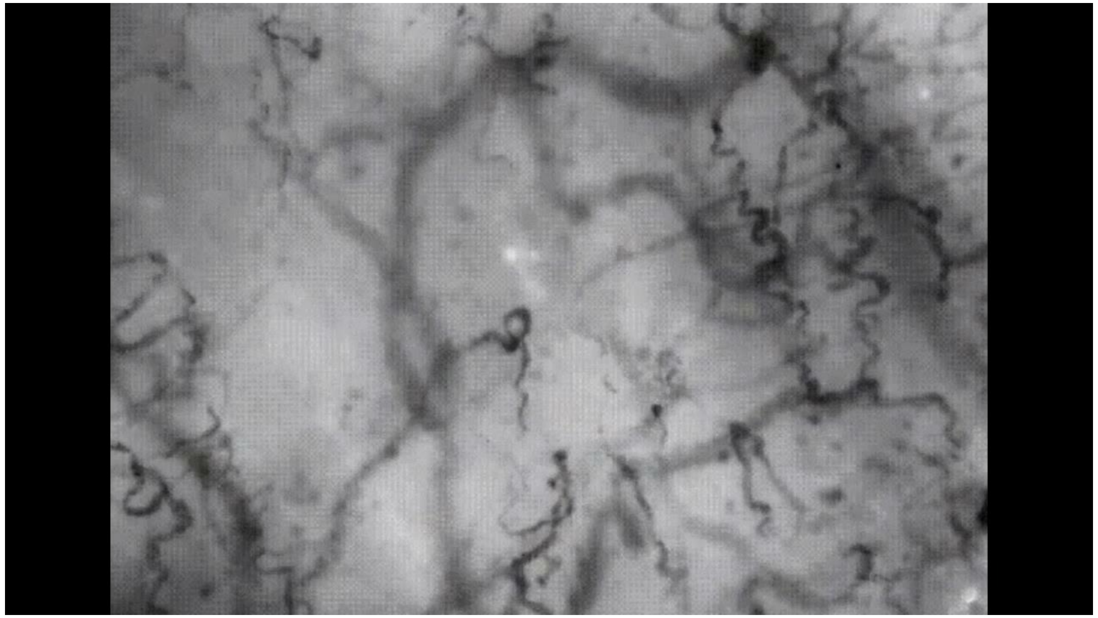
Sakir Akin[1,2*], Dinis dos Reis Miranda[1], Kadir Caliskan[2], Osama I. Soliman[2], Goksel Guven[1,2], Ard Struijs[1], Robert J. van Thiel[1], Lucia S. Jewbali[1,2], Alexandre Lima[1], Diederik Gommers[1], Felix Zijlstra[2] and Can Ince[1]

Microcirculatory image on VA-ECMO weaning trial

successful weaning



unsuccessful weaning



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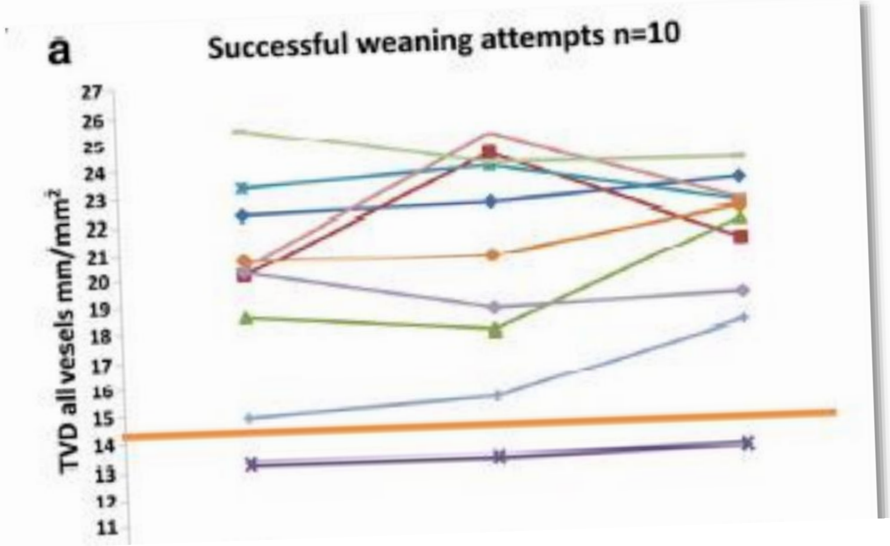

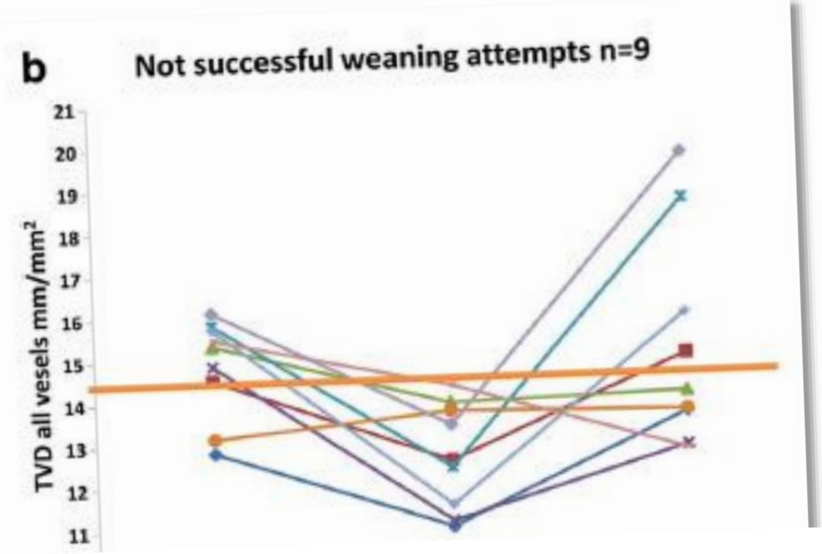

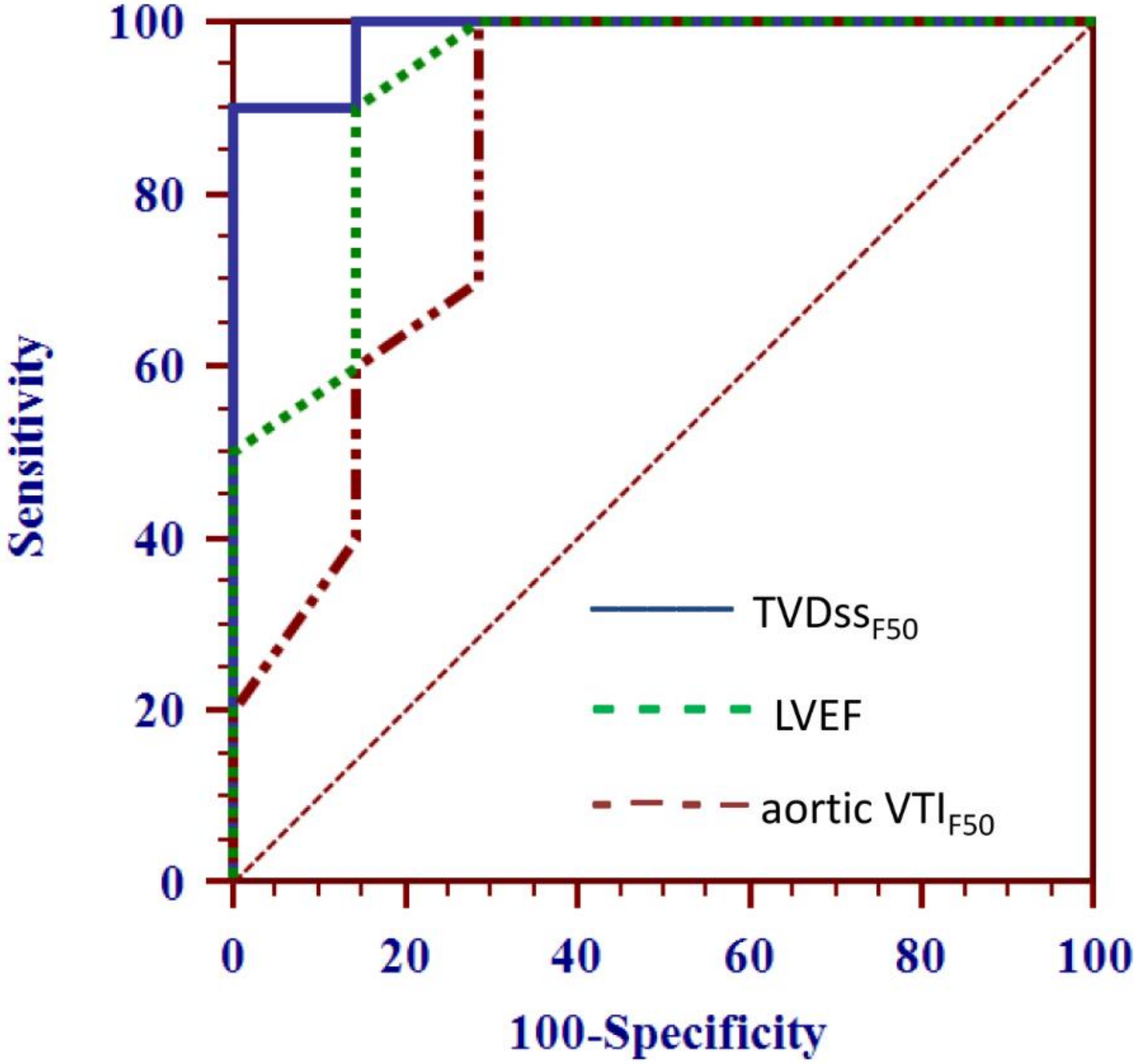

100
80
60
40
20
0
Sensitivity
0
20
40
60
80
100
100-Specificity
TVDss$_{F50}$
LVEF
aortic VTI$_{F50}$

감사합니다.
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