Fluid overload: il concetto di ultrafiltrazione netta, aspetti di nomenclatura, come impostarla, come calcolarla, significato clinico della negativizzazione del bilancio

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Università degli Studi di Padova

Università degli Studi di Padova

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CRRT
Questione di EQUIPE!

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XII Edizione

Scuola di Specializzazione in Anestesia, Rianimazione, Terapia Intensiva e del Dolore
Università di Firenze

SITI ISIC
Società Italiana di Terapia Intensiva
Italian Society of Intensive Care
FONDATA NEL 1975

20-21 aprile 2021

Dip. di Scienze della Salute – Università di Firenze
Dip. di Anestesia e Rianimazione - AOU Careggi - Firenze

Disclosures

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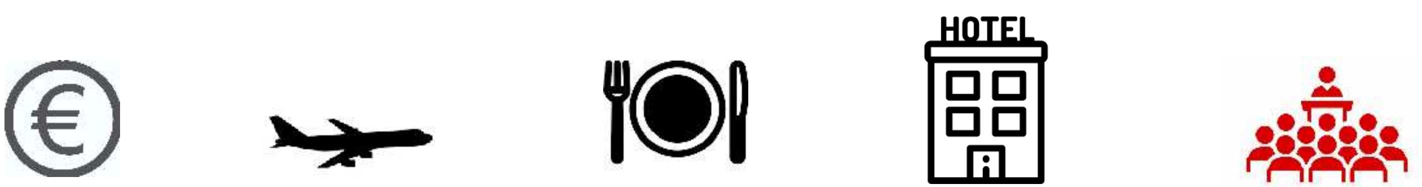


OUTLINE

- Fluid Overload (FO) and glycocalyx dysfunction
- "Personalized" Q_{UF}^{NET}
- The role of Lymphatic System
- Conclusions
- OMNI system

Fluid accumulation, survival and recovery of kidney function in critically ill patients with acute kidney injury

Josée Bouchard[1], Sharon B. Soroko[1], Glenn M. Chertow[2], Jonathan Himmelfarb[3], T. Alp Ikizler[4], Emil P. Paganini[5] and Ravindra L. Mehta[1], Program to Improve Care in Acute Renal Disease (PICARD) Study Group

Kidney International (2009)

Outcome in Children Receiving Continuous Venovenous Hemofiltration

Stuart L. Goldstein, MD*; Helen Currier, RN, CNN‡; Jeanine M. Graf, MD§; Carmen C. Cosio, MD§; Eileen D. Brewer, MD*; and Ramesh Sachdeva, MD§

Pediatrics 2001

Pediatric patients with multi-organ dysfunction syndrome receiving continuous renal replacement therapy

STUART L. GOLDSTEIN, MICHAEL J.G. SOMERS, MICHELLE A. BAUM, JORDAN M. SYMONS, PATRICK D. BROPHY, DOUGLAS BLOWEY, TIMOTHY E. BUNCHMAN, CHERYL BAKER, THERESA MOTTES, NANCY MCAFEE, JONI BARNETT, GLORIA MORRISON, KRISTINE ROGERS, and JAMES D. FORTENBERRY

Kidney International (2005)

Robert S. Gillespie · Kristy Seidel · Jordan M. Symons

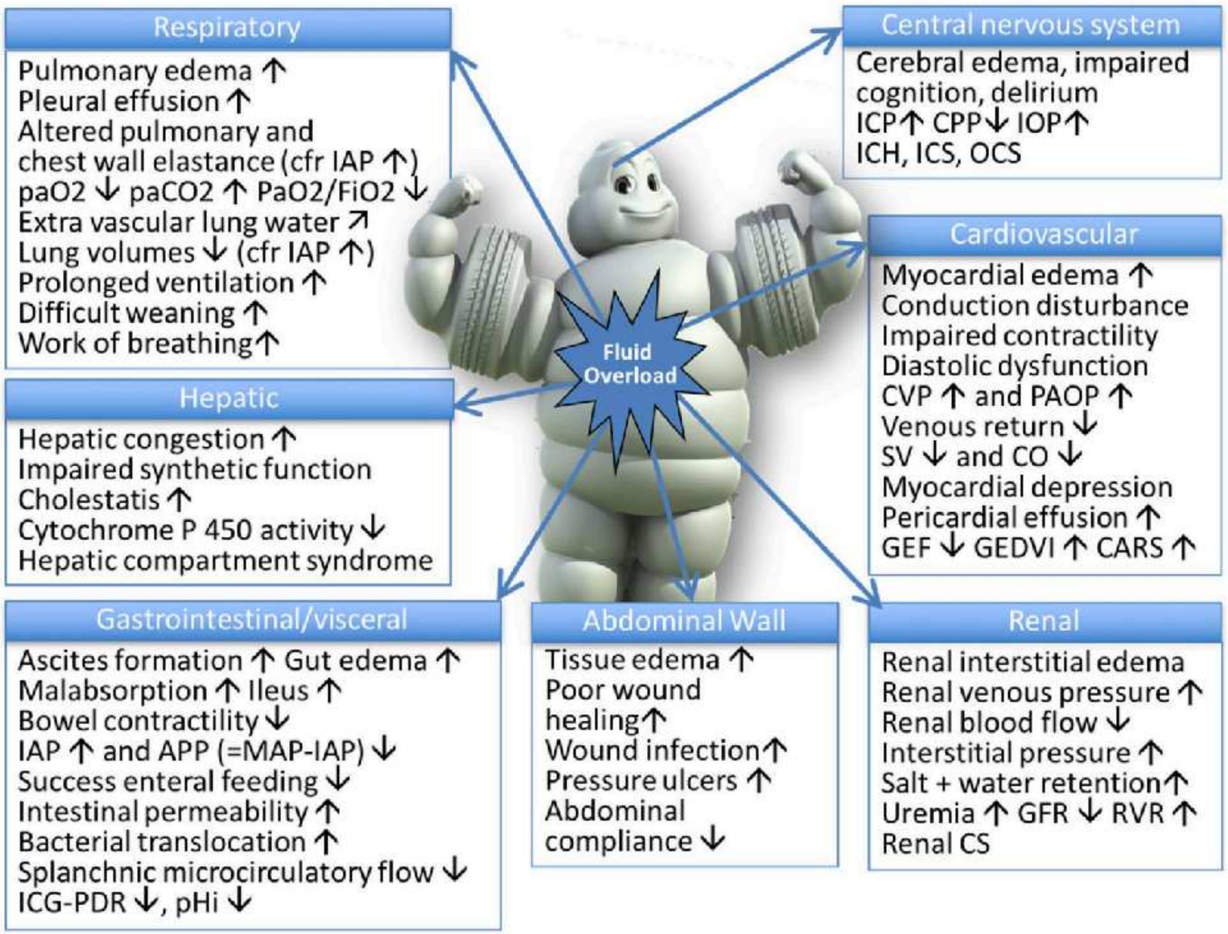
Effect of fluid overload and dose of replacement fluid on survival in hemofiltration

Pediatr Nephrol (2004)

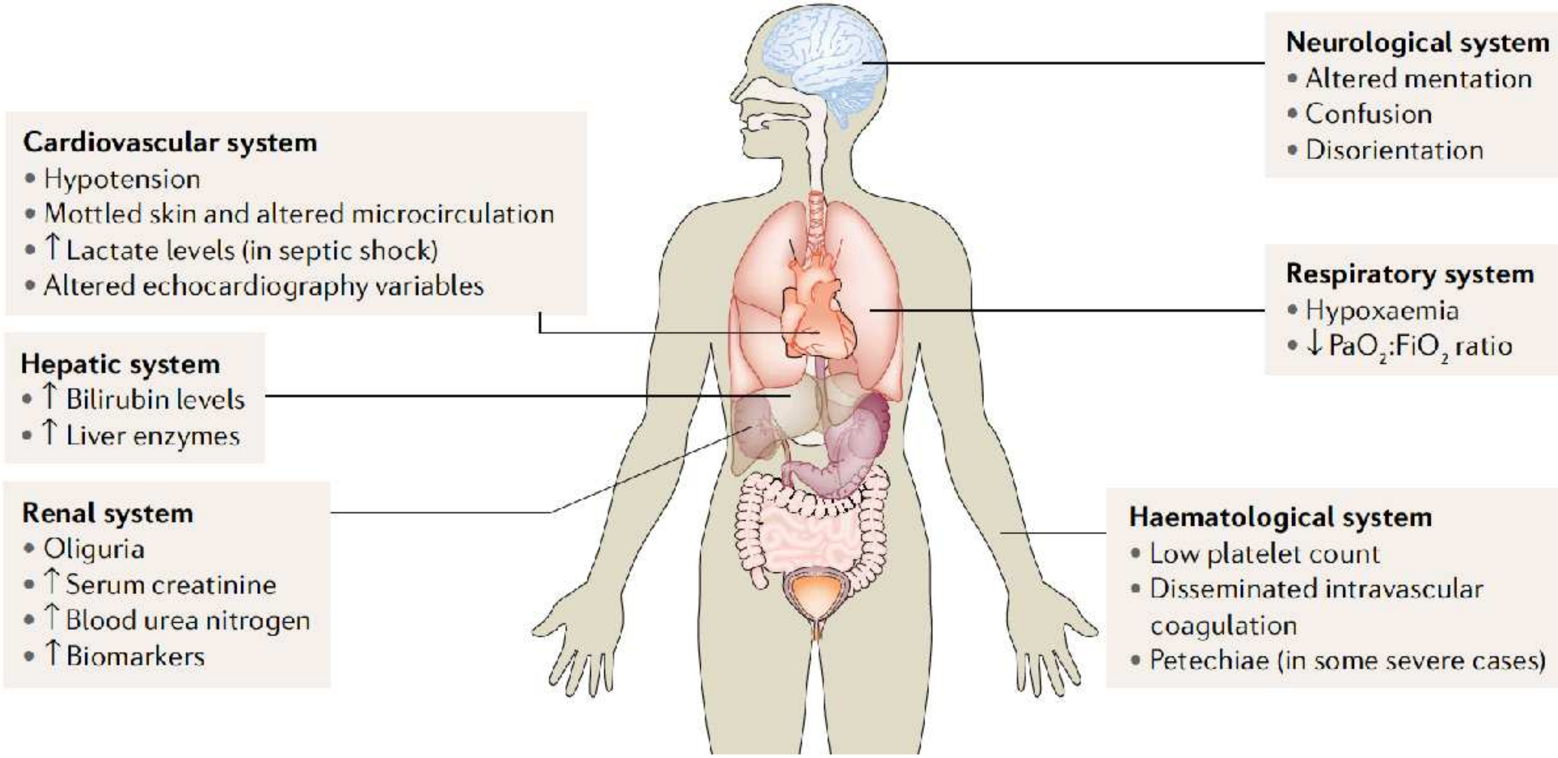
Many studies in adult and pediatric patients who required CRRT (or not) have demonstrated a clear association between fluid overload and mortality

- Positive fluid balance and **venous congestion** have been associated with poor outcome in critically ill patients and in organ dysfunction (i.e. lung, kidney, liver, and gut).

Legrand M et al. Critical Care (2013)



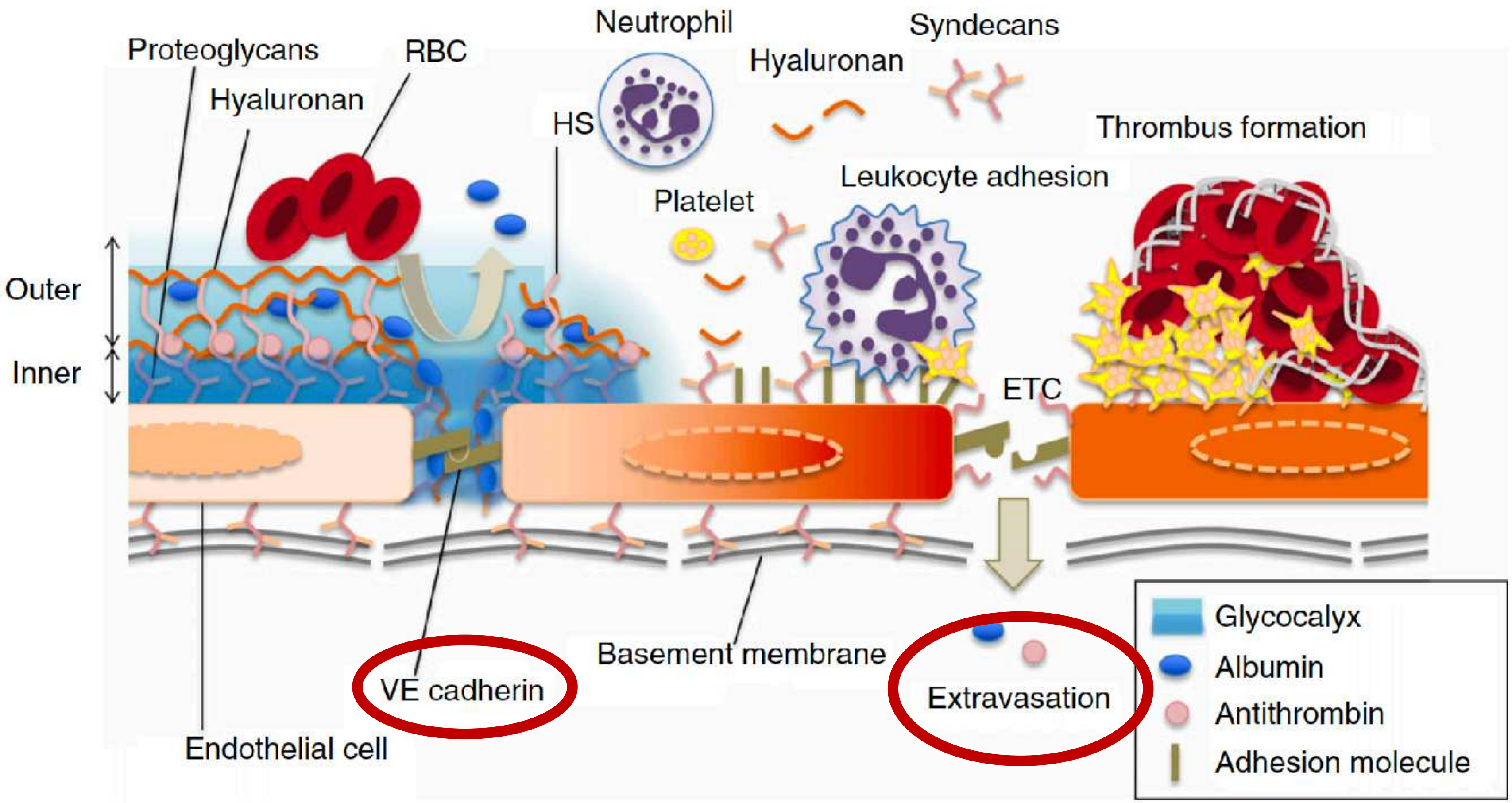
Malbrain MLNG et al. Ann. Intensive Care (2018)



- Cardiovascular
- Respiratory
- Renal
- Neurological
- Haematological
- Hepatic systems

*Christophe Lelubre[1,2] and Jean-Louis Vincent[3]**

NATURE REVIEWS | NEPHROLOGY VOLUME 14 | JULY 2018 | 417



Proteoglycans
RBC
Hyaluronan
HS
Neutrophil
Hyaluronan
Syndecans
Thrombus formation
Leukocyte adhesion
Platelet
Outer
Inner
ETC
Glycocalyx
Albumin
Antithrombin
Adhesion molecule
Basement membrane
VE cadherin
Extravasation
Endothelial cell

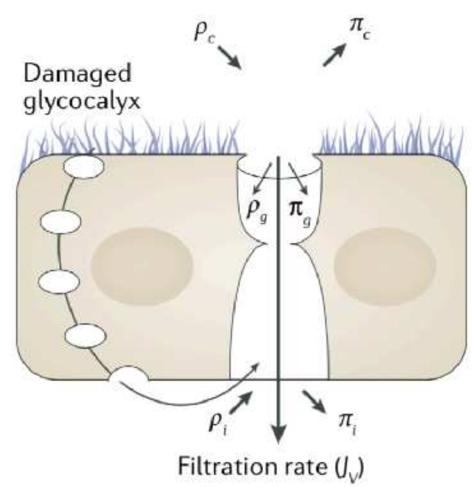
Damage

Endothelial dysfunction

- The **endothelium** forms the inner cell layer of blood vessels and the lymphatics and has a major role in controlling blood flow and vascular tone as well as being involved in immune responses

Opal, S et al. J. Intern. Med. 277, 277–293 (2015).

disruption of normal cell–cell connections, including adherens junctions



Altered endothelial function is common in **all affected organs** in sepsis and has a key role in the pathogenesis of multiple organ failure.

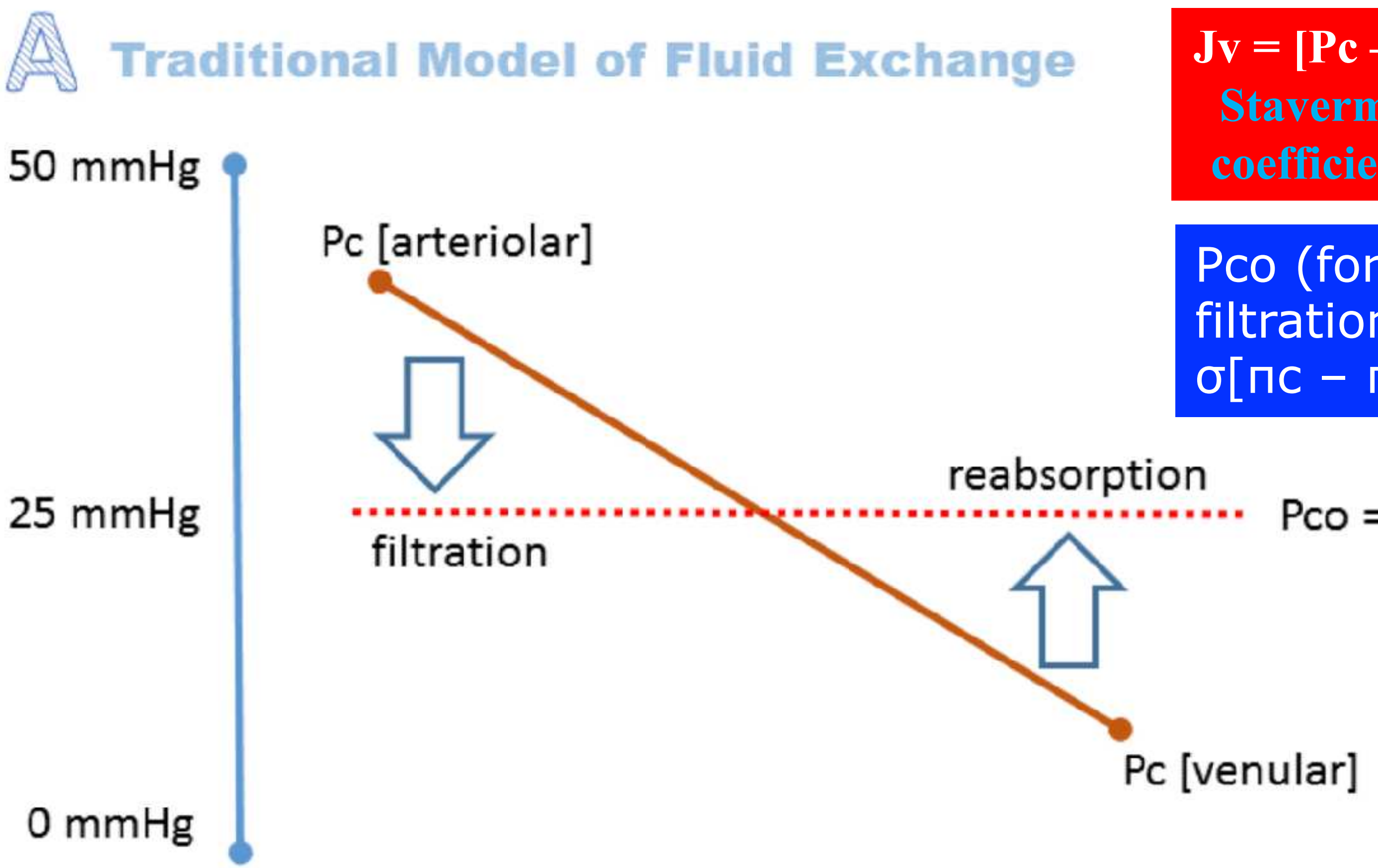
Oedema formation and reduced microvascular perfusion

*Christophe Lelubre[1,2] and Jean-Louis Vincent[3]**
NATURE REVIEWS | NEPHROLOGY VOLUME 14 | JULY 2018 | 417

transendothelial hydrostatic pressure (Pc-Pi) & colloid osmotic pressure difference (πc – πi)

(Alb)

Staverman's reflection coefficient (σ) = n.v. 1
(glycocalyx layer is fully effective)



$Pco = \sigma[\pi c - \pi i] + Pi$

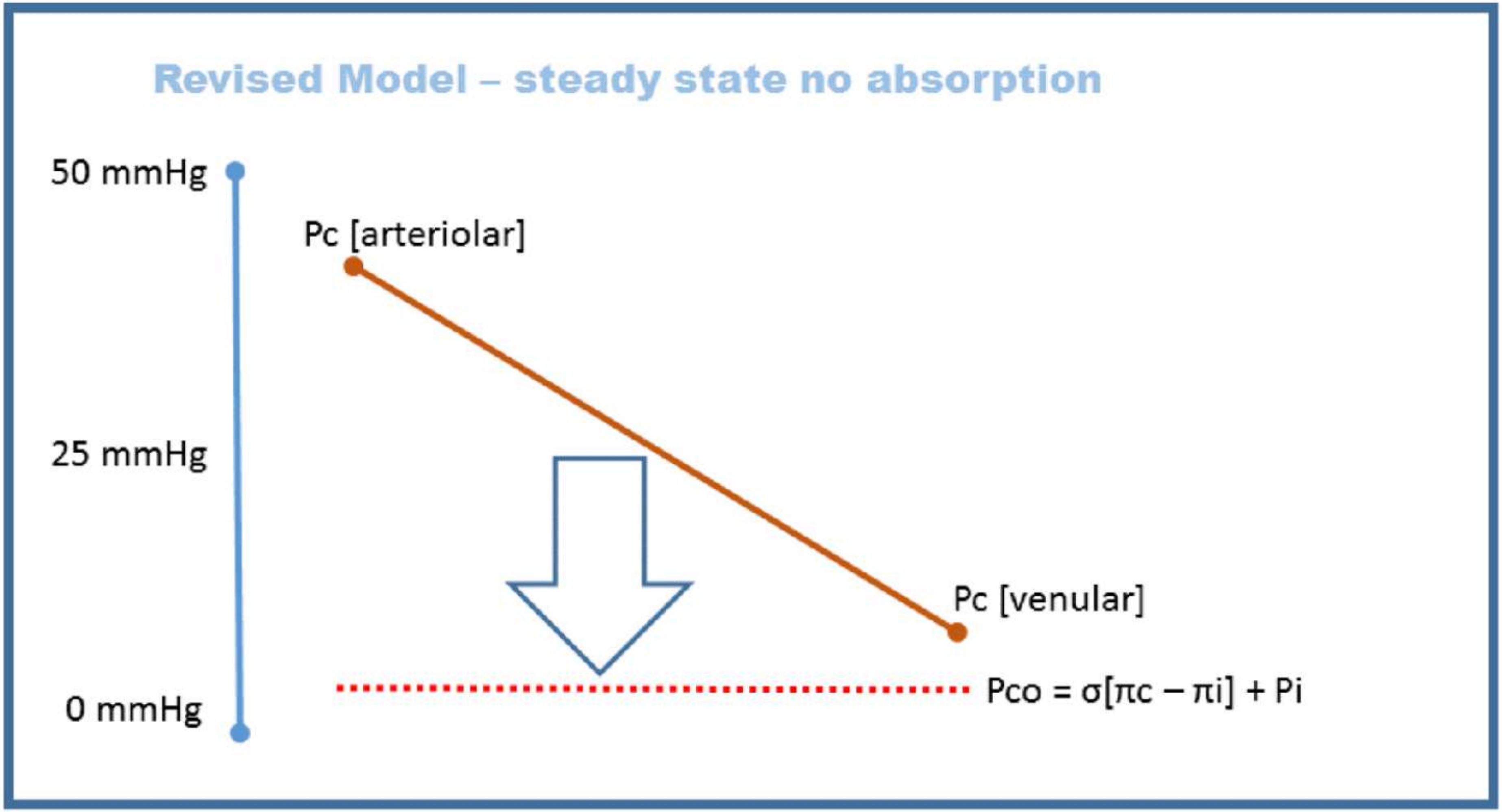
$Jv = [Pc - Pi] - \sigma[\pi c - \pi i]$
Staverman's reflection coefficient (σ) close to 1

Pco (force opposing filtration) =
$\sigma[\pi c - \pi i] + Pi$

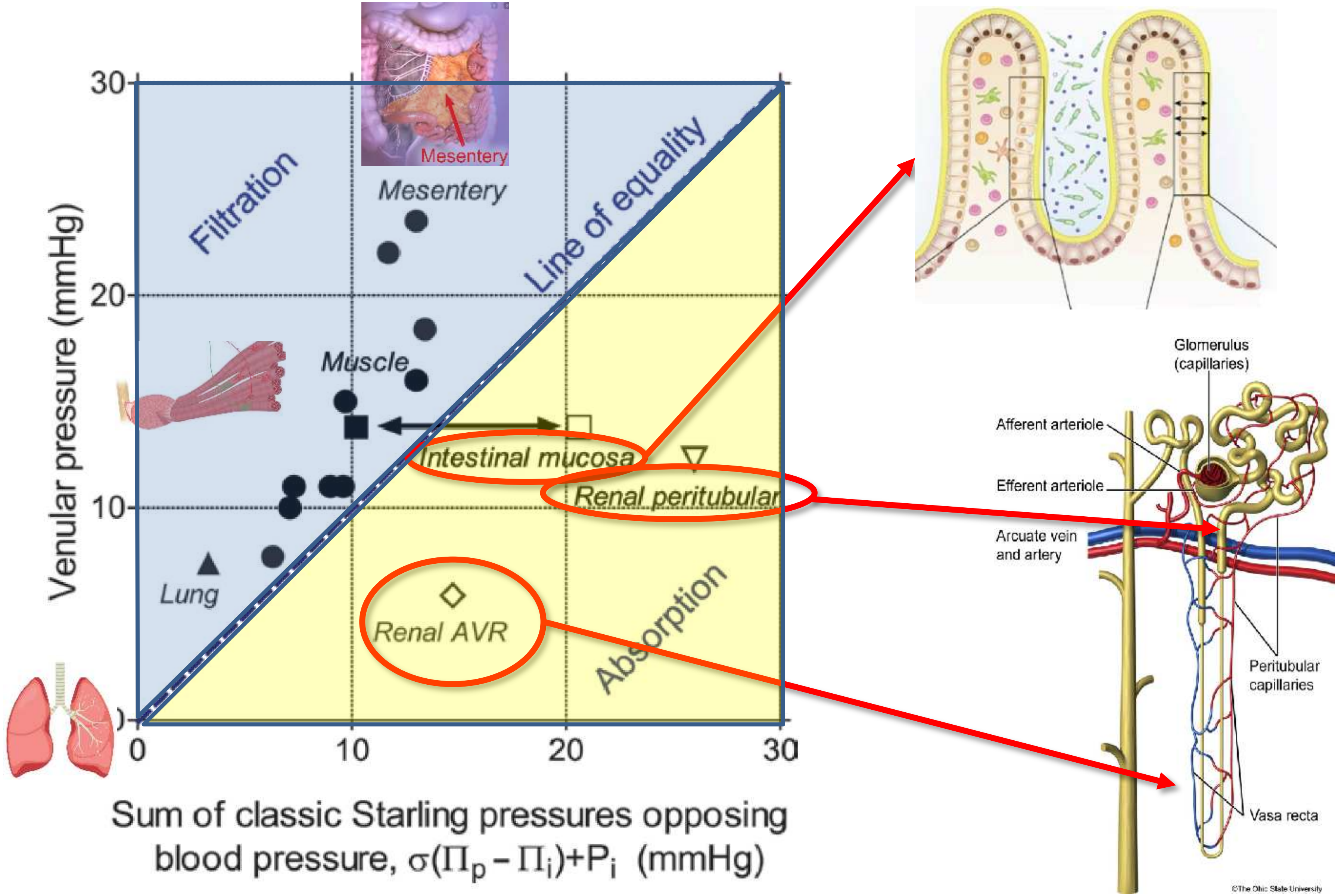
https://pulmccm.org/ards-review/revised-starling-principle-implications-rational-fluid-therapy/

- Πi = High (16 mmHg)
- Pi = Low

No absorption

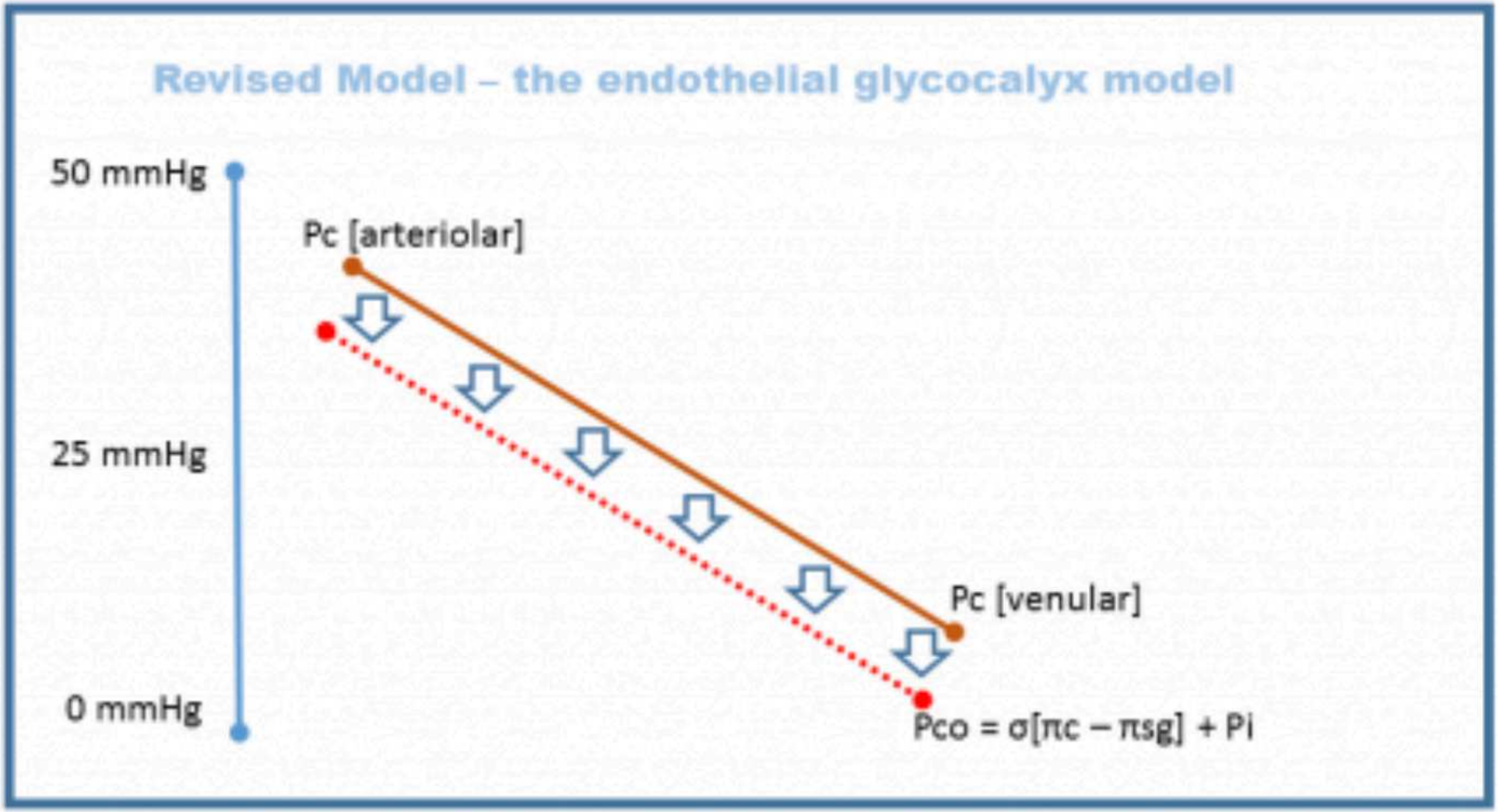


https://pulmccm.org/ards-review/revised-starling-principle-implications-rational-fluid-therapy/



Levick JR, Michel CC. Microvascular fluid exchange and revised Starling principle. Cardiovasc Res. 2010;87:198–210.

The revised Starling-Glycocalyx model



https://pulmccm.org/ards-review/revised-starling-principle-implications-rational-fluid-therapy/

Physiological Reviews

Vol. 73, No. 1, January 1993

Interstitial-Lymphatic Mechanisms in the Control of Extracellular Fluid Volume

K. AUKLAND AND R. K. REED

Aukland K et al. Physiol Rev (1993)

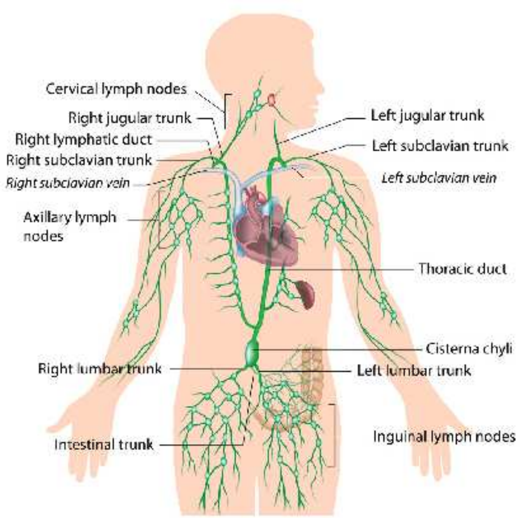
During times of health, the interstitial fluid volume remains fairly constant with estimated **8 to 20 L** of fluid per day leaving the capillaries and entering the interstitial space where it exits through the lymphatics or is reabsorbed at the venular-end of the capillaries.

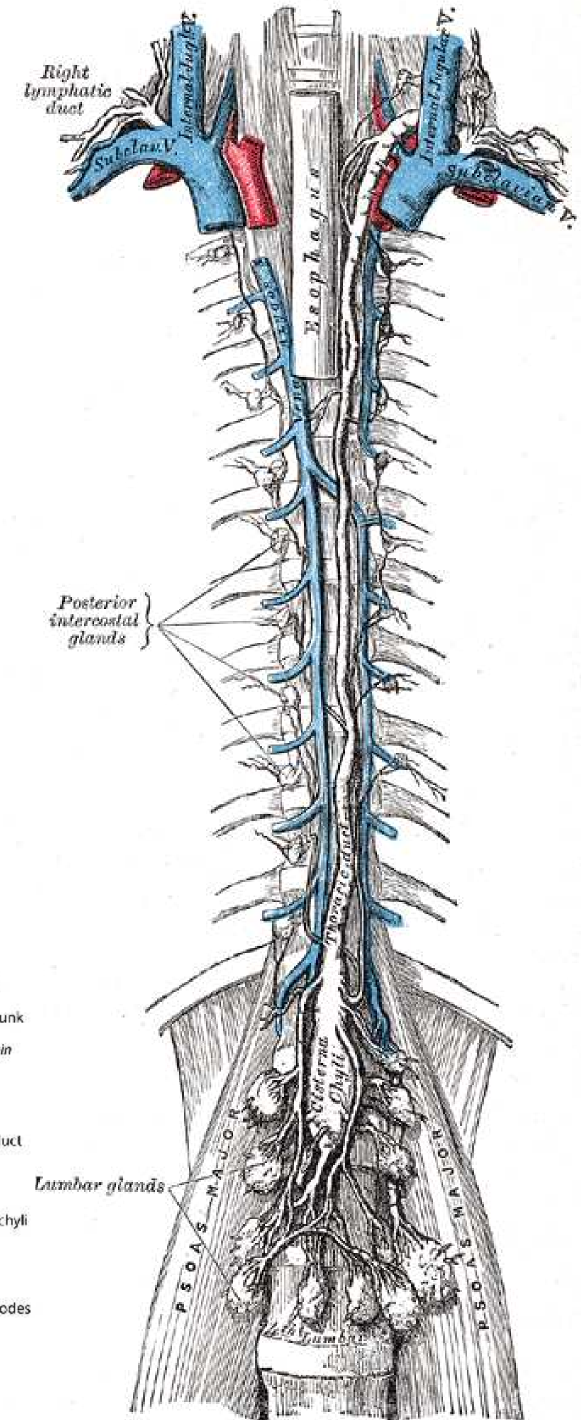
Wiig H et al. Physiol Rev (2012)

Renkin EM. Am J Physiol Heart Circ Physiol (1986)

In an average resting adult, the thoracic duct returns about **100 mL/h** of fluid.

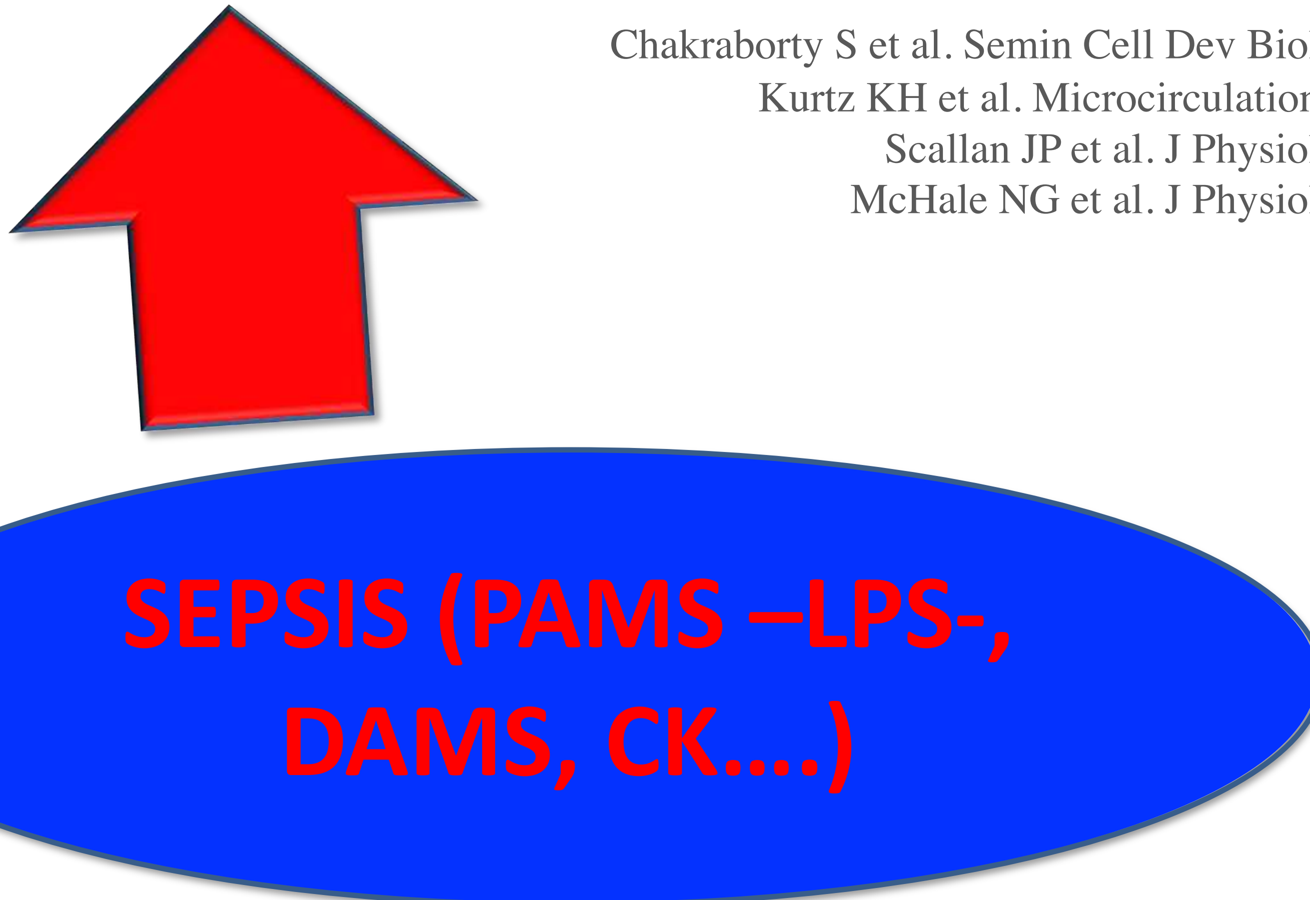
Additional **25 mL/h** from the right lymphatic duct





Lymphatic smooth muscle basal tonicity, contraction amplitude, and frequency are influenced by multiple stimuli including **neuronal, humoral, and cellular signaling**

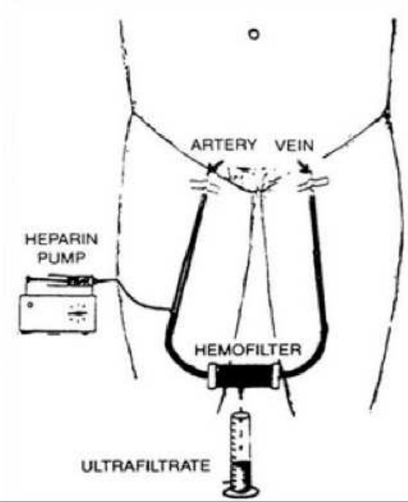
Chakraborty S et al. Semin Cell Dev Biol (2015)
Kurtz KH et al. Microcirculation (2014)
Scallan JP et al. J Physiol (2013)
McHale NG et al. J Physiol (1980)



A number of studies have reported an association between a more positive fluid balance and mortality risk in sepsis

Acheampong et al. Crit. Care 19, 251 (2015).
Brotfain, E. et al. Am. J. Emerg. Med.34, 2122–2126 (2016).
Sakr, Y. et al. Crit. Care Med. 45, 386–394 (2017).

Kramer P, Wigger W, Rieger J, Matthaei D, Scheler F. [Arteriovenous haemofiltration: a new and simple method for treatment of over-hydrated patients resistant to diuretics]. *Klin Wochenschr*. 1977 Nov 15;55(22):1121–1122.



1977

CAVH

Courtesy of Prof. C. Ronco

REVIEW Open Access

Nomenclature for renal replacement therapy in acute kidney injury: basic principles

$$Q_{UF}^{NET}$$

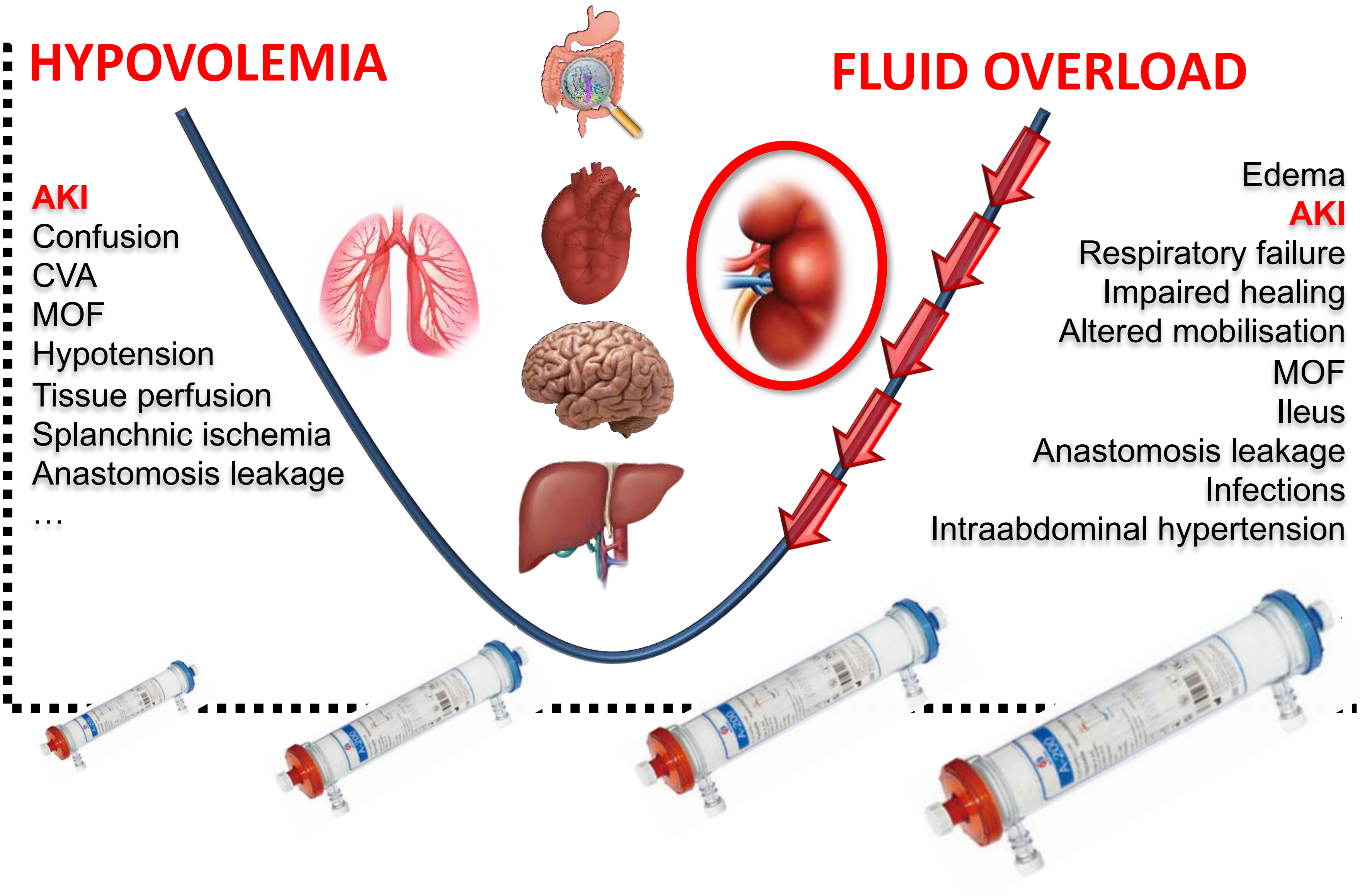
Net ultrafiltration flowrate (Δ weight flowrate) (weight loss flowrate) ml/h

UF^{NET} = net ultrafiltrate volume removed from the patient by the machine

Net volume of fluid removed from the patient by the machine per unit of time

Neri et al. Critical Care (2016) 20:318

FLUID BALANCE and MOF

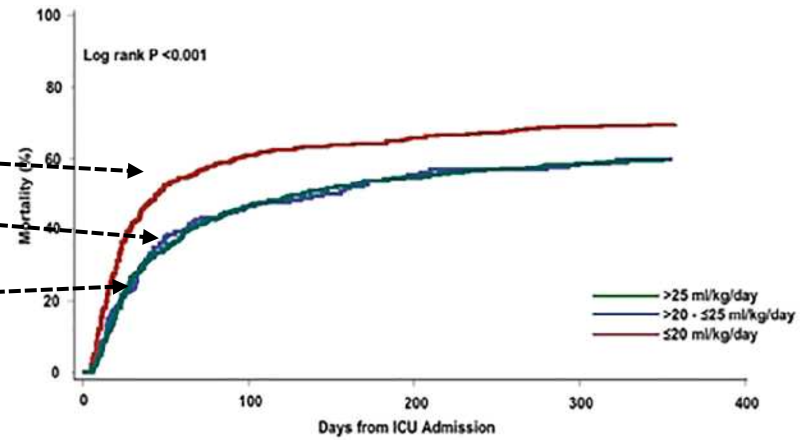


RESEARCH **Open Access**

Net ultrafiltration intensity and mortality in critically ill patients with fluid overload

We stratified UF^{NET} as:

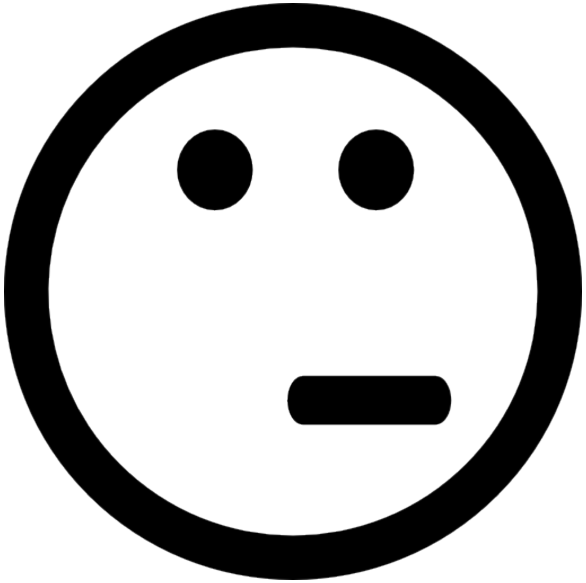
- Low (≤ 20 ml/kg/day)
- Moderate (> 20 to ≤ 25 ml/kg/day)
- High (> 25 ml/kg/day) intensity



Conclusions:

Among critically ill patients with ≥ 5% fluid overload and receiving RRT, UF^{NET} intensity > 25 ml/kg/day compared with ≤ 20 ml/kg/day was associated with lower 1-year risk-adjusted mortality. **Whether tolerating intensive UF^{NET} is just a marker for recovery or a mediator requires further research**.

We (Murugan at al) asked a … question: does UF^{NET} intensity and a **threshold “dose”** of UF^{NET} **matter** in the treatment of FO independent of fluid balance?



Murugan R et al. Critical Care (2018)

less intensive UF^{NET}

Slower rate or smaller volume of fluid removed

may be associated with prolonged exposure to tissue and organ edema and increased morbidity and mortality!

MORE intensive UF^{NET}

Faster rate or larger volume of fluid removed

may be associated with increased hemodynamic and cardiovascular stress!

Ischemic organ injury and mortality in critically ill patients

Murugan R et al. Critical Care (2018)

RESEARCH ARTICLE Open Access

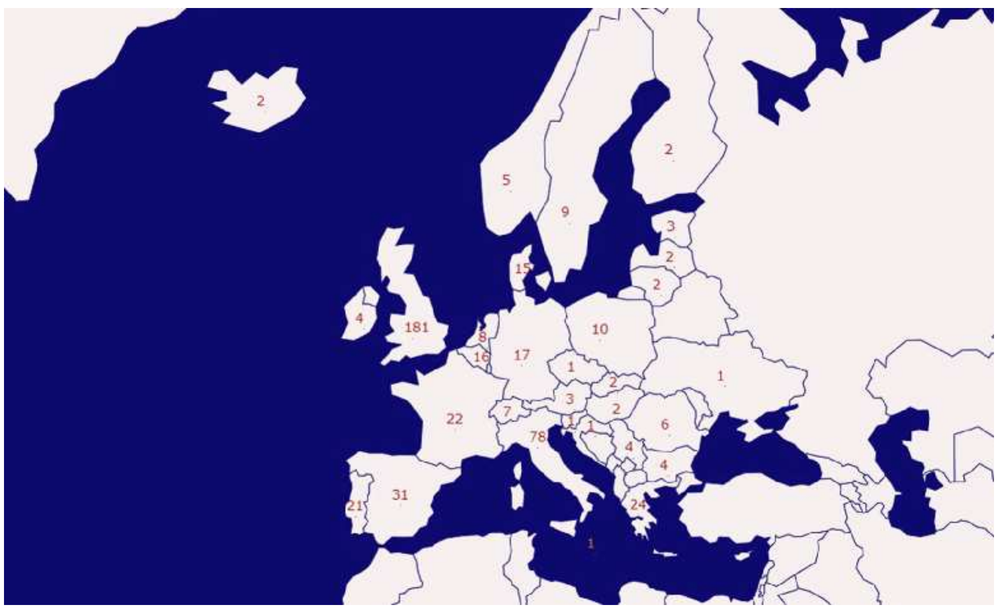
Net ultrafiltration prescription survey in Europe

Nuttha Lumlertgul[1,2,3,4], Raghavan Murugan[5,6], Nina Seylanova[1,7], Patricia McCready[1] and Marlies Ostermann[1*]

Lumlertgul et al. BMC Nephrology (2020)

- The survey was distributed to 23,009 practitioners from three societies (16,360 from ESICM, 4649 from Italian Society of Intensive care, and 2000 from British Association of Critical Care Nurses).

- The most represented countries were the United Kingdom (UK) (37.3%), Italy (16.1%), Spain (6.4%), Greece (5.0%), France (4.5%), Portugal (4.3%), and Germany (3.5%);



679 practitioners from 31 European countries who responded

Lumlertgul et al. BMC Nephrology (2020)

Fluid removal practice

IHD

- IHD = median of 5.0% (IQR,0–25.0%)
- PIRRT = median of 1.0% (IQR, 0–20%)

CRRT

- CRRT = 90.0% (IQR, 30.0–100.0%) as the first modality for ultrafiltration.

Lumlertgul et al. BMC Nephrology (2020)

CRRT

The median initial net ultrafiltration (UFNET) prescription in hemodynamically stable patients = **149 mL/hr** (IQR 100–200)

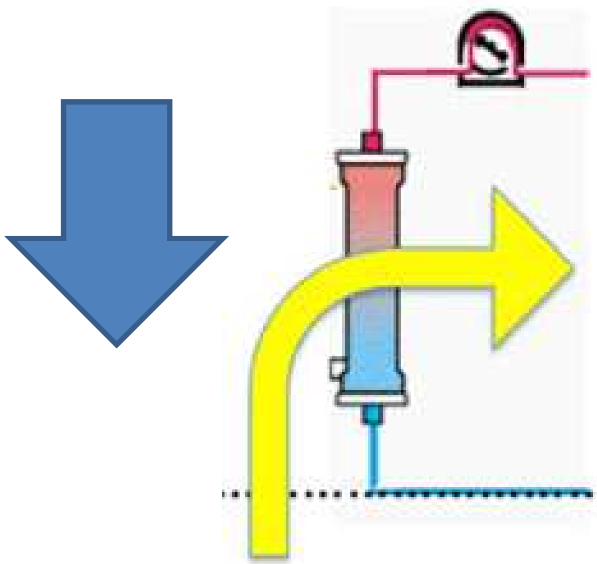
The median initial maximal rate of and **300 mL/hr** (IQR 201–352)

The median UFNET in hemodynamically unstable patients rate = **98 mL/hr** (IQR 51–108)

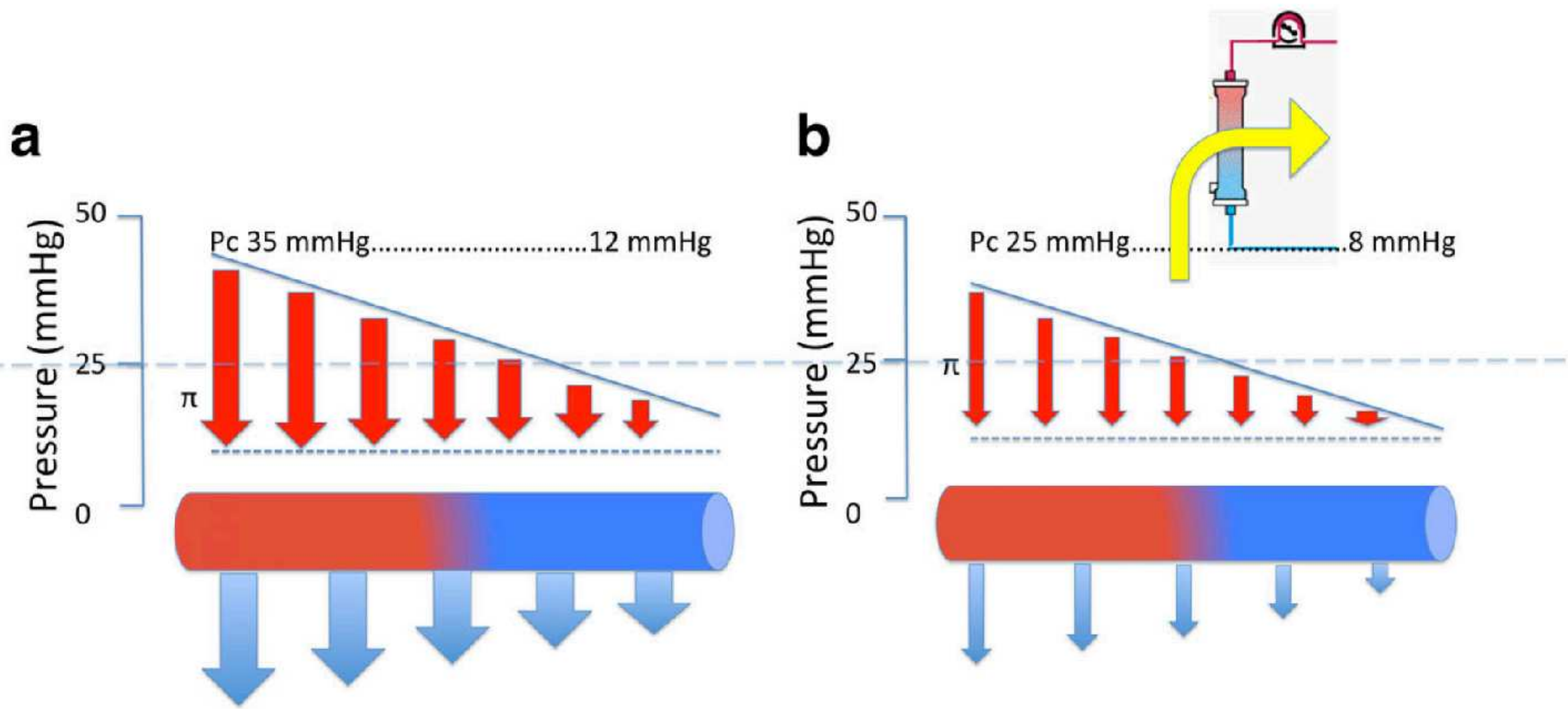
. . . and varied significantly between countries

Lumlertgul et al. BMC Nephrology (2020)

When hemodynamic instability occurred, 70.1% of practitioners reported <u>decreasing the rate of fluid **removal**</u>, followed by starting or increasing the dose of a **vasopressor** (51.3%).



Lumlertgul et al. BMC Nephrology (2020)



Legrand M et al. Critical Care (2018)

- This strategy **may**, however, **compromise venous return and therefore cardiac output**, which may impact organ perfusion and organ function recovery.

Venous Return at Various Right Atrial Pressures and the Normal Venous Return Curve[1]

ARTHUR C. GUYTON, ARTHUR W. LINDSEY, BERRY ABERNATHY AND TRAVIS RICHARDSON

From the Department of Physiology and Biophysics, University of Mississippi School of Medicine, Jackson, Mississippi

ABSTRACT

GUYTON, ARTHUR C., ARTHUR W. LINDSEY, BERRY ABERNATHY AND TRAVIS RICHARDSON. (U. Mississippi School Med., Jackson.) *Venous return at various right atrial pressures and the normal venous return curve.* Am. J. Physiol. 189(3): 609–615. 1957.—The normal venous return curve has been determined in 12 open-chest dogs with intact circulatory reflexes and in 14 open-chest areflex dogs. These curves show that venous return reaches a maximum value when the right atrial pressure falls to −2 to −4 mm Hg and remains at this maximum value down to infinitely low negative pressures. As the right atrial pressure rises to positive values venous return falls and reaches zero when the right atrial pressure has risen to equal the mean circulatory pressure. A venous return curve for the normal, intact dog has been tentatively formulated on the basis of these studies and previous studies in which individual points on the venous return curves of intact dogs have been measured.

WHEN A CHANGE occurs in the hemodynamics of the circulatory system one cannot predict what will happen to the cardiac output unless he takes into consideration both the effect of this change on the ability of the heart to pump blood and also on the tendency for blood to return to the heart from the blood vessels. The ability of the heart to pump blood can be depicted by a curve showing cardiac output plotted against right atrial pressure, a type of Starling's curve used for many years to describe the functional ability of the heart. The tendency for blood to return to the heart from the circulatory system can be depicted by a 'venous return curve' which is a plot of blood flow into the right atrium against right atrial pressure.

The general characteristics of venous return curves are illustrated in figures 2–5 of this paper. All of these curves show that at negative right atrial pressures blood returns to the heart as rapidly as possible, but, as the right atrial pressure rises to positive values, a point is finally reached at which the back pressure from the right atrium is great enough to prevent all venous return.

If one can characterize both the cardiac output curve and the venous return curve in an animal, he can then predict by equating the two curves what the cardiac output and right atrial pressure will be. This procedure has already been explained in previous publications (1, 2), and it has proved to be especially valuable for analyzing quantitatively how much the cardiac output will be affected by exercise, sympathetic stimulation, transfusion, arteriovenous fistulae and many other factors that can change circulatory dynamics from the normal. Therefore, it has become important to record with as much care as possible the normal venous return curve to provide an accurate basis for these analyses.

METHODS

Thirty-one mongrel dogs of varying sizes, lightly anesthetized with sodium pentobarbital, were used in these studies. Arterial and venous pressures were recorded on a kymograph using mercury manometers with

Received for publication December 19, 1956.
[1] This investigation was supported by a grant-in-aid from the National Heart Institute.

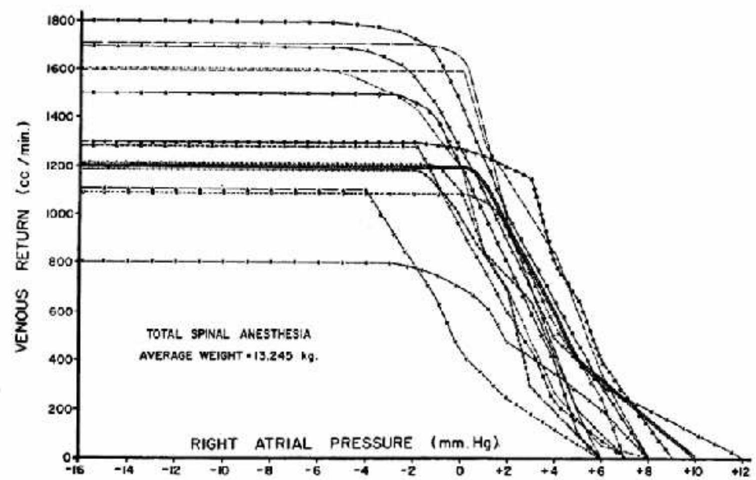


FIG. 3. Venous return curves recorded from 14 areflex, open-chest dogs.

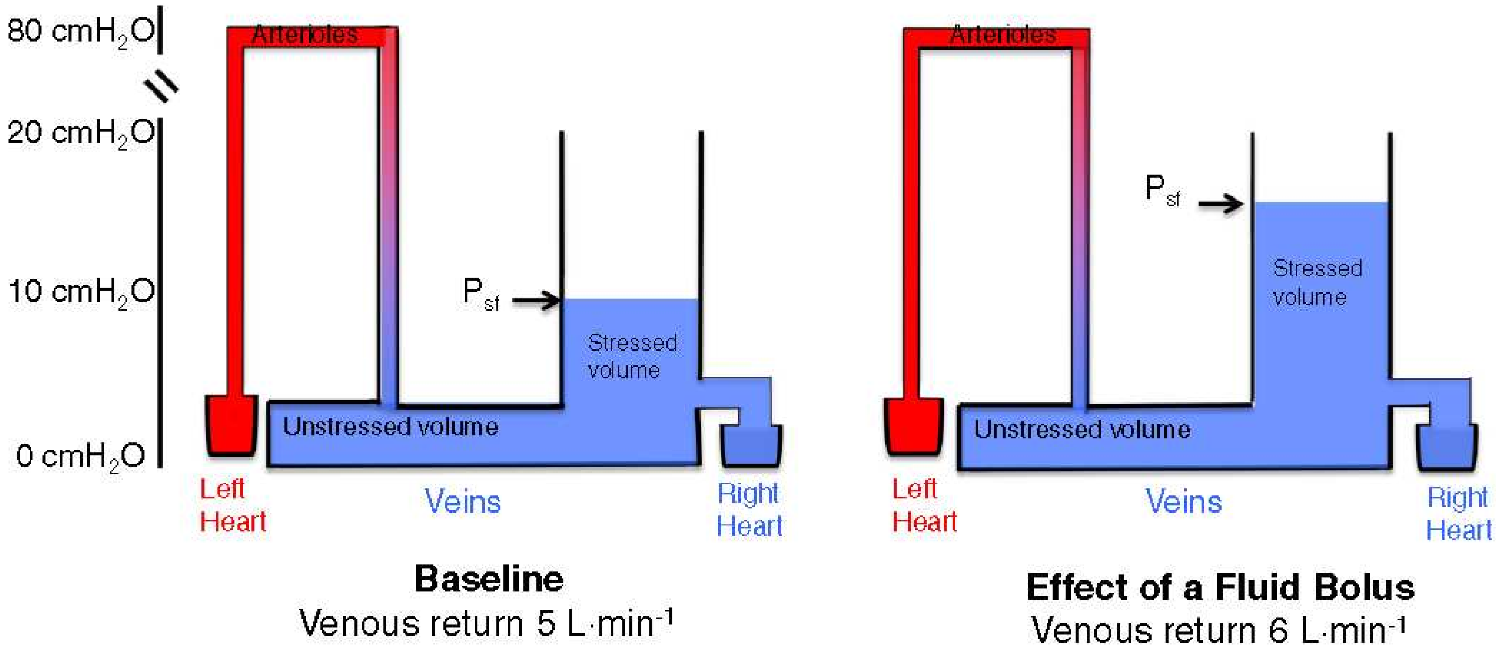
Guyton AC et al.
Am J Physiol (1957); 189:609-15

Intensive Care Med (2014) 40:1564–1566
DOI 10.1007/s00134-014-3379-4

UNDERSTANDING THE DISEASE

David A. Berlin
Jan Bakker

Understanding venous return



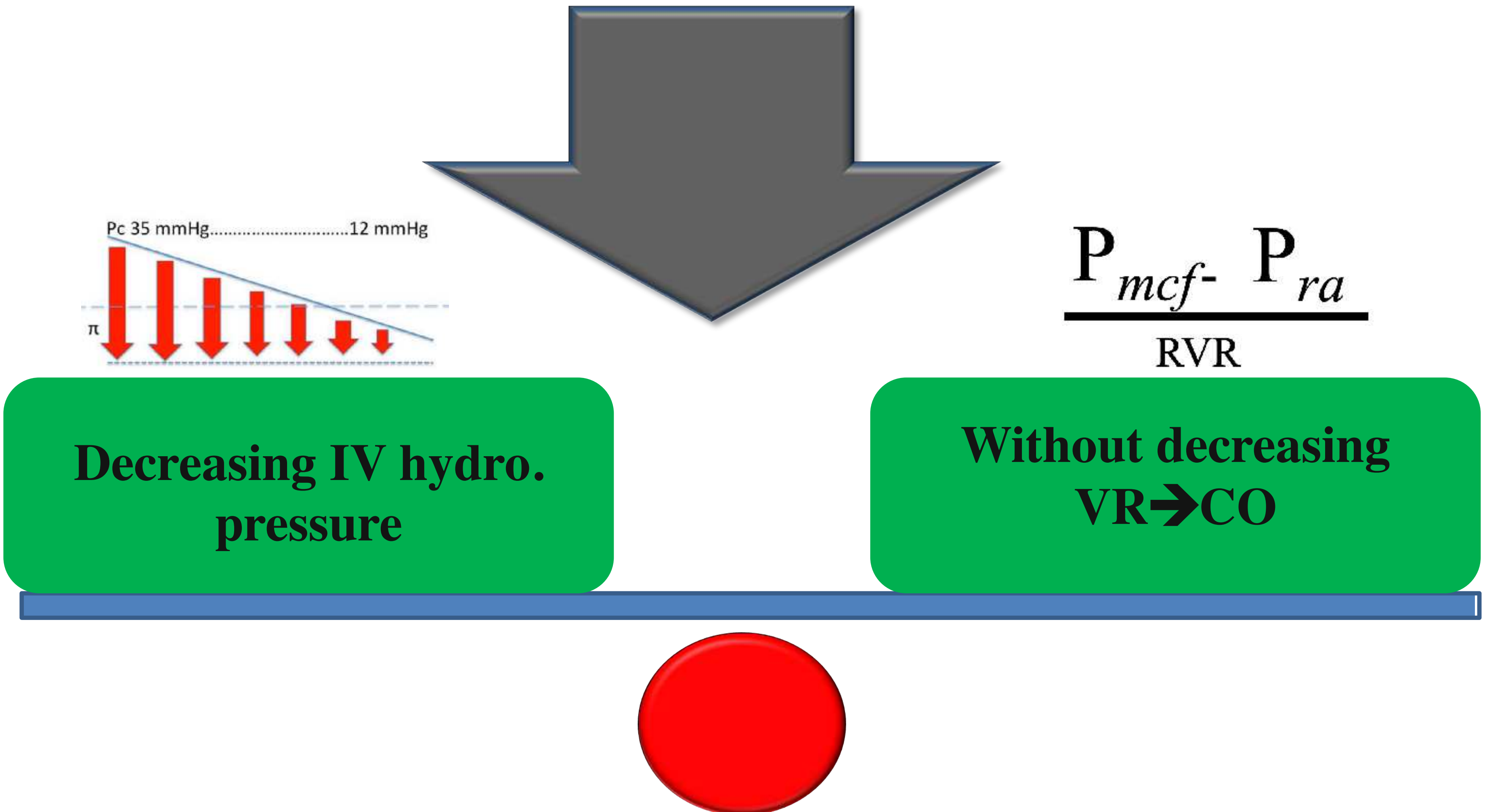
Venous Return = Cardiac Output

$$\frac{P_{cf} - P_{ra}}{RVR}$$

. . .

- Sedation
- Analgesia
- Inflammation
- Sepsis . . .

- Initiation of **volume depletion** should be associated with haemodynamic monitoring in order to avoid either under- or over-treatment with a risk of hypoperfusion.

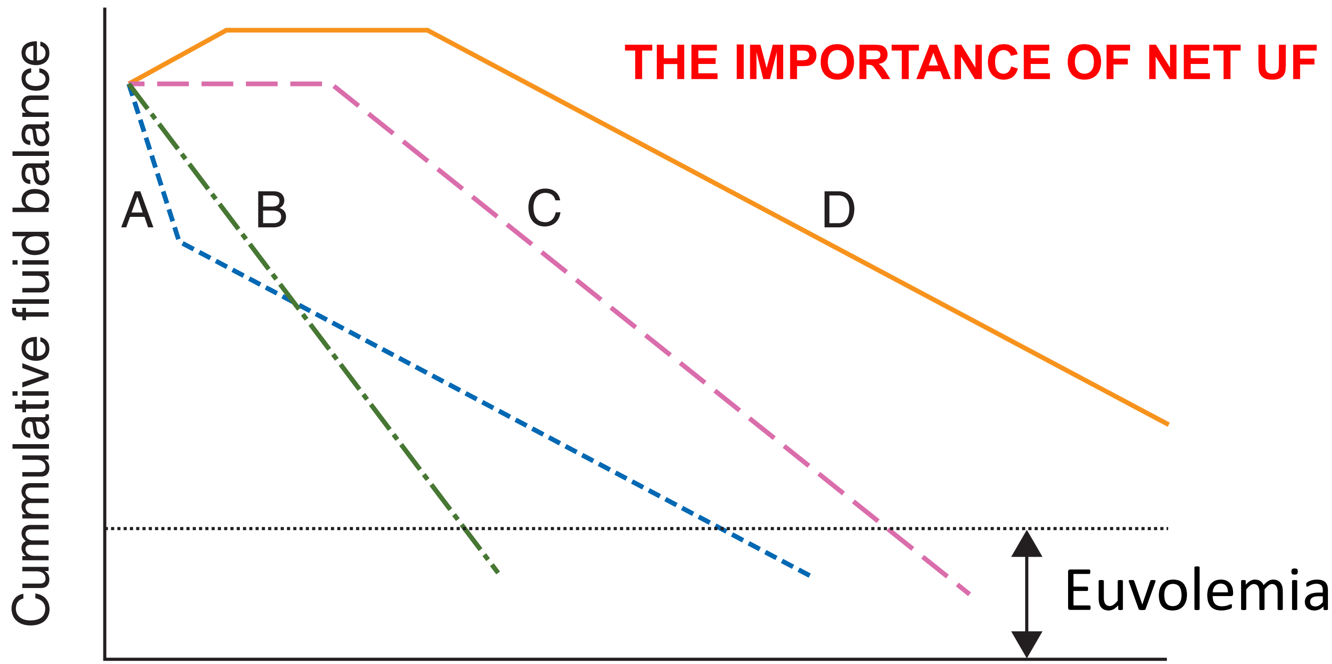


Indications and management of mechanical fluid removal in critical illness

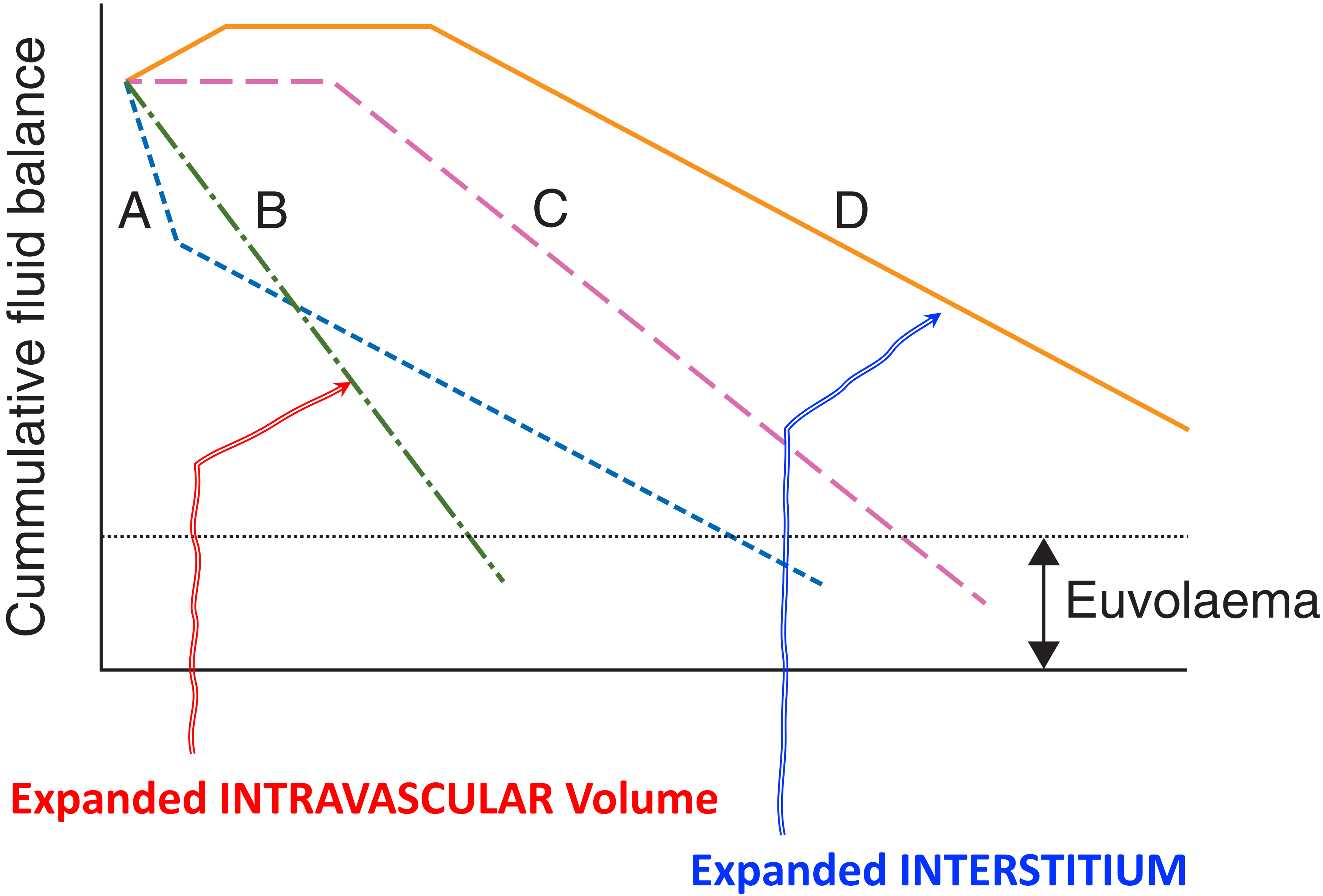
M. H. Rosner[1†], M. Ostermann[2†*], R. Murugan[3], J. R. Prowle[4], C. Ronco[5], J. A. Kellum[3], M. G. Mythen[6] and A. D. Shaw[7] for the ADQI XII Investigators Group

BJA 2014

THE IMPORTANCE OF NET UF TRAJECTORY



Rapid early fluid removal may be indicated in cardio-renal syndrome (A), but a slower removal may be required for haemodynamic tolerance after resolution of pulmonary oedema. Patients with single organ renal failure (B) may tolerate more rapid fluid removal than those with AKI complicating severe sepsis (C) or septic shock (D).



Cummulative fluid balance
A
B
C
D
Euvolaema
Expanded INTRAVASCULAR Volume
Expanded INTERSTITIUM

Conclusions

- ✓ UF^{NET} is a key issue in ICU patients
- ✓ Both excessive and insufficient UF^{NET} eventually lead to negative outcomes
- ✓ Lymphatic drainage has in important role in decreasing tissue edema and may be impaired in septic patients.
- ✓ Hemodynamic monitoring could be useful <u>before</u> and <u>during</u> CRRT to set UF^{NET} intensity!

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XII Edizione

20-21 aprile 2021

Stefano Romagnoli, MD, Ph.D

SCUOLA DI SPECIALIZZAZIONE IN
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UNIVERSITÀ DI FIRENZE

SITI ISIC
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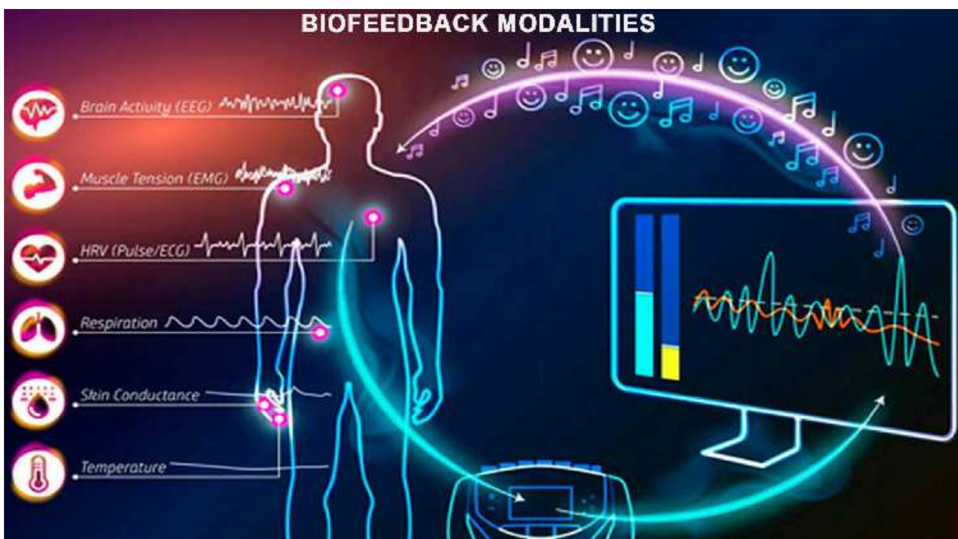
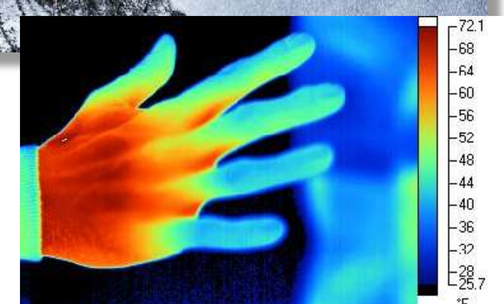
Italian Society of Intensive Care
FONDATA NEL 1975

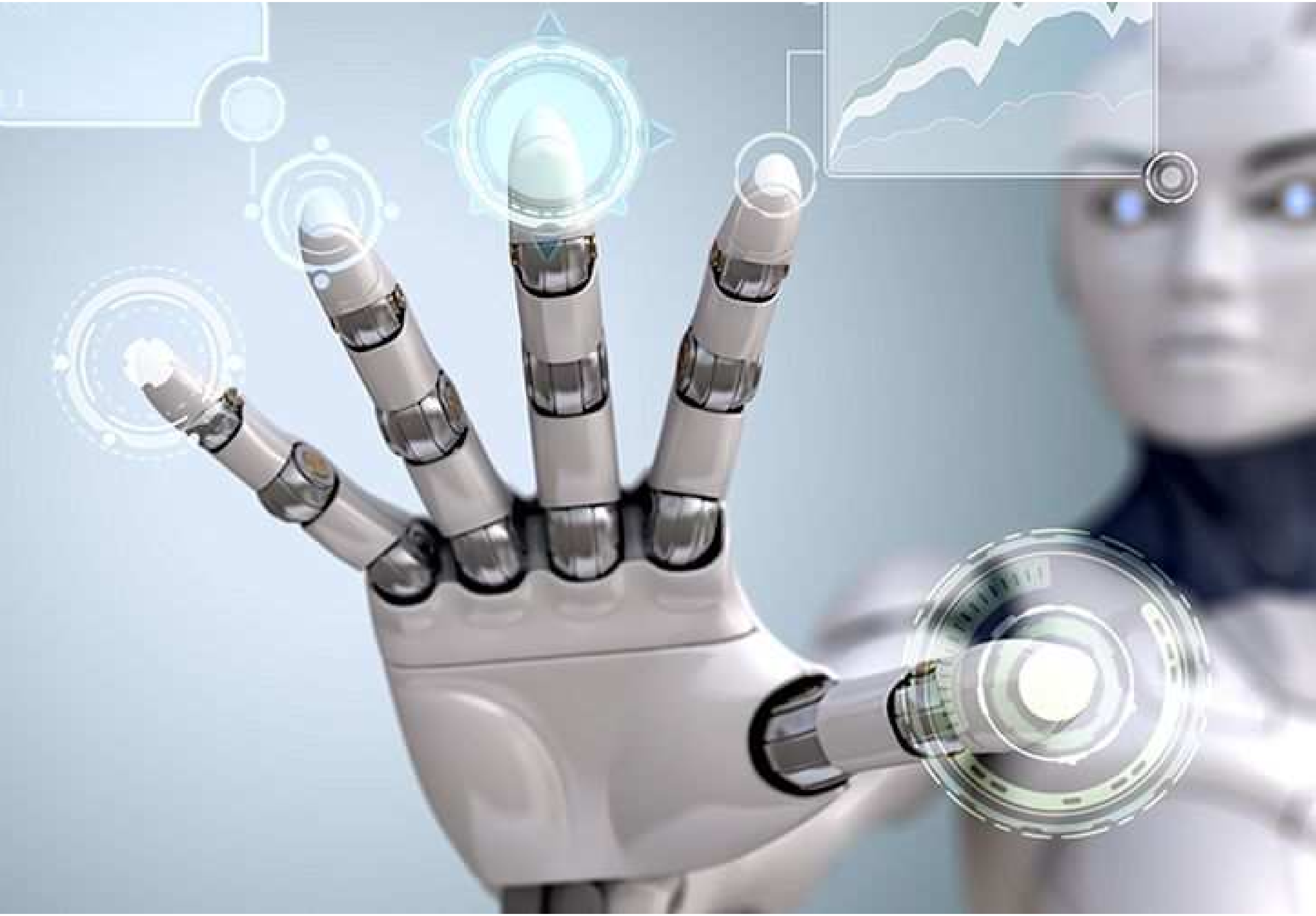
Dip. di Scienze della Salute – Università di Firenze
Dip. di Anestesia e Rianimazione - AOU Careggi - Firenze

Il Biofeedback

L'organismo umano **interagisce** continuamente con **l'ambiente** esterno attraverso l'elaborazione di comportamenti adattativi, cioè di meccanismi di **autoregolazione** che avvengono spesso automaticamente e indipendentemente dalla consapevolezza della persona, poiché sono regolati dai sistemi neurovegetativo, endocrino ed immunitario.

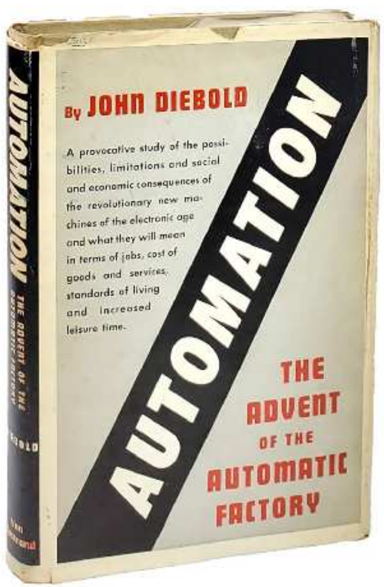




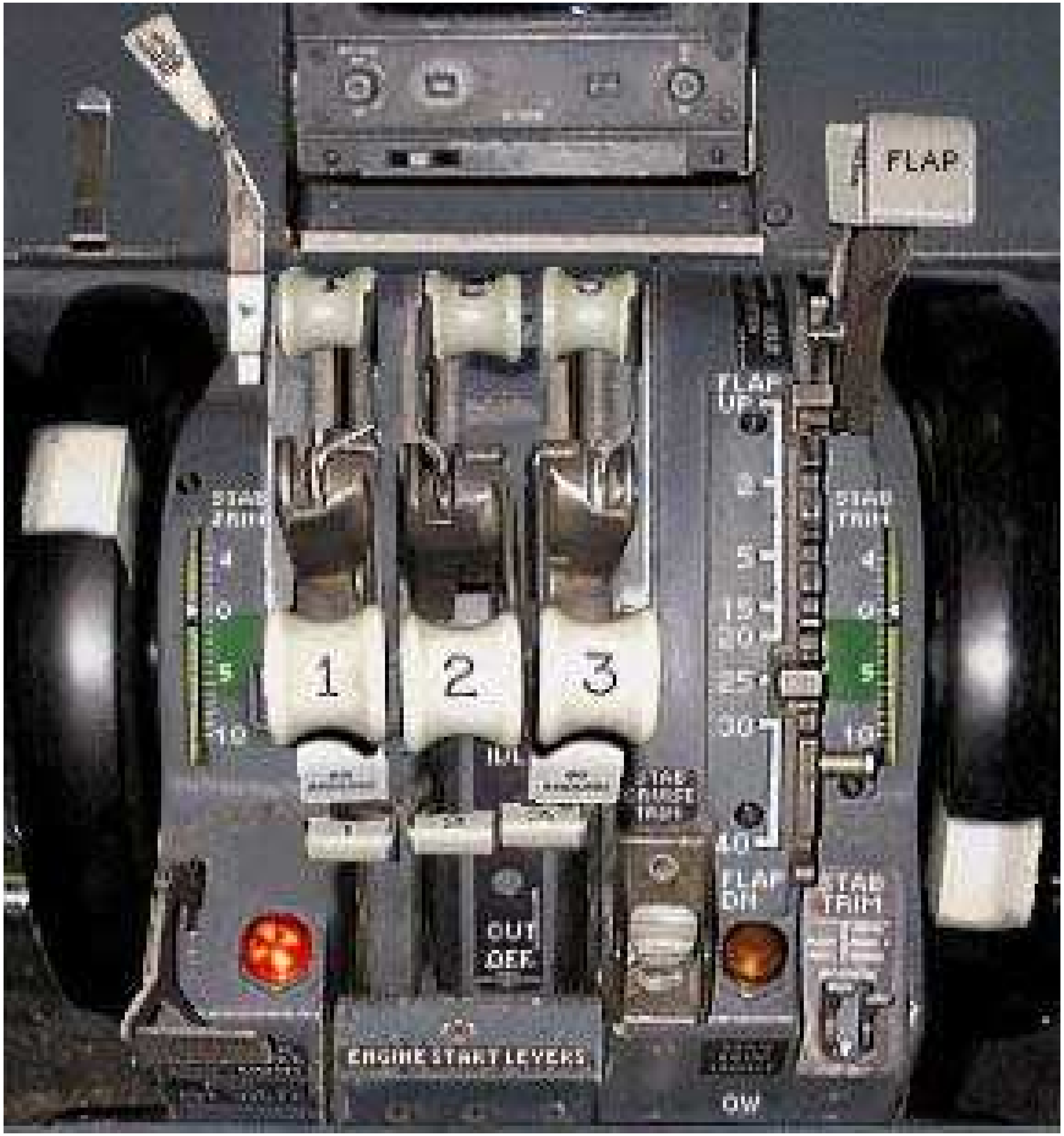


Automazione

la tecnologia che usa **sistemi di controllo** (come circuiti logici o elaboratori) per **gestire macchine e processi**, **riducendo la necessità dell'intervento umano**, ovvero per l'esecuzione di operazioni ripetitive o **complesse**, ma anche **dove si richieda sicurezza o certezza dell'azione** o semplicemente per maggiore comodità.



L'origine del termine "automazione" risale al 1952



FLAP
STAB TRIM
1
2
3
FLAP UP
5
15
20
25
30
40
FLAP DN
OUT OFF
ENGINE START LEVERS

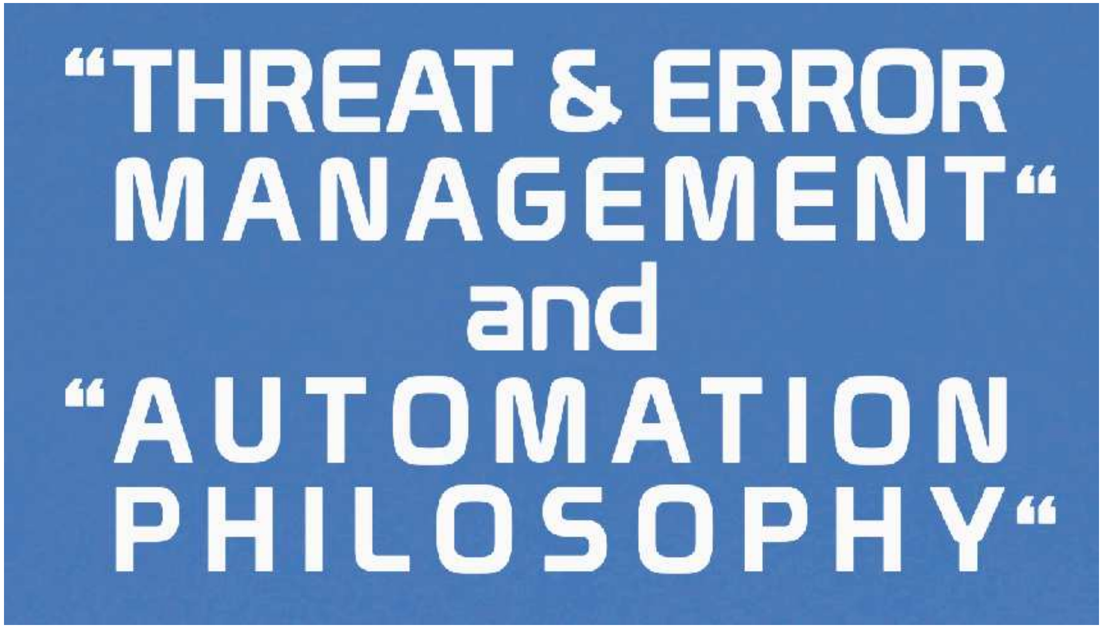

AIRBUS
0:00 / 0:56
HD


TO ERR IS HUMAN
BUILDING A SAFER HEALTH SYSTEM

L'uomo è per natura **fallace**. Ogni MEDICO, così come gli INFERMIERI e il personale DI REPARTO, deve convivere e combattere questa **debolezza**.

Evitare del tutto la possibilità di commettere un errore sarebbe utopistico.

L'errore, oltre che intrinsecamente legato alla natura umana, è favorito da una serie di fattori come ad esempio i **carichi di lavoro**, la *time pressure etc*.



L’uomo è per natura fallace. Ogni **pilota**, così come gli equipaggi e il personale a terra, deve convivere e combattere questa debolezza.

Evitare del tutto la possibilità di commettere un errore sarebbe utopistico.

L’errore, oltre che intrinsecamente legato alla natura umana, è favorito da una serie di fattori come ad esempio i carichi di lavoro, la *time pressure* etc.

L'errore in medicina

Frequenza, meccanismi e prospettive di prevenzione

BIF Mag-Giu 2001 - N. 3 9

BMJ Publications, 1995:31-54 (modif)

Bellomo R, Kellum JA, La Manna G, Ronco C (eds): 40 Years of Continuous Renal Replacement Therapy.
Contrib Nephrol. Basel, Karger, 2018, vol 194, pp 99–108 (DOI: 10.1159/000485607)

Technical «Complications» of Continuous Renal Replacement Therapy

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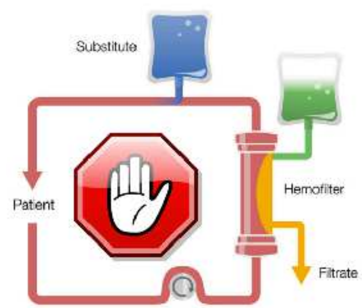
Table 1. Technical complications (see text for details)

Source of complications	Complications
Vascular access	Bleeding Pneumothorax Hemothorax Arterial puncture Venous and catheter thrombosis Blood flow reductions (diastolic flow) Aneurysm Air embolism Hematoma Kinking Distortion Misplacement Recirculation
Filter life and efficiency (clotting and protein layer deposition)	Costs Blood loss Increased nursing workload Decrease in filter effectiveness (decreases the sieving coefficient)
Hypothermia	Increase in patient's energy requirements Increase in oxygen demand Vasoconstriction Shivering Inhibition of leukocyte function Impairment of the coagulation system Mask fevers
Air embolism	Chest pain Dyspnea Hypoxia Tachycardia Arterial hypotension Cardiac arrest
Fluid balance	Effectively delivered net ultrafiltration and prescribed ultrafiltration can differ significantly
Others	Cytokine production Bradykinin release Anaphylactoid reactions

Fluid balance	Effectively delivered net ultrafiltration and prescribed ultrafiltration can differ significantly

- The most frequent cause for the interruption of CRRT was clotting of the extracorporeal circuit.
- The other common reason for interruption of CRRT was transport of patients to various diagnostic and therapeutic procedures.

"down time"



Venkataraman R et al. Journal of Critical Care, 2002:246-250

- The most frequent cause for the interruption of CRRT was clotting of the extracorporeal circuit.
- The other common reason for interruption of CRRT was transport of patients to various diagnostic and therapeutic procedures.

- ✓ ***Pump‘s stop***
- ✓ ***Fluid Balance alarms***
- ✓ ***Bag / Syringe changes***
- ✓ ***Patient‘s mobilization***
- ✓ ***Bag‘s change anytime***
- ✓ ***Stop for diagnostics***
- ✓ ***Stop for surgical / internetional procedures***

Venkataraman R et al. Journal of Critical Care, 2002:246-250

Dose Dialitica e Q^{NET}_{UF}

mg/die

mg/Kg/die

mcg/Kg/min

. . .

Previous studies of CRRT have shown that delivered dose is 68–89% of prescribed dose

Evanson, J. A. et al. Am. J. Kidney Dis. 32, 731–738 (1998).
Vesconi, S. et al. Crit. Care 13, R57 (2009).

In a study by **Venkataraman** et al. the lower delivered dose of CRRT was caused by interruptions in the CRRT, which led to a total effluent volume over 24 h that was lower than the prescribed dose.

Venkataraman, R et al. J. Crit. Care 17, 246–250 (2002)

In the **RENAL** trial, the actual effluent volume computed by the machine was used to determine an estimated dialysis dose. The difference between the p**rescribed dose and this estimated dose was 16% in the high-intensity dose group and 12%** in the low-intensity dose group

Bellomo R et al. N. Engl. J. Med. 361, 1627–1638 (2009)

In the **ATN** study, the average daily duration of therapy was approximately 21 h in both groups, allowing for 89% and 95% of the prescribed effluent volume to be delivered to the intensive and less-intensive dose groups, respectively

Palewsky PM et al. N. Engl. J. Med. 359, 7–20 (2008)

DOSE DIALITICA e Q_{UF}^{NET}

1

Compensazione automatica del volume di sostituzione

Il sistema è progettato in modo da compensare deviazioni dalla prescrizione (*downtime*) nel corso della terapia per poter raggiungere la dose impostata.

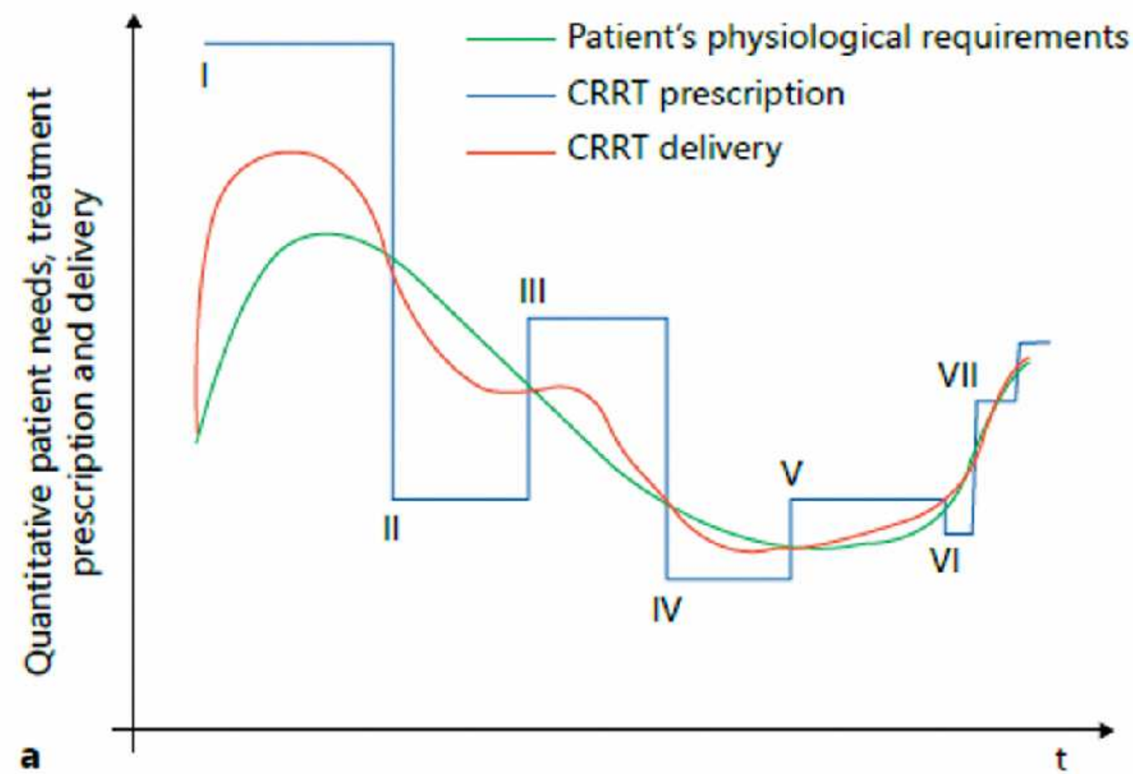
- Se il sistema rileva uno scostamento tra valore impostato e quello erogato, il flusso del fluido di sostituzione viene temporaneamente aumentato di una percentuale compresa tra +1 % e +5 % (in base al volume mancante).

Quando la deviazione è stata compensata, questa funzione si disattiva.

Role of Technology for the Management of AKI in Critically Ill Patients: From Adoptive Technology to Precision Continuous Renal Replacement Therapy

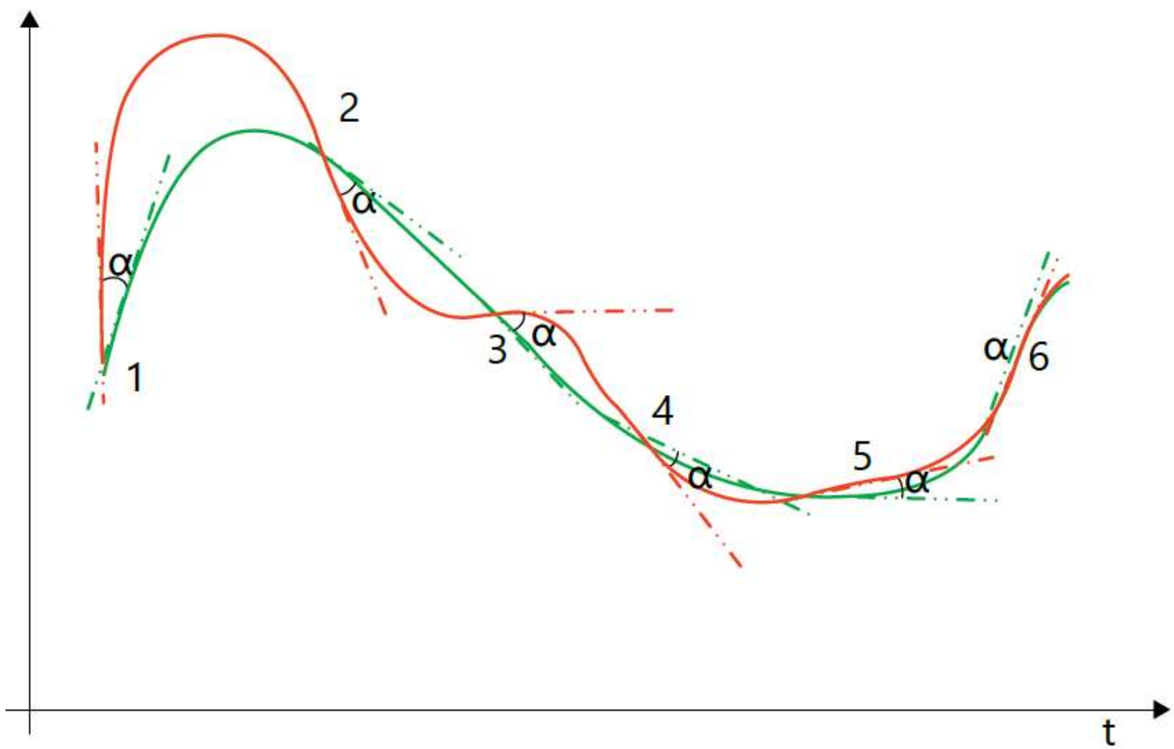
Cerdà J et al. Blood Purif (2016)

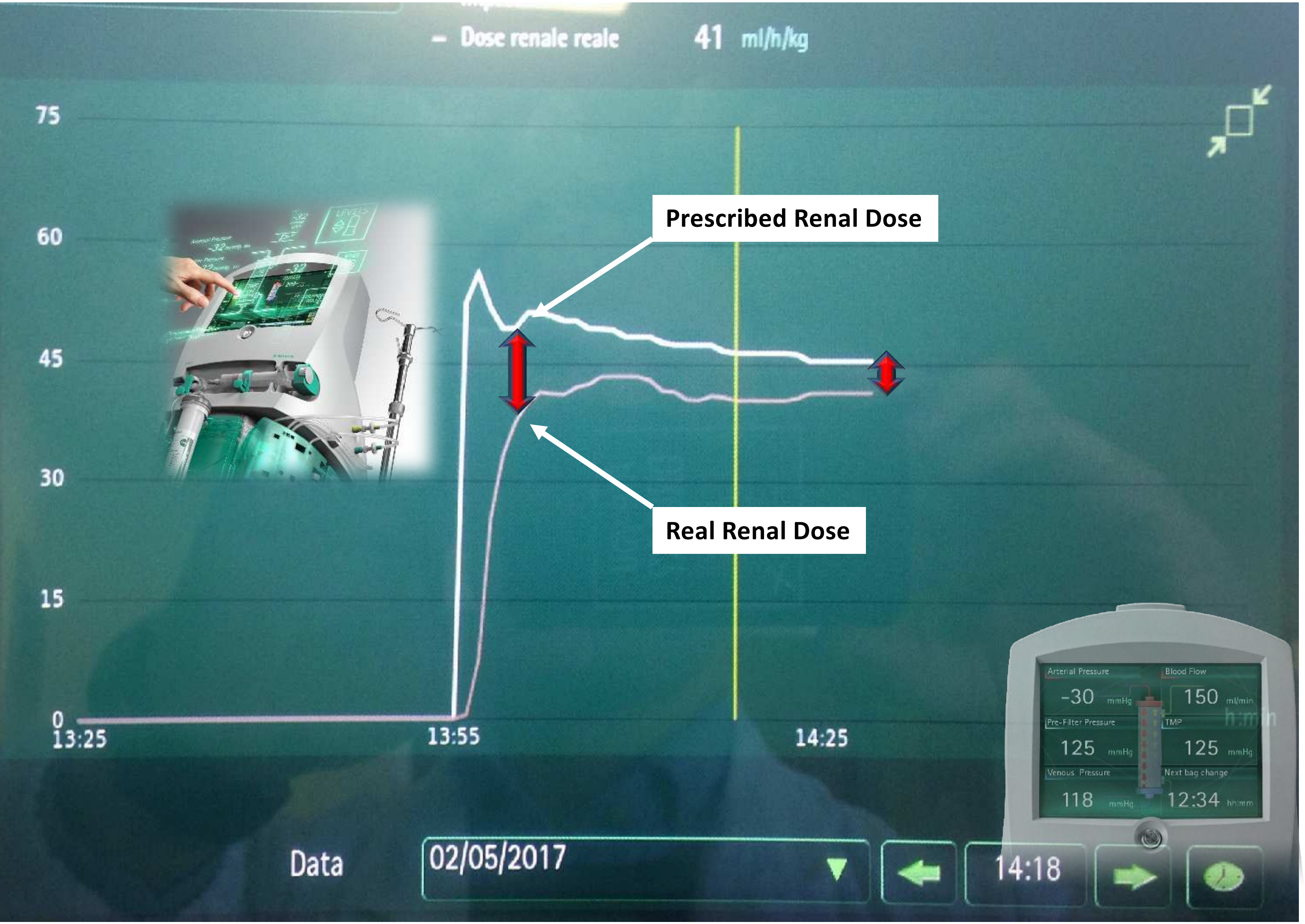
The role of prescription-delivery feedback loop during CRRT.

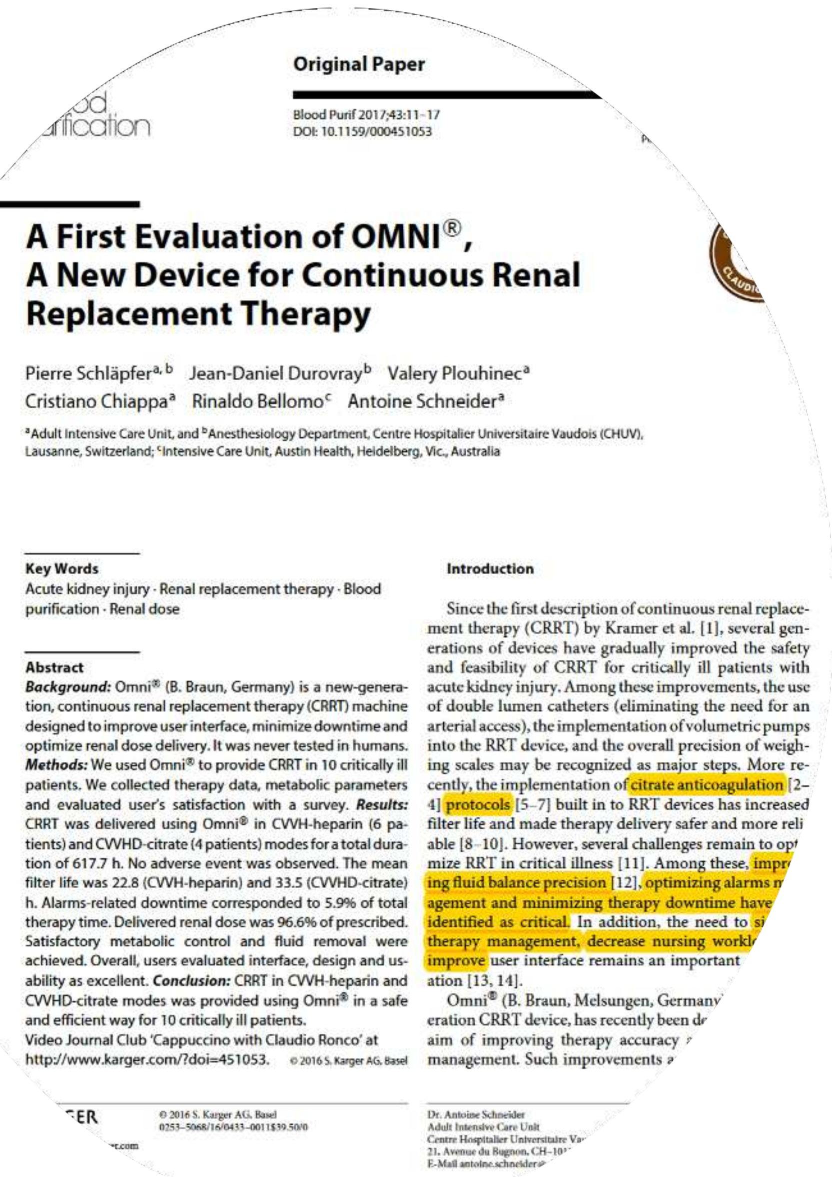


The role of prescription-delivery feedback loop during CRRT.

If a **prescription delivery feedback loop** is used (e.g., biofeedback), the differences between the treatment delivery and patient's physiologic requirement might be instantaneously measured.




Dose renale reale
41 ml/h/kg
75
60
45
30
15
0
13:25
13:55
14:25
Prescribed Renal Dose
Real Renal Dose
Arterial Pressure
-30 mmHg
Blood Flow
150 ml/min
Pre-Filter Pressure
125 mmHg
TMP
125 mmHg
Venous Pressure
118 mmHg
Next bag change
12:34 hh:mm
Data
02/05/2017
14:18


Original Paper

ood
urification

Blood Purif 2017;43:11–17
DOI: 10.1159/000451053

A First Evaluation of OMNI®, A New Device for Continuous Renal Replacement Therapy

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Cristiano Chiappa[a] Rinaldo Bellomo[c] Antoine Schneider[a]

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Key Words
Acute kidney injury · Renal replacement therapy · Blood purification · Renal dose

Abstract
Background: Omni® (B. Braun, Germany) is a new-generation, continuous renal replacement therapy (CRRT) machine designed to improve user interface, minimize downtime and optimize renal dose delivery. It was never tested in humans. ***Methods:*** We used Omni® to provide CRRT in 10 critically ill patients. We collected therapy data, metabolic parameters and evaluated user's satisfaction with a survey. ***Results:*** CRRT was delivered using Omni® in CVVH-heparin (6 patients) and CVVHD-citrate (4 patients) modes for a total duration of 617.7 h. No adverse event was observed. The mean filter life was 22.8 (CVVH-heparin) and 33.5 (CVVHD-citrate) h. Alarms-related downtime corresponded to 5.9% of total therapy time. Delivered renal dose was 96.6% of prescribed. Satisfactory metabolic control and fluid removal were achieved. Overall, users evaluated interface, design and usability as excellent. ***Conclusion:*** CRRT in CVVH-heparin and CVVHD-citrate modes was provided using Omni® in a safe and efficient way for 10 critically ill patients.
Video Journal Club 'Cappuccino with Claudio Ronco' at http://www.karger.com/?doi=451053.

Introduction

Since the first description of continuous renal replacement therapy (CRRT) by Kramer et al. [1], several generations of devices have gradually improved the safety and feasibility of CRRT for critically ill patients with acute kidney injury. Among these improvements, the use of double lumen catheters (eliminating the need for an arterial access), the implementation of volumetric pumps into the RRT device, and the overall precision of weighing scales may be recognized as major steps. More recently, the implementation of citrate anticoagulation [2–4] protocols [5–7] built in to RRT devices has increased filter life and made therapy delivery safer and more reli able [8–10]. However, several challenges remain to opt mize RRT in critical illness [11]. Among these, impr ing fluid balance precision [12], optimizing alarms m agement and minimizing therapy downtime have identified as critical. In addition, the need to si therapy management, decrease nursing workl improve user interface remains an important ation [13, 14].

Omni® (B. Braun, Melsungen, Germany eration CRRT device, has recently been de aim of improving therapy accuracy management. Such improvements a

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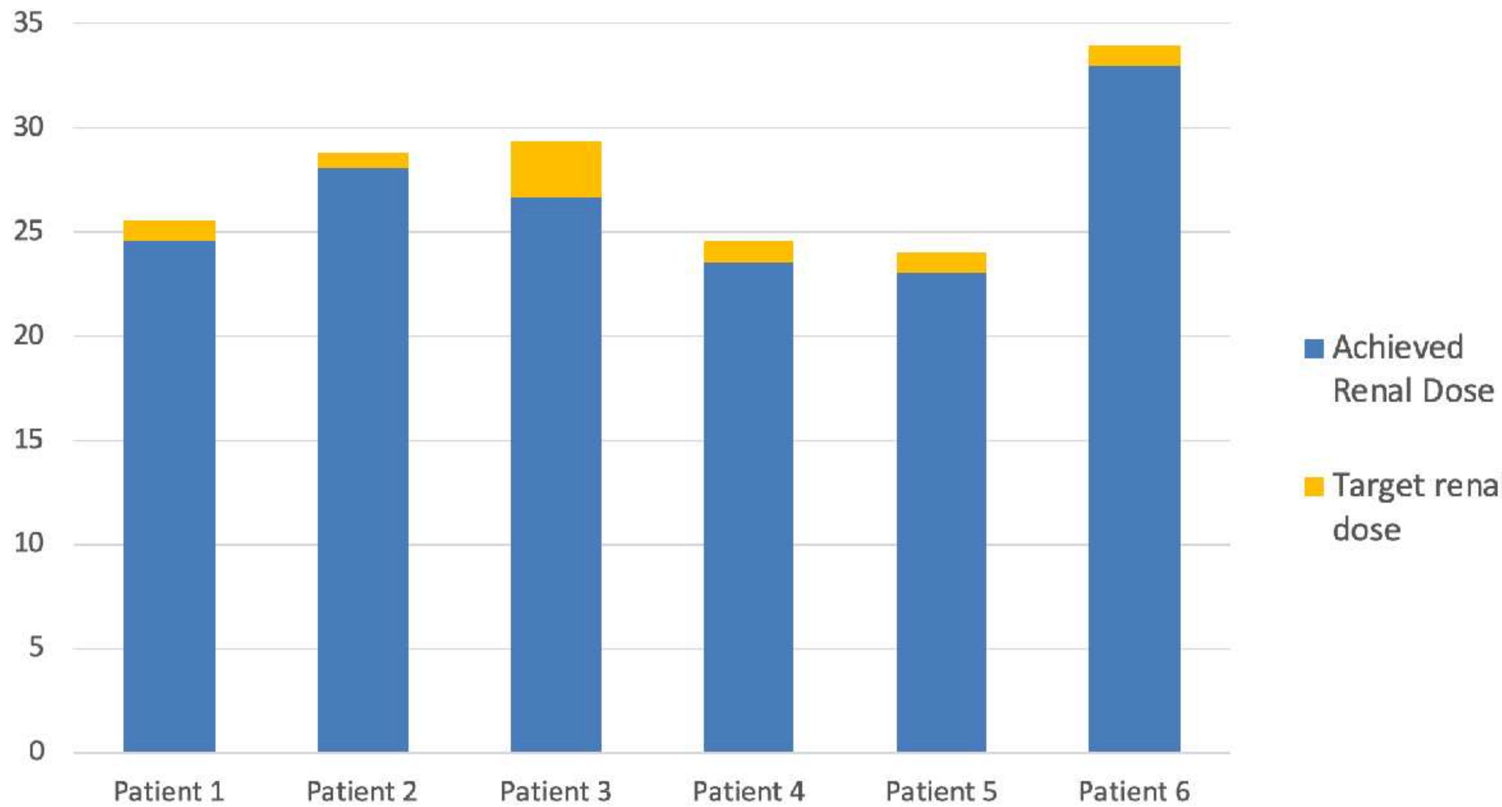
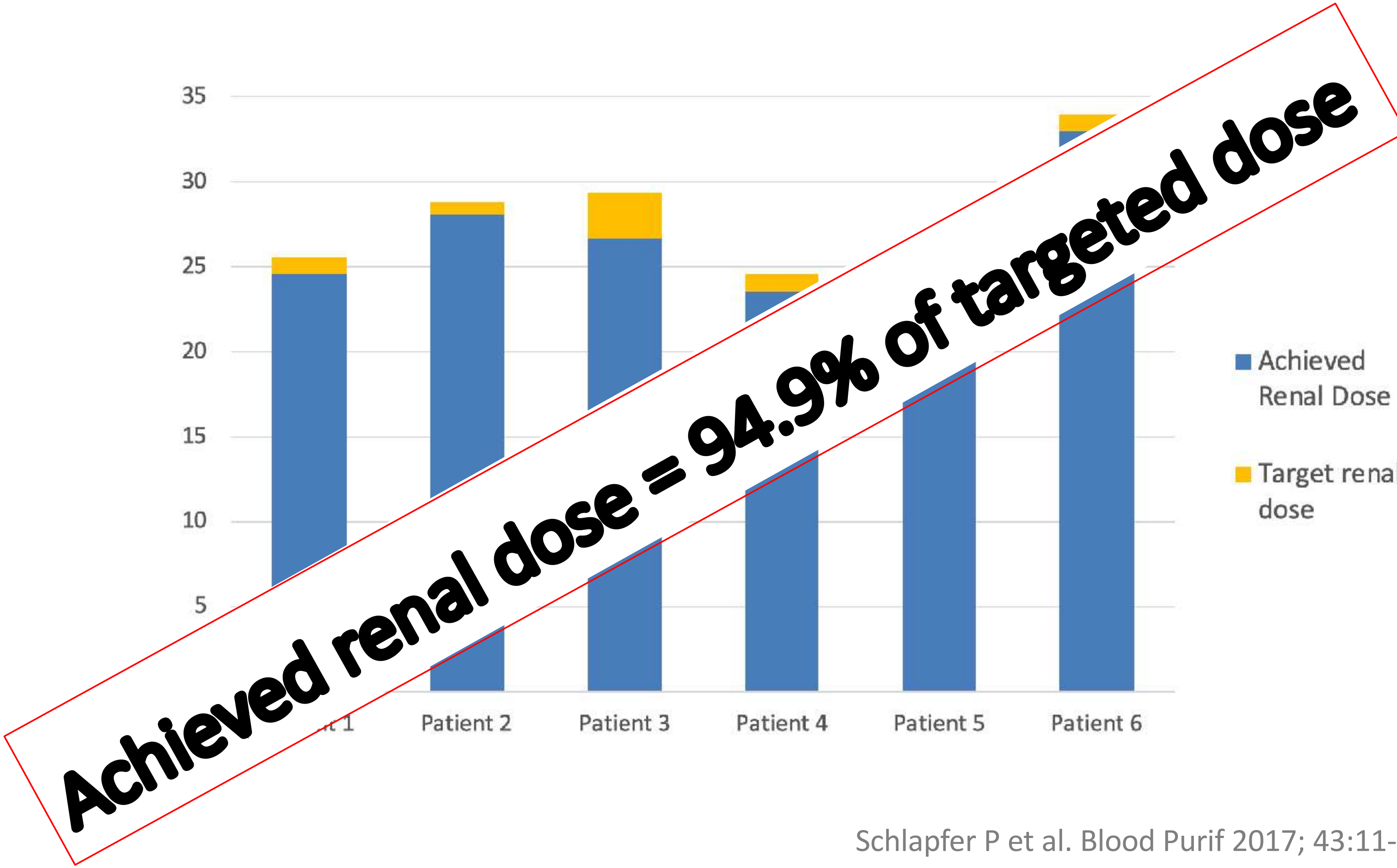
Schlapfer P et al. Blood Purif 2017; 43:11-17

Renal Dose



Schlapfer P et al. Blood Purif 2017; 43:11-17

Renal Dose

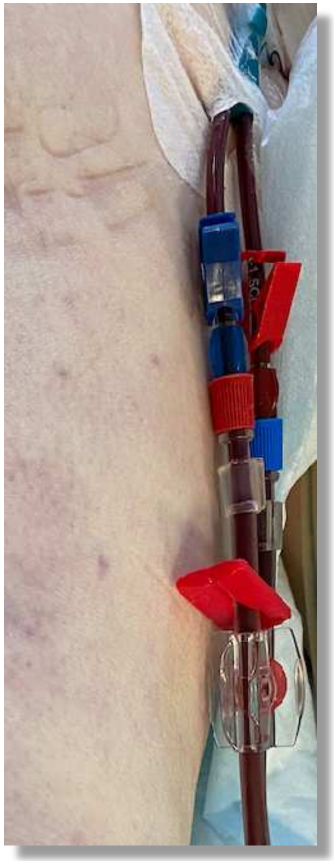


Schlapfer P et al. Blood Purif 2017; 43:11-17

2

Esclusione temporanea degli allarmi di pressione

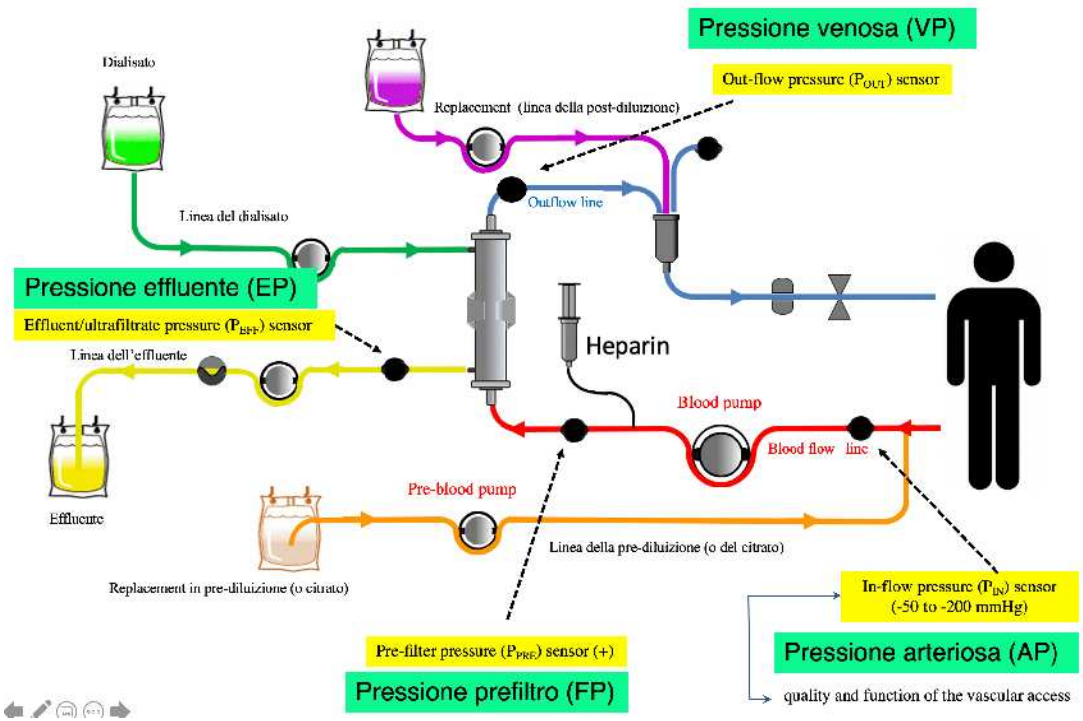
L'apparecchiatura cerca di gestire automaticamente le situazioni in cui gli allarmi relativi alla pressione arteriosa e venosa possano essere causati dal **movimento del paziente o da temporanee strozzature delle linee di accesso** che provocano sbalzi pressori.



Continuous renal replacement therapy: understanding circuit hemodynamics to improve therapy adequacy

Thibault Michel[a], Hatem Ksouri[b], and Antoine G. Schneider[a]

Curr Opin Crit Care 2018



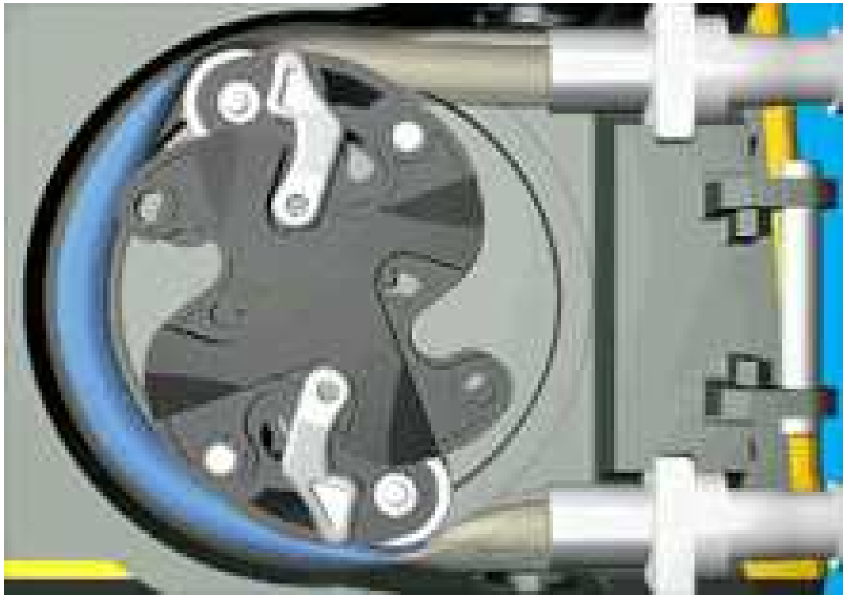
Inflow pressure

Inflow pressure is an indirect indicator of the quality and function of the vascular access. Acute drops in inflow pressure may be encountered during patient's **mobilization**, **coughing** or other instances, particularly when the vascular access is imperfectly placed.

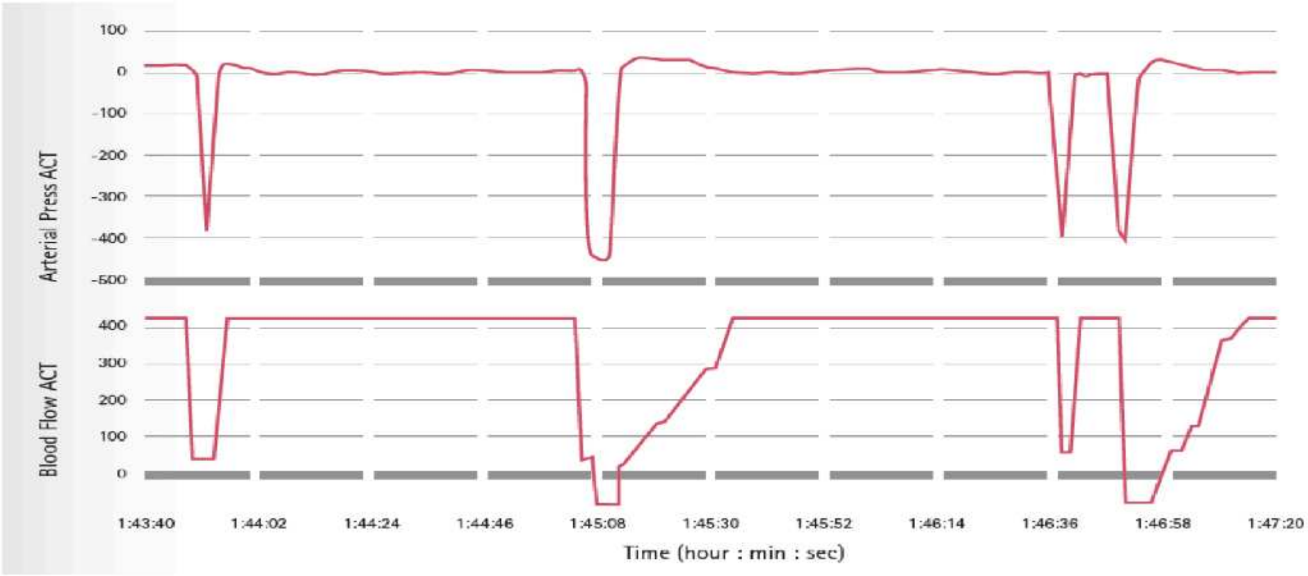
Such acute drops, even if reversible, should be prevented to **optimize filter life**.

Pressione arteriosa (AP) e/o
Pressione venosa (VP)

- Q_B viene abbassato a **1 mL/min per 3 secondi** per evitare il blocco della pompa sangue e l'attivazione di allarmi non necessari.



Automatic Blood Flow Reduction



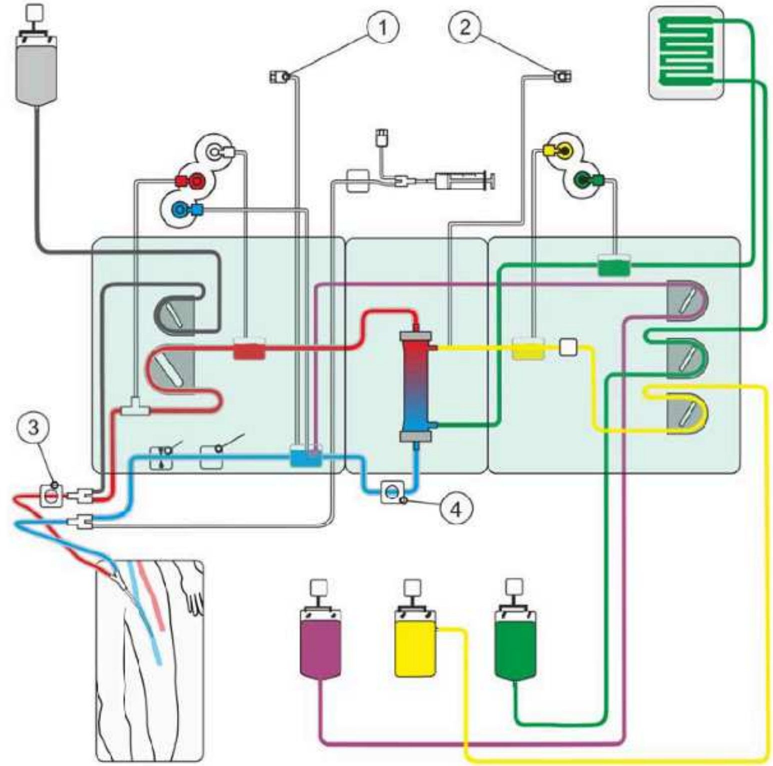
Lines kinked

During patient mobilization

- Se la pressione arteriosa e venosa sono rientrate nell'intervallo di normalità, il flusso sangue viene incrementato progressivamente fino al valore impostato.

- Se la pressione arteriosa rimane al di sotto dei limiti o la pressione venosa rimane al di sopra dei limiti, vengono generati gli **allarmi Pressione arteriosa bassa e Pressione venosa elevata**.

Conclusions



Editorial

Blood Purification

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Automatic Dialysis and Continuous Renal Replacement Therapy: Keeping the Primacy of Human Consciousness and Fighting the Dark Side of Technology

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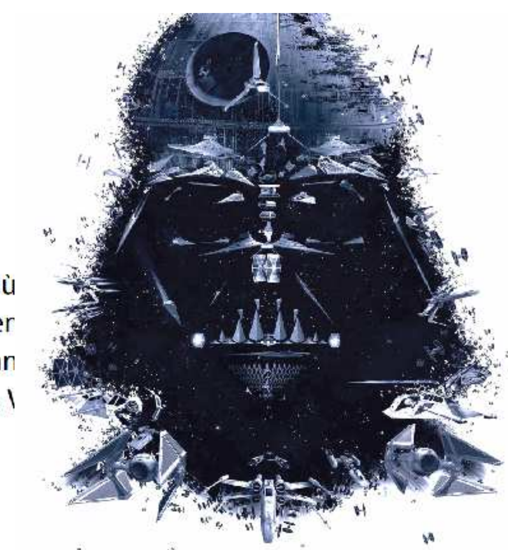

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Ultrafiltration in critically ill patients treated with kidney replacement therapy

REVIEWS

Raghavan Murugan[1,2]✉, Rinaldo Bellomo[3], Paul M. Palevsky[1,4] and John A. Kellum[1,2]

Murugan R et al. Nature Reviews I Nephrology 2020

Murugan R et al. Nature Reviews | Nephrology 2020

Murugan R et al. Nature Reviews I Nephrology 2020

Murugan R et al. Nature Reviews I Nephrology 2020