CRRT e Anticoagulazione *Una scelta ponderata: come mantenere la pervietà e il perfetto funzionamento del circuito. Diversi regimi di anticoagulazione*

Stefano Romagnoli, MD, PhD

UO di Nefrologia, Dialisi e Trapianto Renale
Ospedale San Bortolo - ULSS 8 Berica
International Renal Research Institute Vicenza (IRRIV)

CRRT
Questione di EQUIPE!

Videoconferenza LIVE per
INFERMIERI
NEFROLOGI
INTENSIVISTI ...
e tutti i Medici in Formazione Specialistica!
XI Edizione

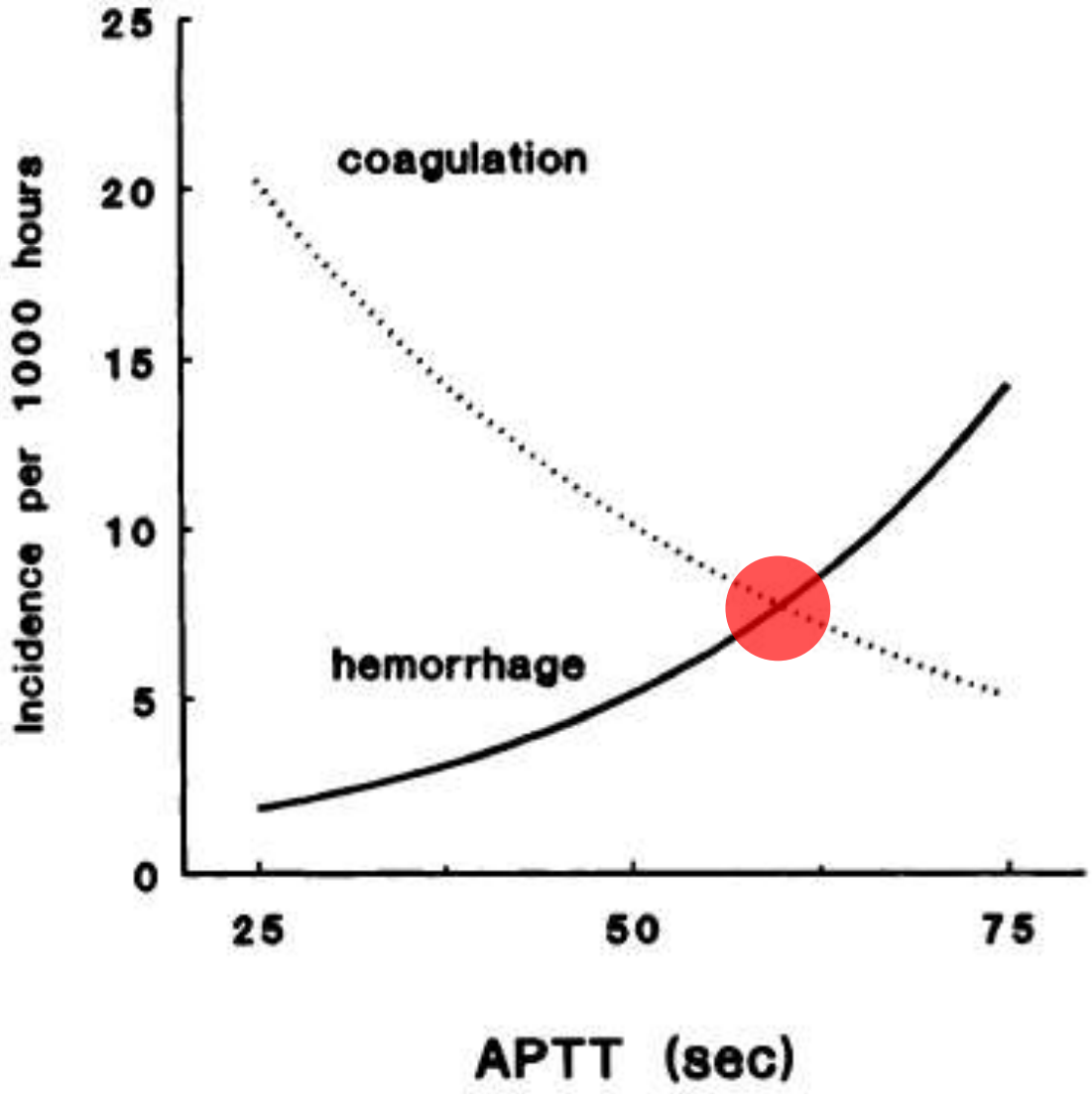
15-16 giugno 2020

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

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

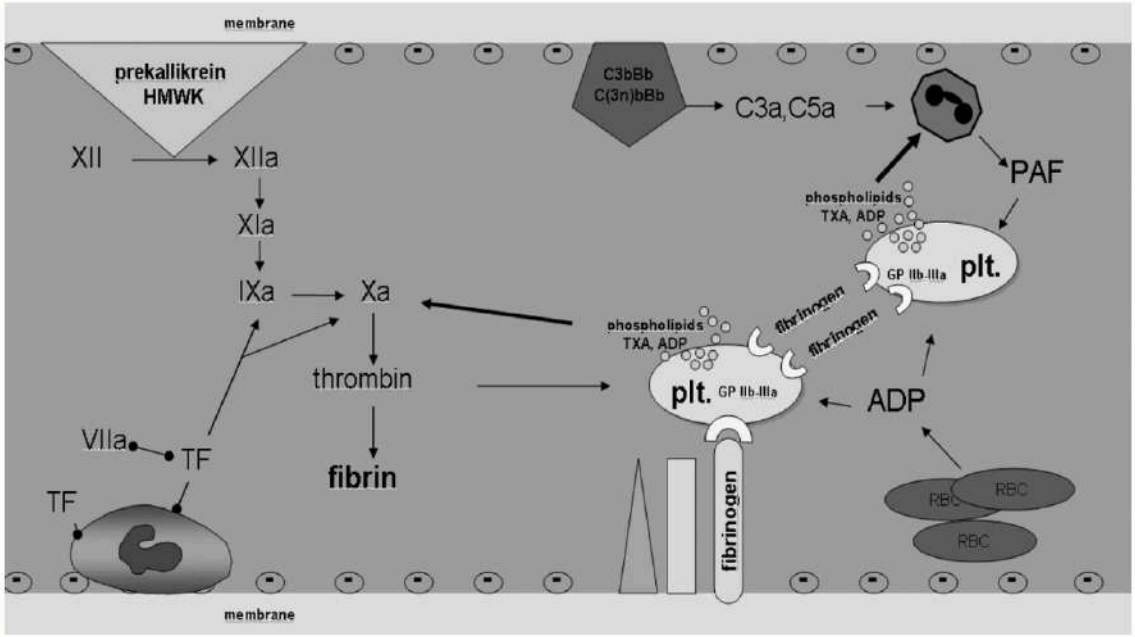
Heparin Use in Continuous Renal Replacement Procedures: The Struggle Between Filter Coagulation and Patient Hemorrhage[1]

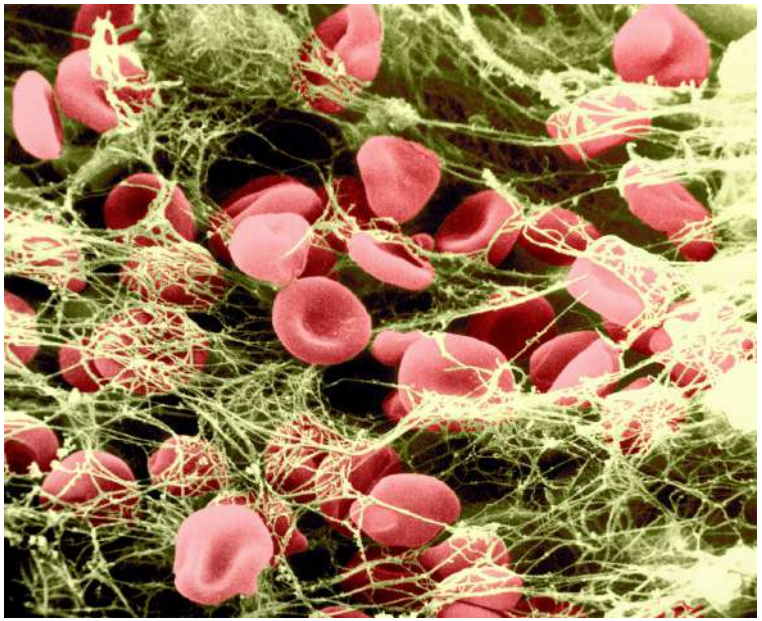


van de Wetering J et al. J Am Soc Nephrol (1996)

Review

Clinical review: Patency of the circuit in continuous renal replacement therapy





‘artificial kidney failure’ (AKF)

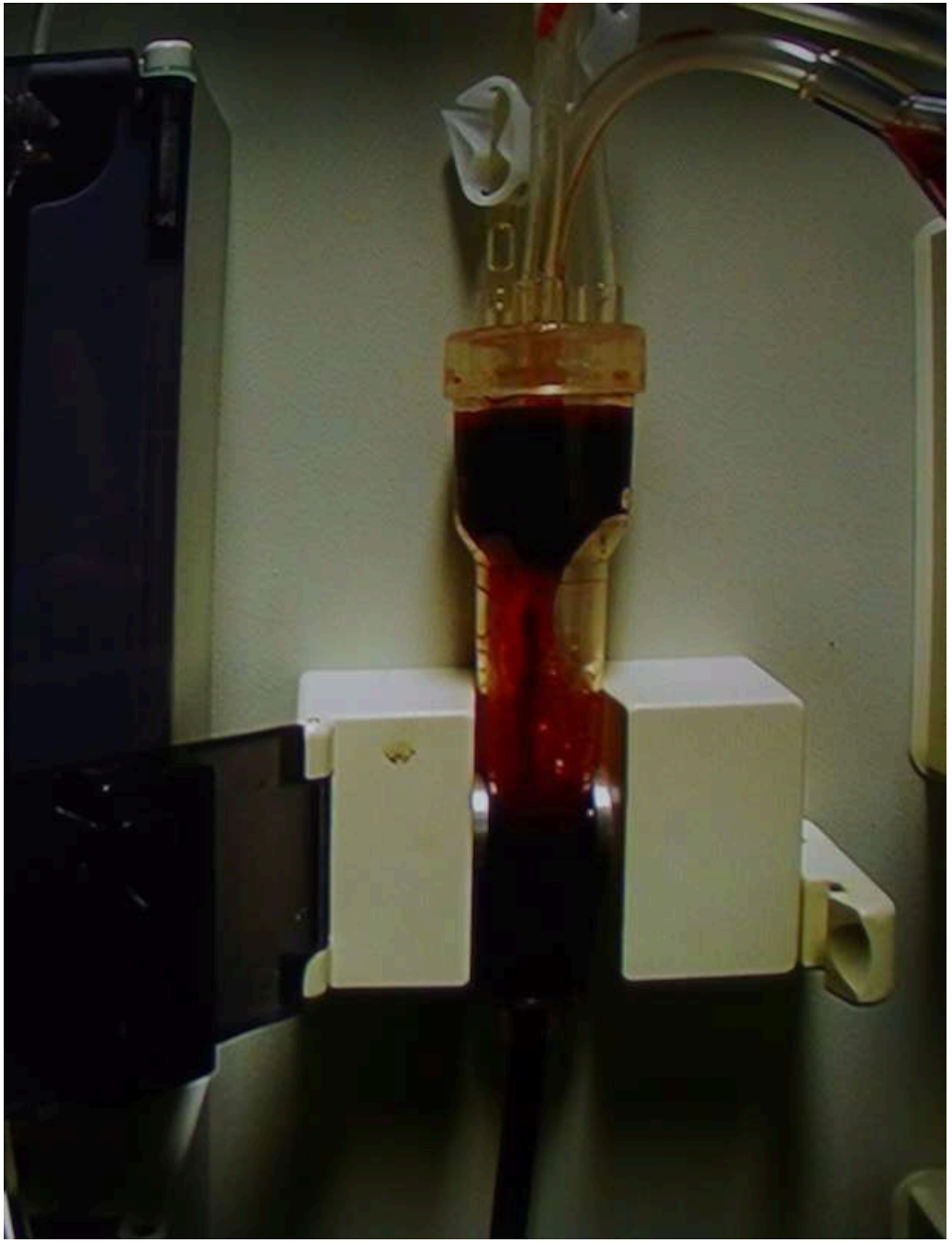
- In most situations, it is related to progressive **clotting** and/or clogging of extracorporeal circuits components.

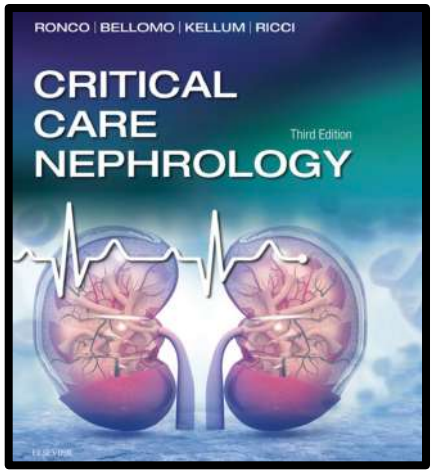
Blood circulation through an extra-corporeal circuit is associated with intense activation of the coagulation cascade.

- Clotting can occur as a slow and progressive process or rapidly.
- Clots are most frequently observed at the **venous chamber level** (blood gas interface and relative stasis) and **within the hemofilter**.

Zhang L et al. Blood Purif (2016)

- Delivery failure
- Blood loss
- Increased workload
- Increased costs





- Develop your own **expertise** with your protocols.
- If the circuit clots, it can be replaced. If the patient bleeds, a more serious and adverse outcome may occur.

- To loose a filter to protect a patient is entirely acceptable.
- To loose a patient to protect a filter is NOT.

Kidney Disease: Improving Global Outcomes (2012)

In patients with AKI requiring RRT, the contact of blood with the foreign surface of the extracorporeal circuit results in activation of both the intrinsic and the extrinsic pathway of plasmatic coagulation and activation of platelets.[571] Prevention of dialyzer/hemofilter clotting often requires some form of anticoagulation, which may represent a particular challenge in patients with AKI. The need for continuous anticoagulation represents a potential drawback of CRRT.

OFTEN; SOME; CHALLANGE

http://kdigo.org/home/guidelines/acute-kidney-injury/

Kidney Disease: Improving Global Outcomes (2012)

- In a patient with **AKI requiring RRT**, base the decision to use anticoagulation for RRT on assessment of the patient's **potential risks and benefits** from anticoagulation (Not Graded)

- We **recommend using anticoagulation** during RRT in AKI if a patient does not have an increased bleeding risk or impaired coagulation and is not already receiving systemic anticoagulation. (1B)

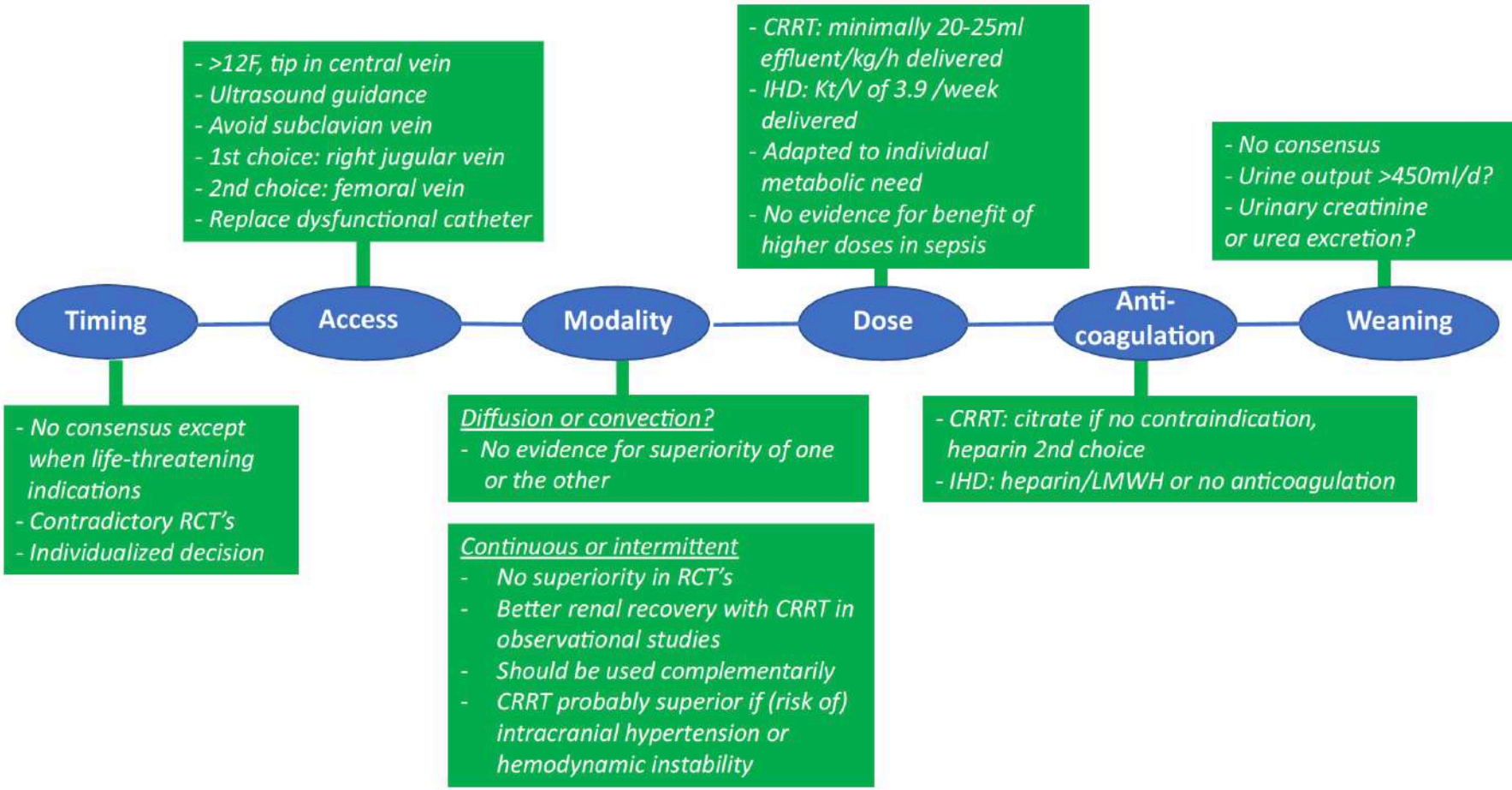
Kidney Disease: Improving Global Outcomes (2012)

- For patients without an increased bleeding risk or impaired coagulation and not already receiving effective systemic anticoagulation, we suggest the following:
    - For anticoagulation in CRRT, we suggest using **regional citrate anticoagulation** rather than heparin in patients who do not have contraindications for citrate.
    - For anticoagulation during CRRT in patients who have **contraindications for citrate**, we suggest using either unfractionated or low-molecular-weight **heparin**, rather than other anticoagulants.

http://kdigo.org/home/guidelines/acute-kidney-injury/.

RESEARCH AGENDA

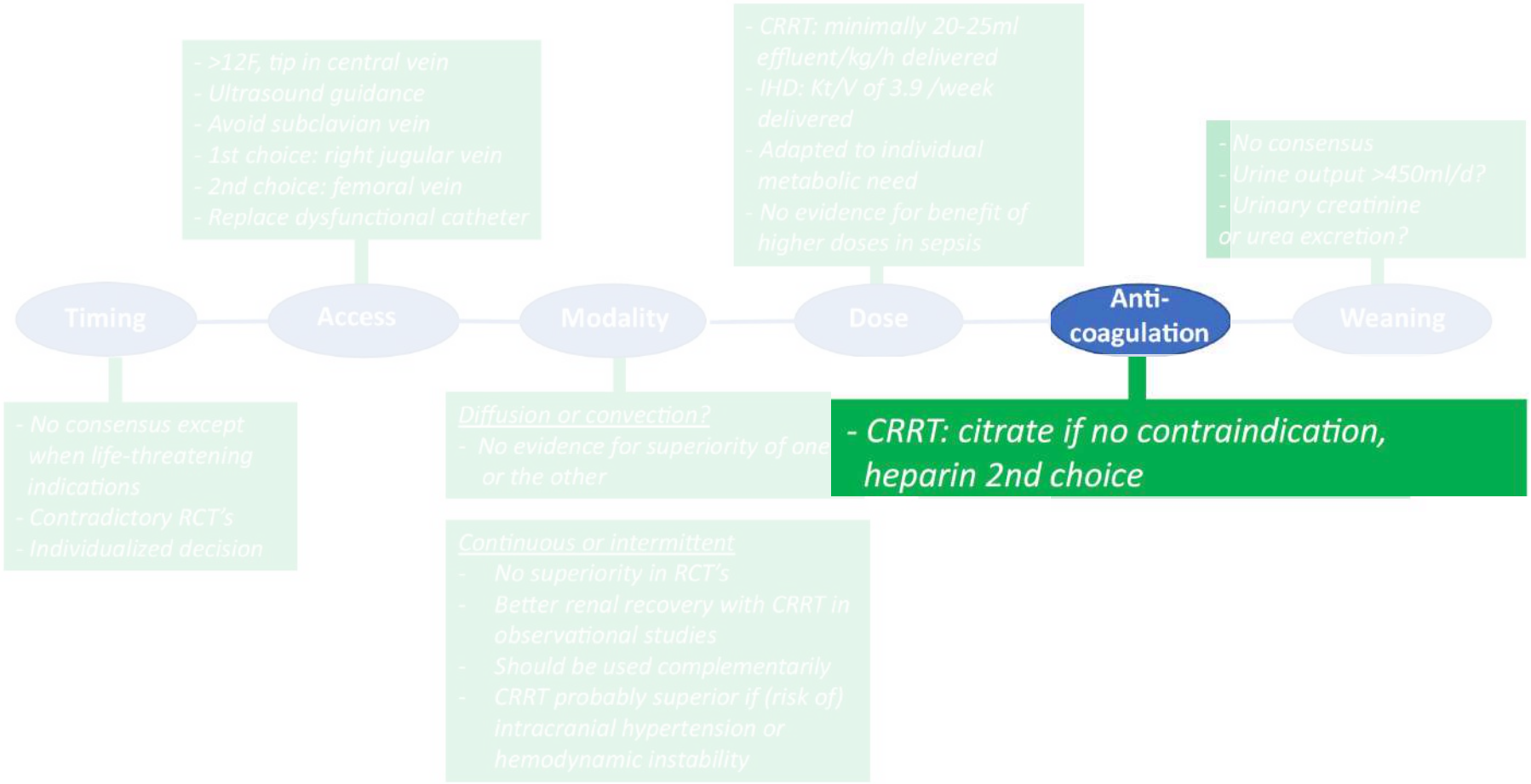
The intensive care medicine agenda on acute kidney injury



Pickkers P et al. Intensive Care Med (2017)

RESEARCH AGENDA

The intensive care medicine agenda on acute kidney injury



Pickkers P et al. Intensive Care Med (2017)

Anticoagulation OPTIONS for CRRT

1. Regional Anticoagulation
2. Systemic Anticoagulation
3. ~~Anticoagulation Free~~

Continuous Renal Replacement Therapy
Who, When, Why, and How

Anticoagulation for CRRT

- Clotting of the extracorporeal circuit is the most common complication during CRRT.
- Practice patterns regarding the use of anticoagulation vary widely, with estimates of **30% to 60% of patients undergoing CRRT without anticoagulation**.

VA/NIH Acute Renal Failure Trial Network, Palevsky PM et al. N Engl J Med (2008)
Uchino S et al. Intensive Care Med (2007)

- Although the use of anticoagulation is often avoided in patients who are coagulopathic, thrombocytopenic, or are having active hemorrhage, anticoagulation-free treatment may also be successful in the absence of coagulopathy and thrombocytopenia

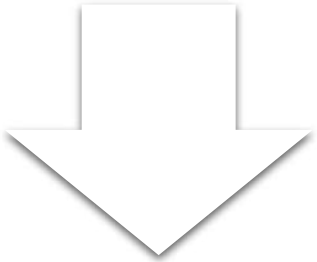
Tandukar S; Palevsky PM. Chest (2019)

Regional Anticoagulation

Regional CITRATE anticoagulation (RCA)

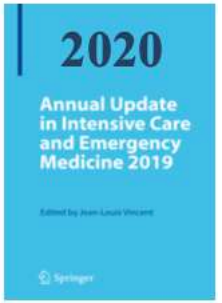
Regional Heparin-Protamine anticoagulation

Regional Anticoagulation



Regional CITRATE anticoagulation (RCA)

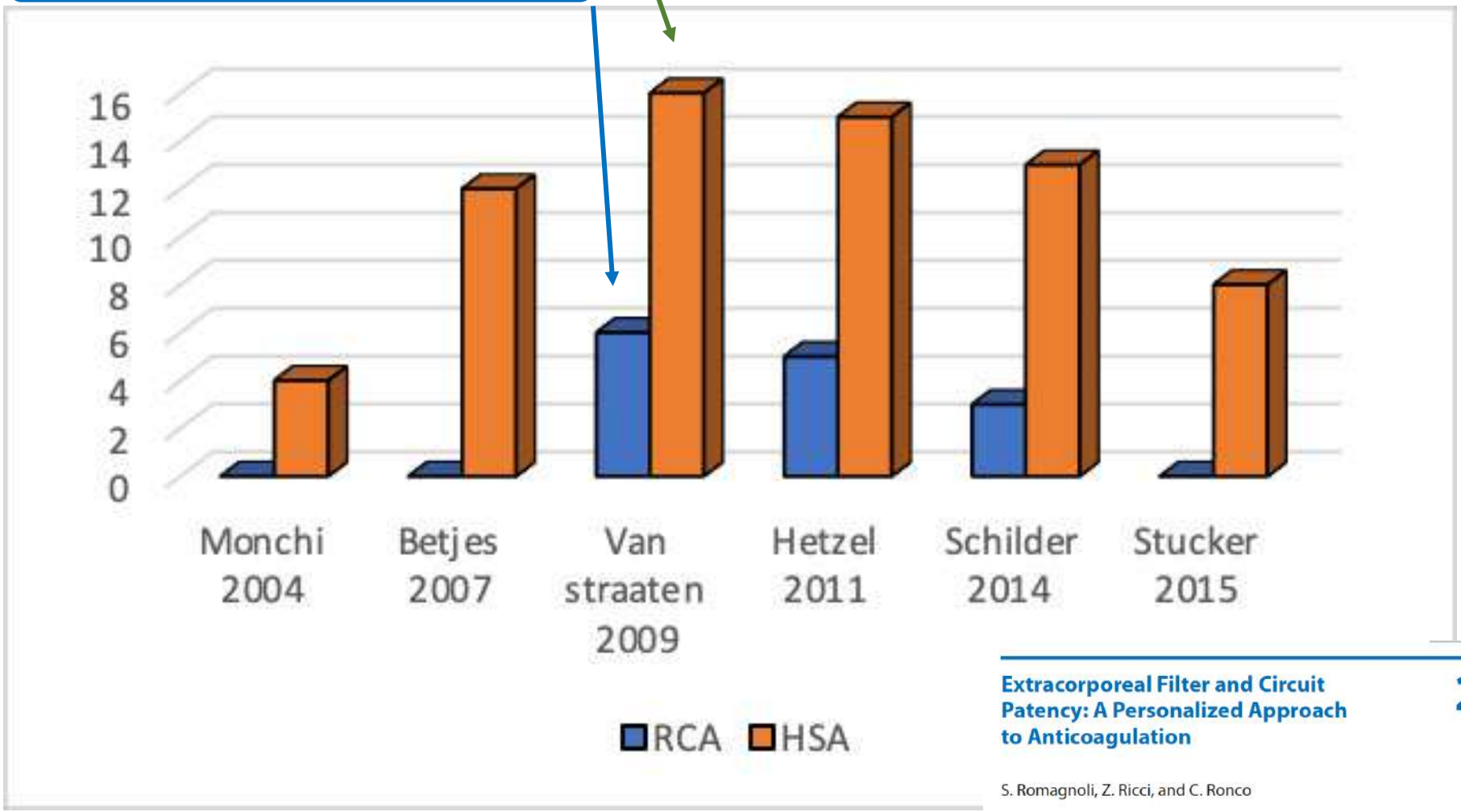
Romagnolis, Ricci Z, Ronco C.
Annual Update in Intensive Care and Emergency Medicine (2020)



Regional Anticoagulation

Systemic Anticoagulation

Bleeding complications



Extracorporeal Filter and Circuit Patency: A Personalized Approach to Anticoagulation **28**

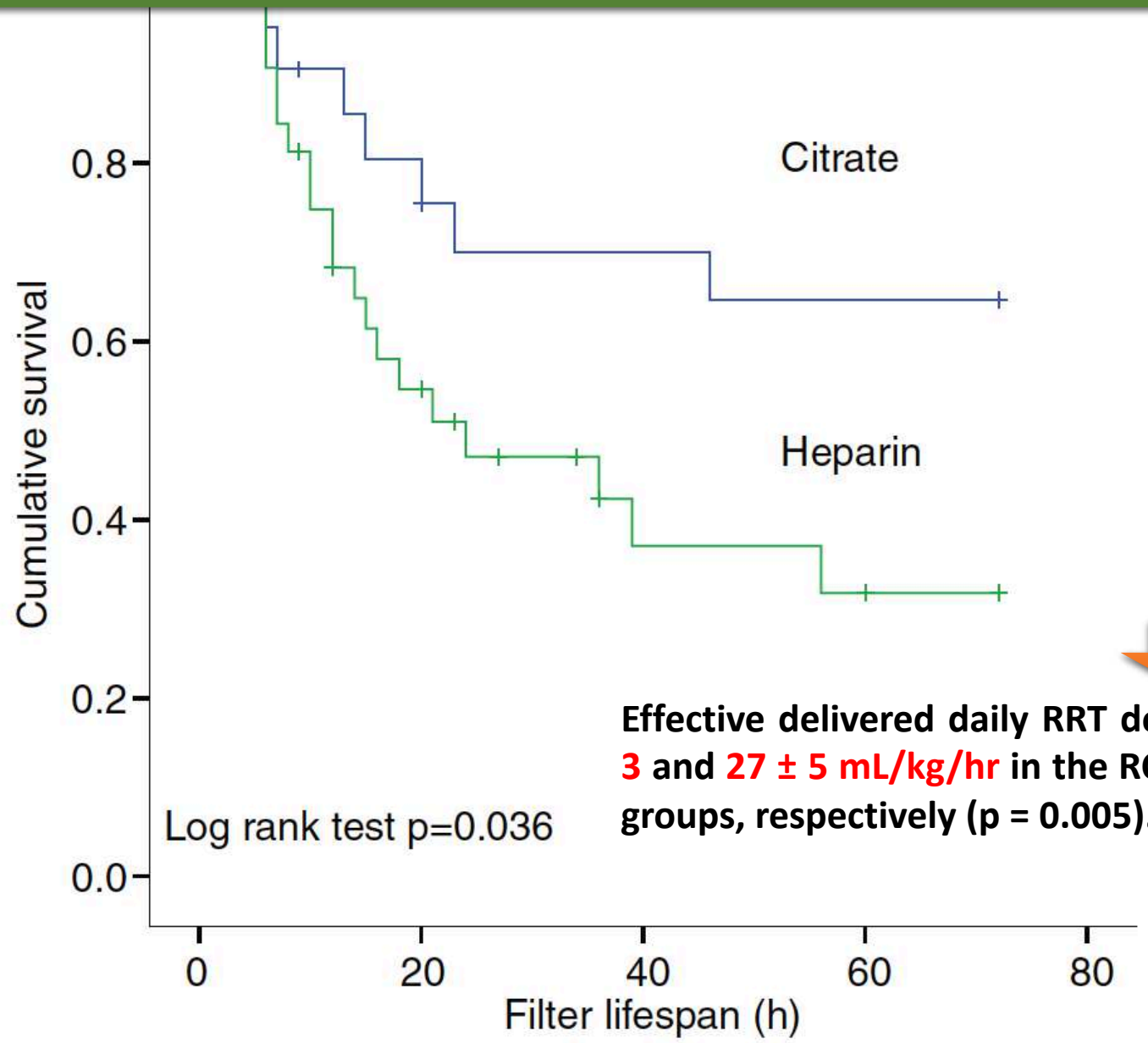
S. Romagnoli, Z. Ricci, and C. Ronco

Regional Citrate Anticoagulation (RCA)

- ↗ Filter life without systemic anticoagulation
- 👍🏻 Patients with moderate to high risk of bleeding
- ↘ Bleeding rates
- ↘ Transfusion rates
- ↘ Incidence of HIT
- ↘ Costs
- Similar overall mortality vs. systemic anticoagulation (heparin-based)

Pickkers P et al. Intensive Care Med (2017)
Ahmed AR et al. Critical Care Research and Practice (2019)
Bai M, et al. Intensive Care (2015)

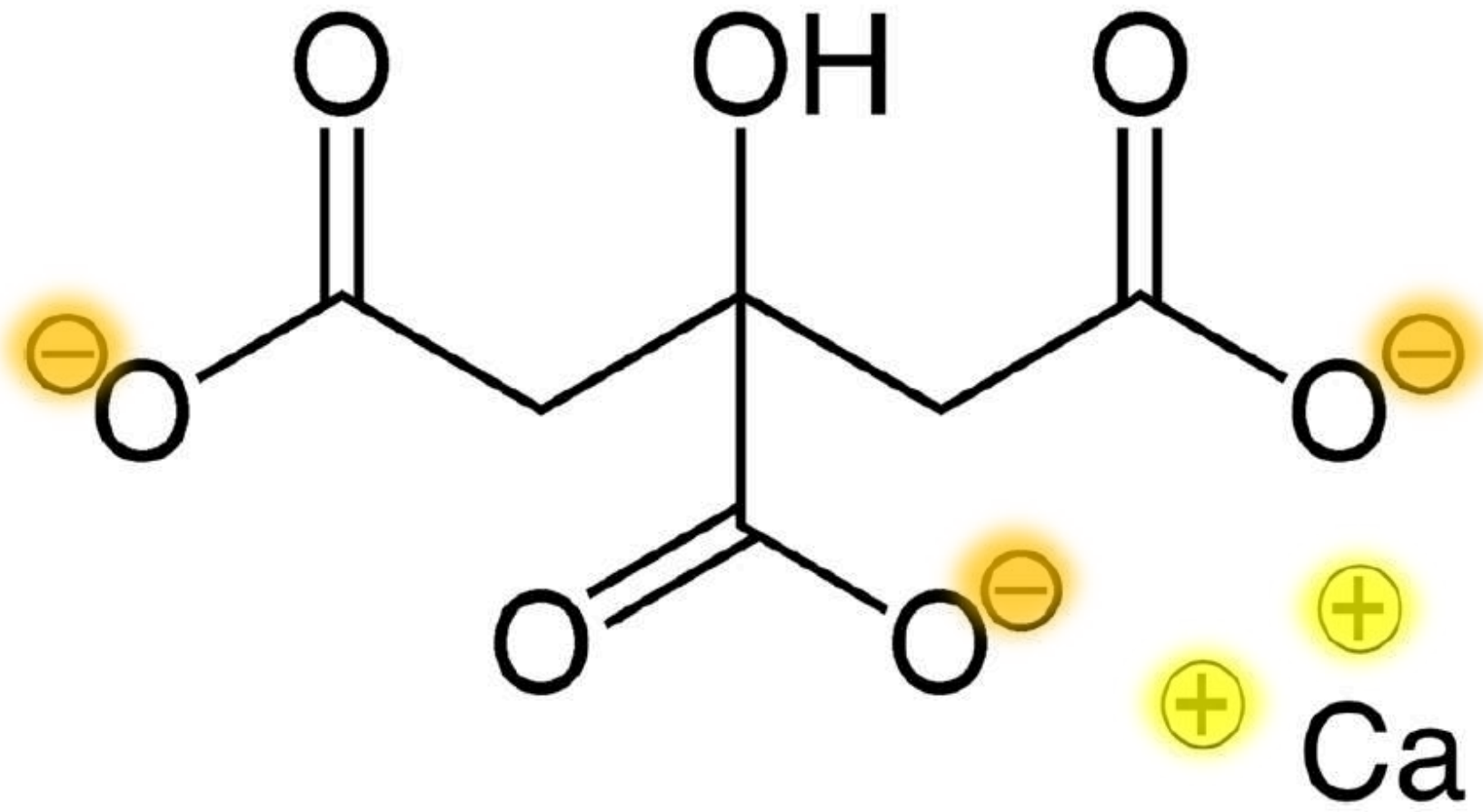
RCA: filter life → delivered RRT dose



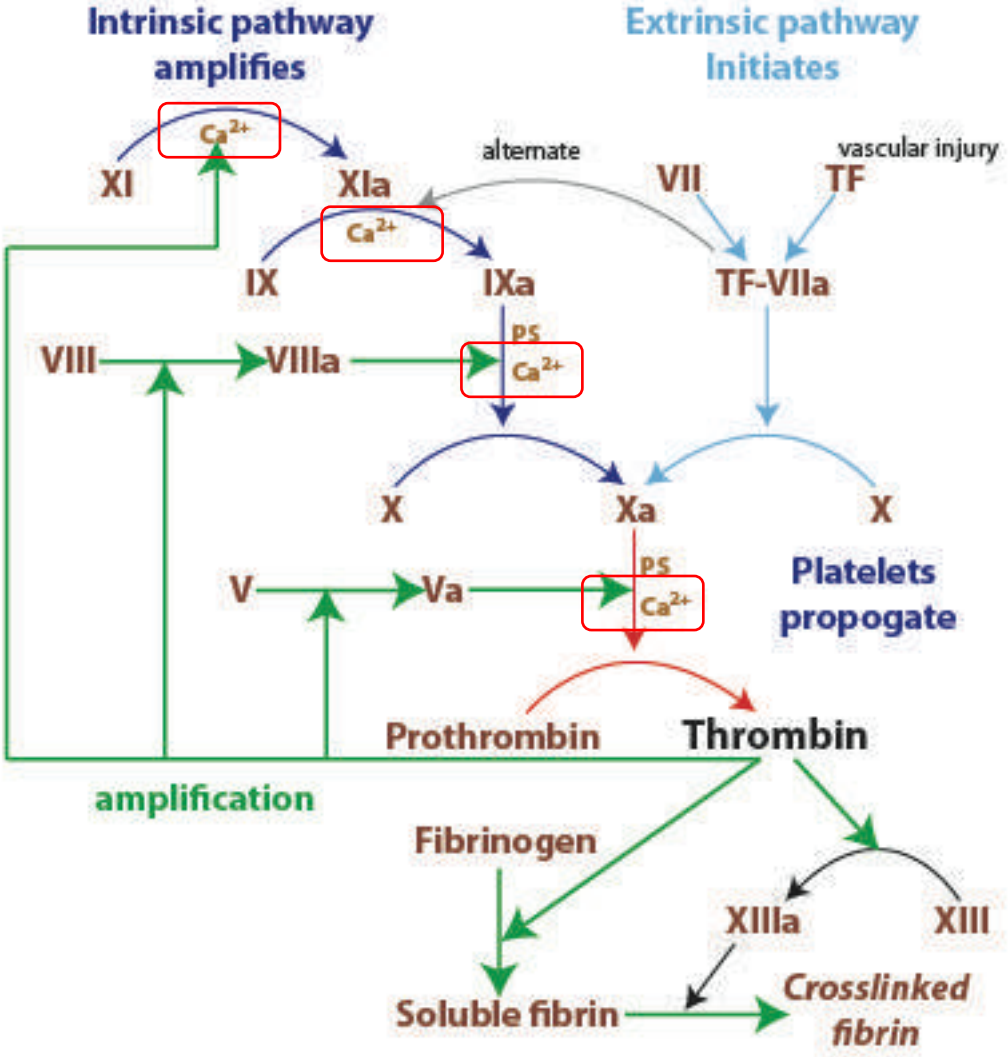
Effective delivered daily RRT doses were 29 ± 3 and 27 ± 5 mL/kg/hr in the RCA and heparin groups, respectively (p = 0.005).

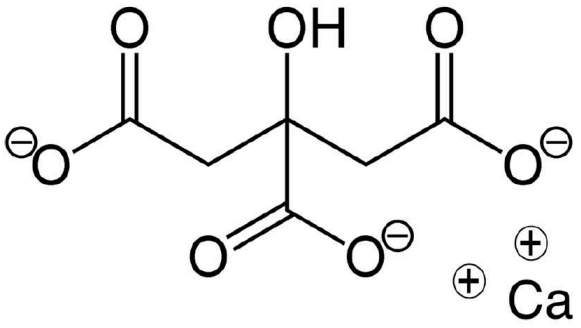
Stucker et al. Critical Care (2015)

CITRATE



The anticoagulant effect of sodium **citrate** relies on forming a complex with **ionized calcium**, thus removing an essential component of the coagulation cascade.

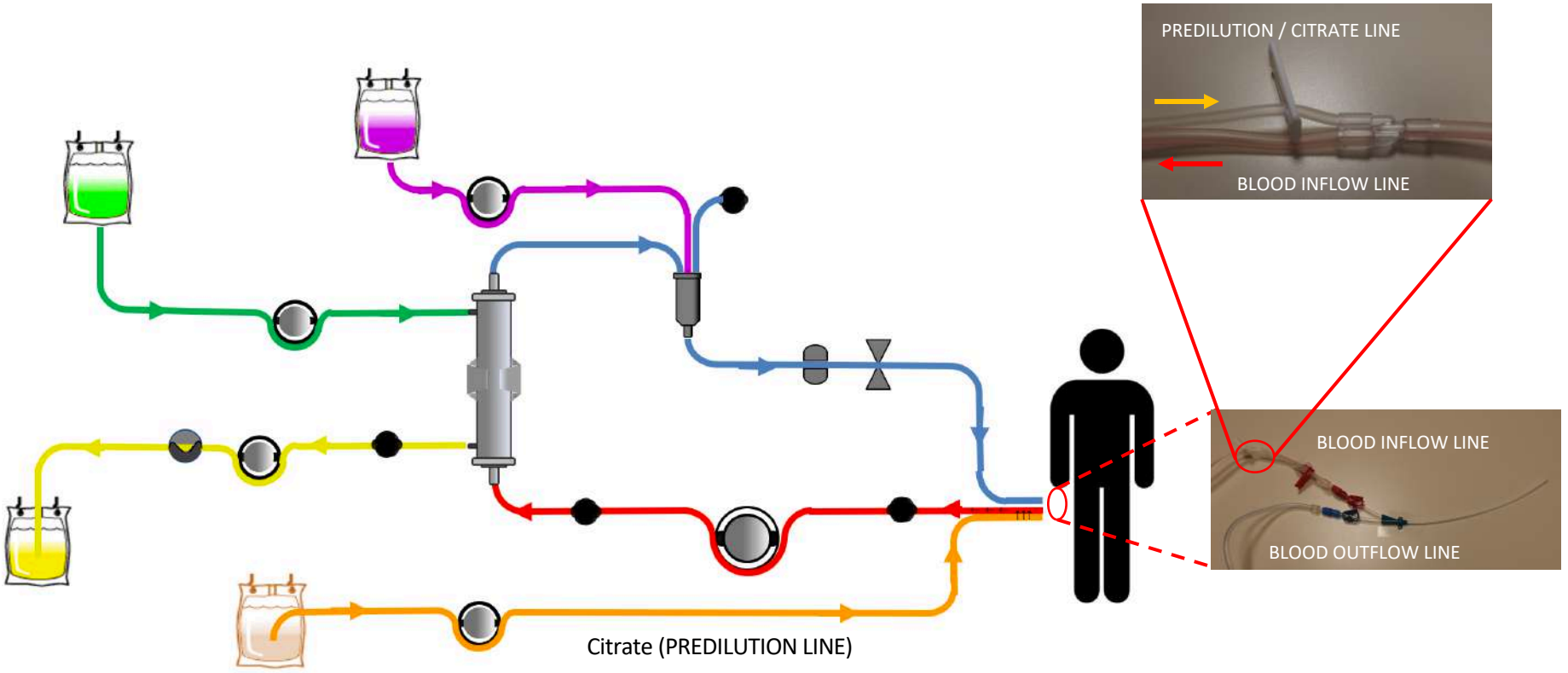




Citrate forms a complex with the Ca^{++} ions, making them unavailable as co-factor within the clotting cascade

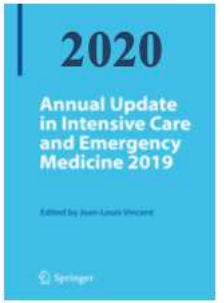

Xiris

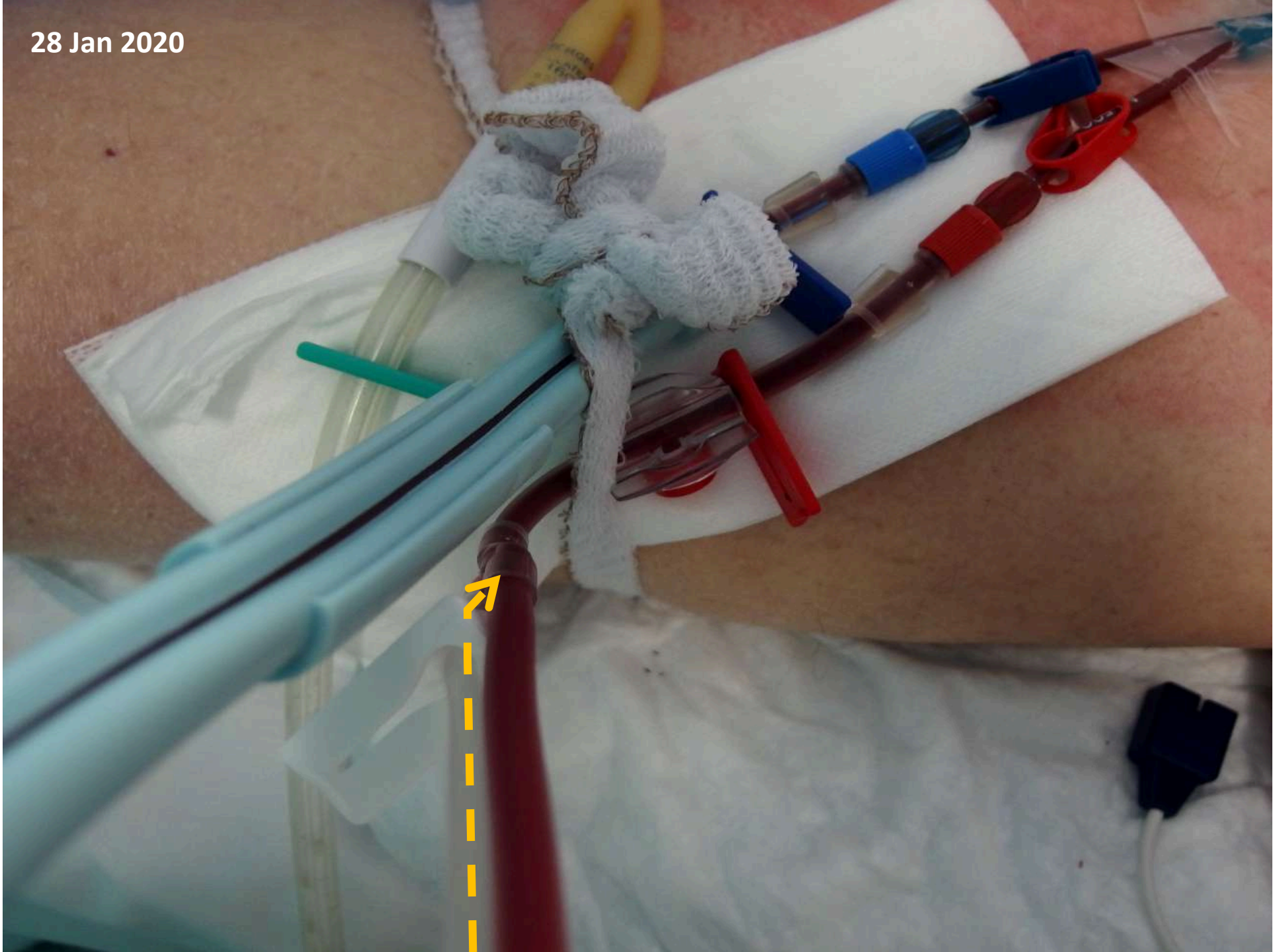

prismaflex
Xiris



Continuous Veno-Venous Hemo DiaFiltration

Romagnolis, Ricci Z, Ronco C.
Annual Update in Intensive Care and Emergency Medicine (2020)




28 Jan 2020

Blood is removed via the inflow line and citrate is added

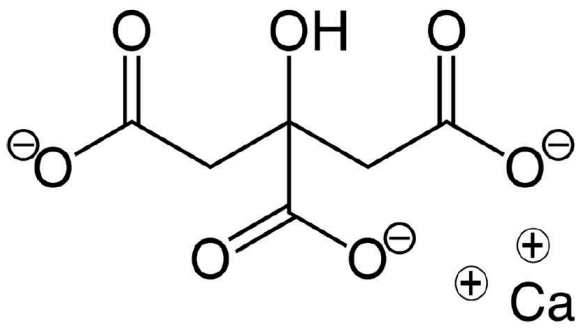
Citrate complexes with calcium and prevent clotting

30-60% of the citrate-calcium complexes are removed by the filter

298 Da
High hydosolubility
Sc = 1

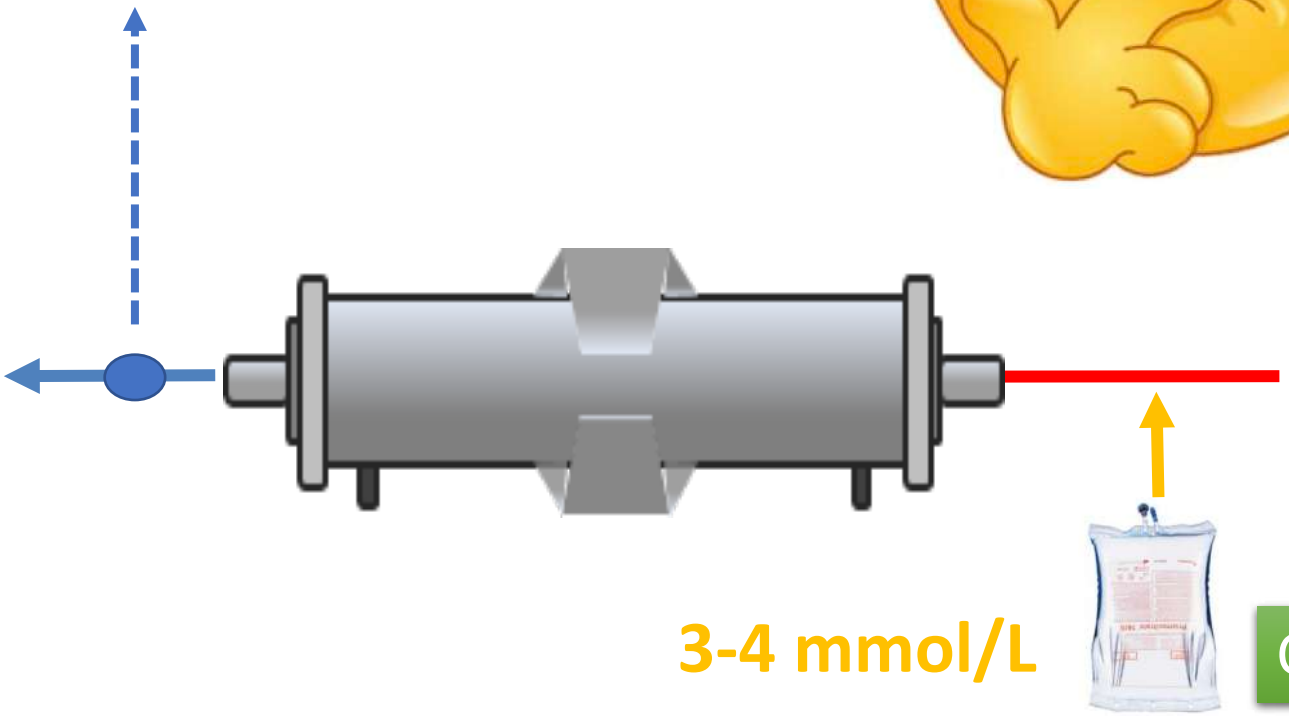
Calcium is replaced in the outflow line

Remaining citrate-calcium compl. are metabolized to bicarbonate and Ca^{++} Is released



Regional Citrate Anticoagulation (RCA)

Ca^{++} (post-filter)
0.25 - 0.4 mmol/L
or
1.0 – 1.6 mg/dL

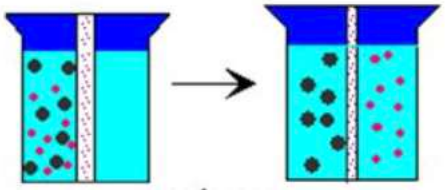


Kellum JA, Bellomo R, Ronco C (2015)

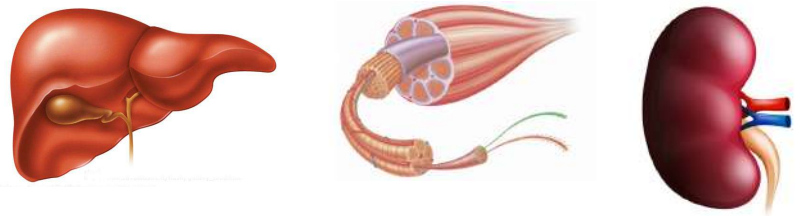
Citrate

Citrate is partially removed by filtration or dialysis.

(Mariano F, et al. Nephrol Dial Transplant 2011; 26: 3882–3888)



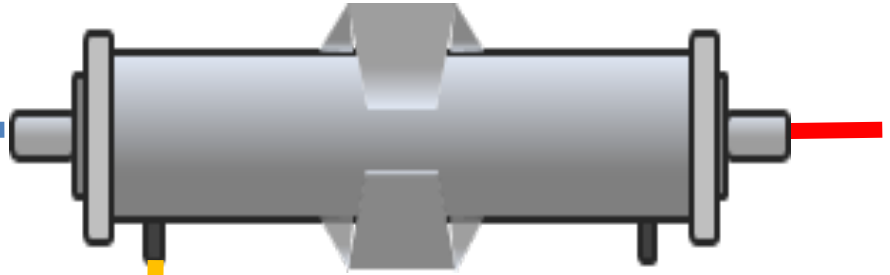
The remaining amount, infused into the patient, is rapidly metabolized in the citric acid (Krebs) cycle, especially in the liver, muscle, and renal cortex



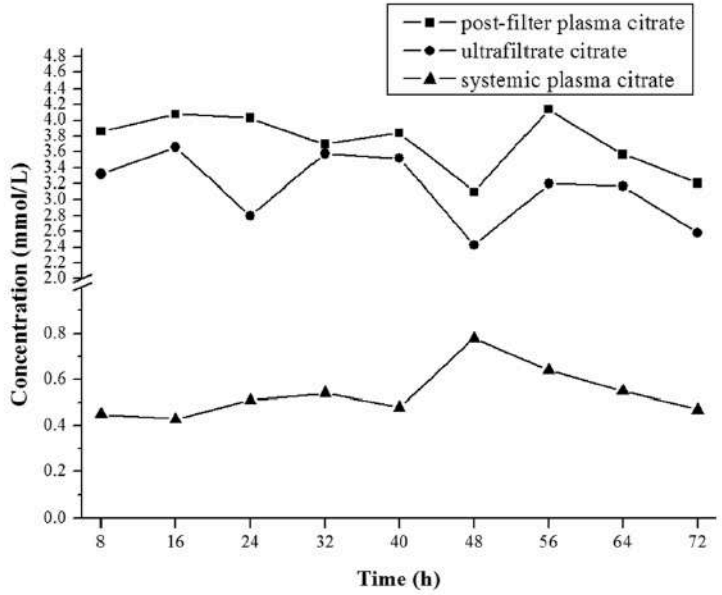
The ensuing regional hypocalcemia in the filter inhibits thrombin generation.

[0.45-0.62 mmol/L]

[3.44-4.01 mmol/L]



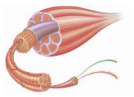
[2.69-3.48 mmol/L]



A mode of CVVH with regional citrate anticoagulation compared to no anticoagulation for acute kidney injury patients at high risk of bleeding

Gao J et al. Sci Rep. 2019

REGIONAL CITRATE

- There is no systemic anticoagulation as a result of:
  - Any citrate-calcium complex → patient's blood →    → **1 cit = 3 bicarbonate** ions
  - During this metabolism, **Calcium is released** contributing to normalizing of the coagulation
  - 1 mmol citrate → 2.48 kJ (593 cal/mmol citrate)

    Am J Clin Nutr 2017; 105:1559-63

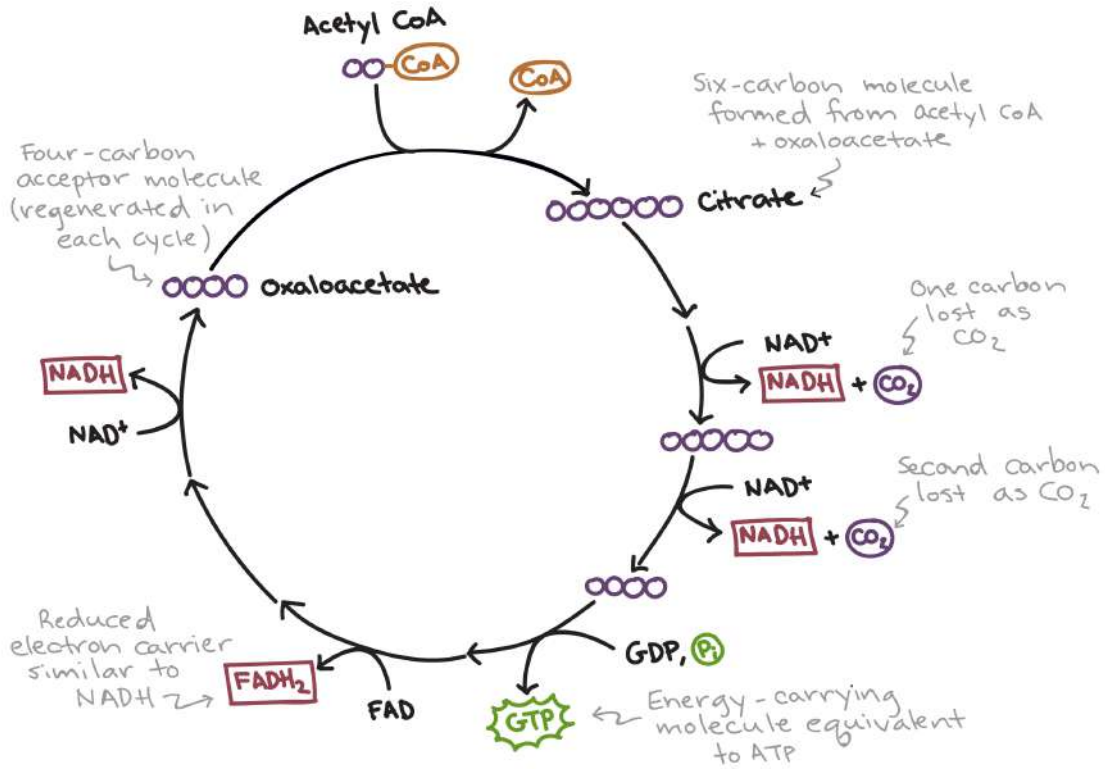
- Pay attention to … Magensium (Mg^{++})

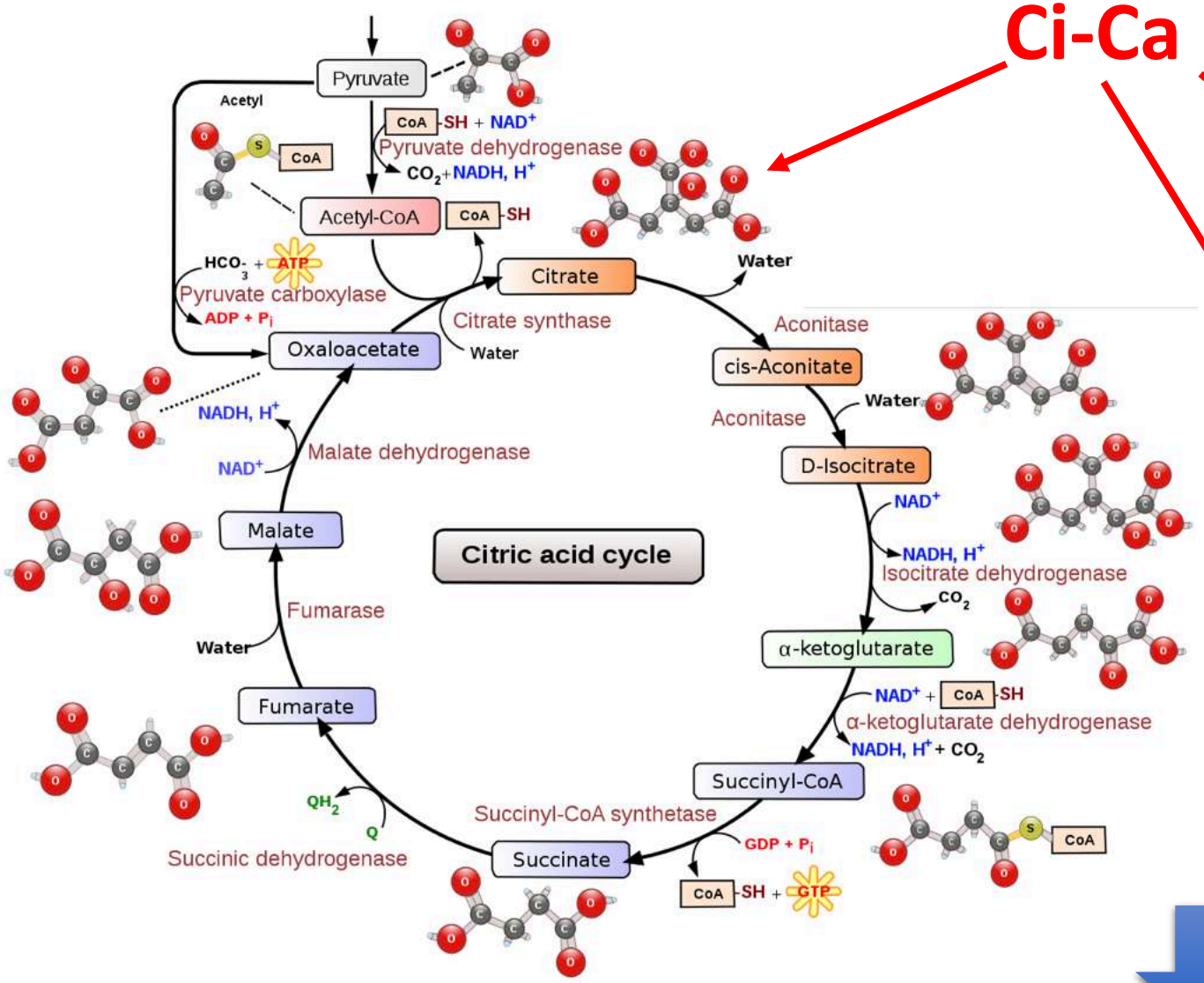
Kellum JA, Bellomo R, Ronco C (2015)

The citrate **metabolic load** to the patient is:

$$[\text{Citrate}]_{pre} - [\text{Citrate}]_{eff}$$

With the more commonly reported citrate protocols, the citrate load is approximately **10–20 mmol/h**.





Ci-Ca

Ca^{++}

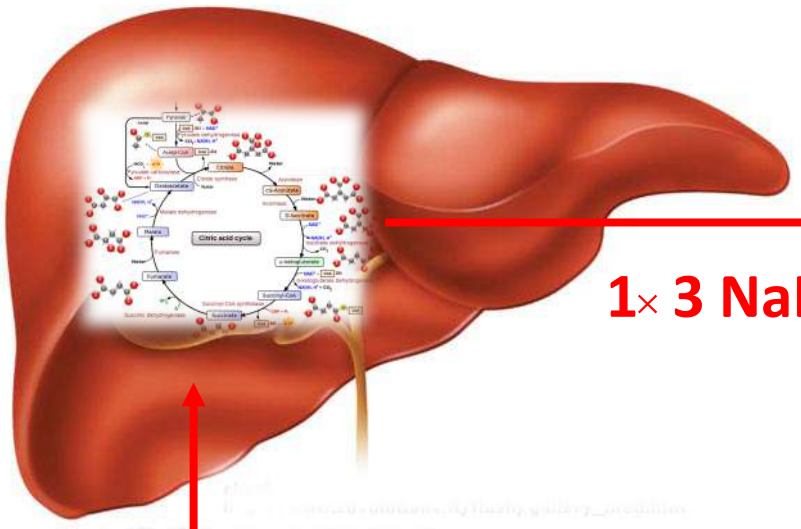
Na^{+}

Half life 5’

2.48kJ – 593 cal/mmol citrate

O_2 dependent

Acid-base effects



Metabolic Alkalosis

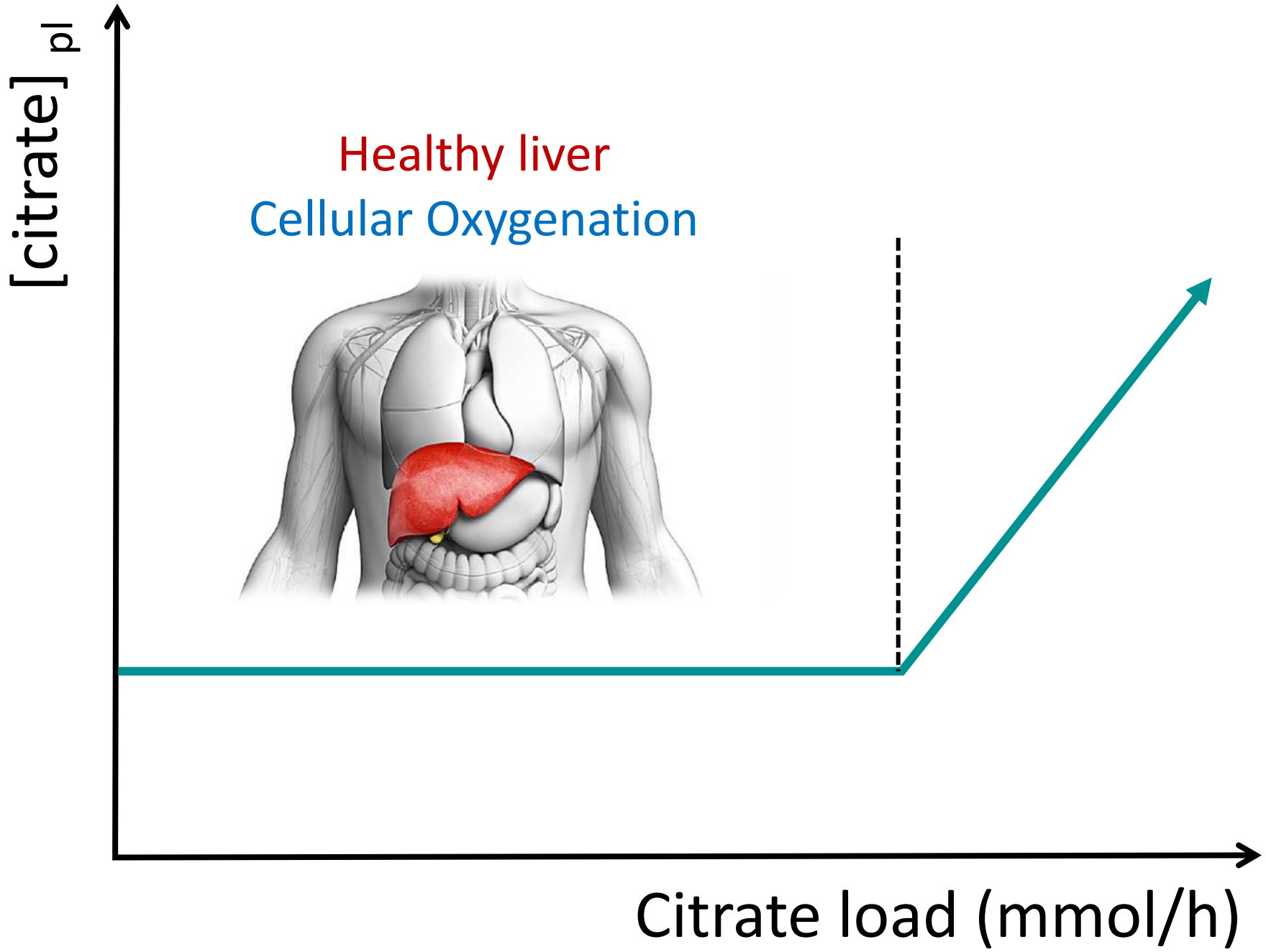
1× 3 $NaHCO_3^-$

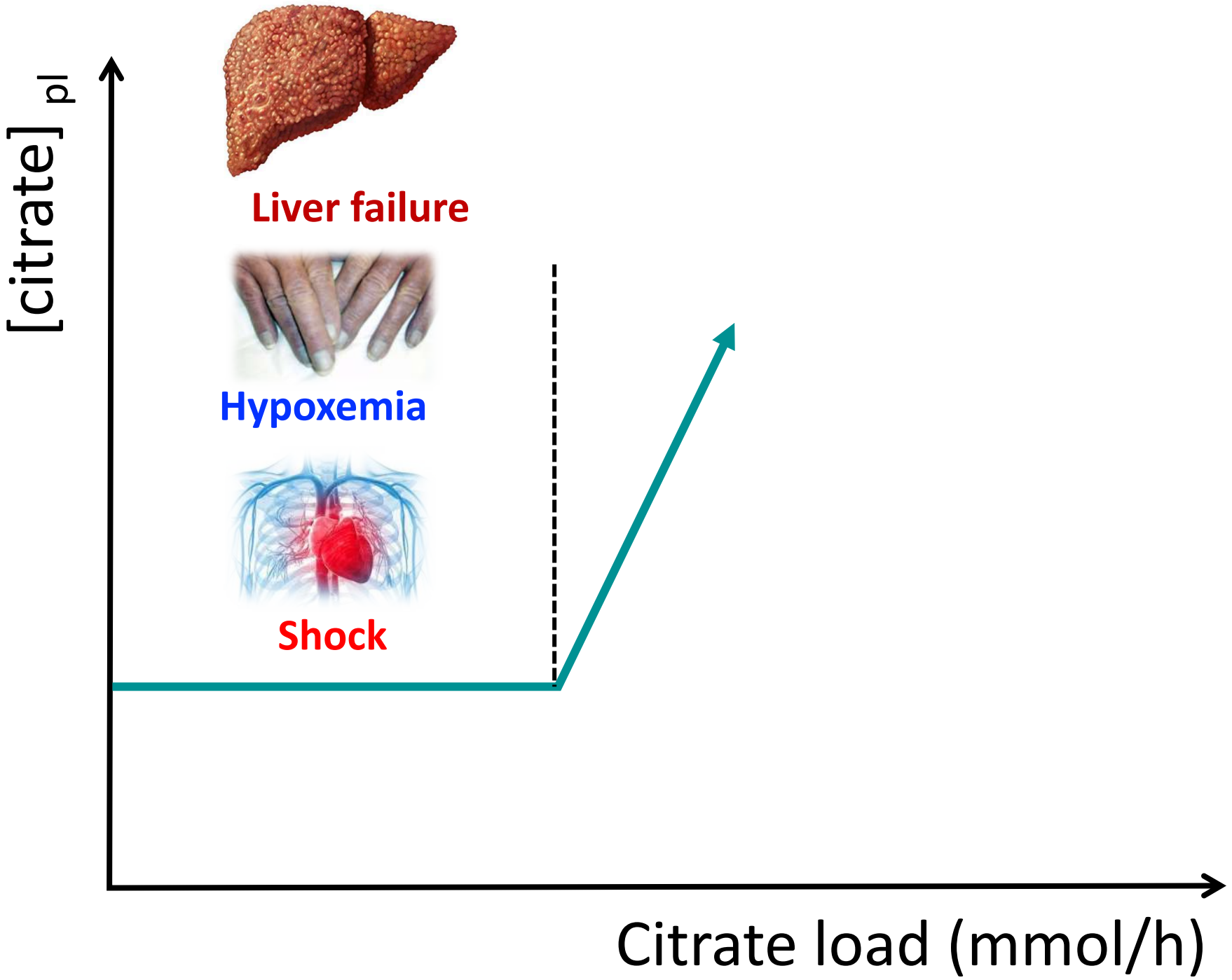
Ci-Ca

4% Na_3 Citrate

⇑ SID

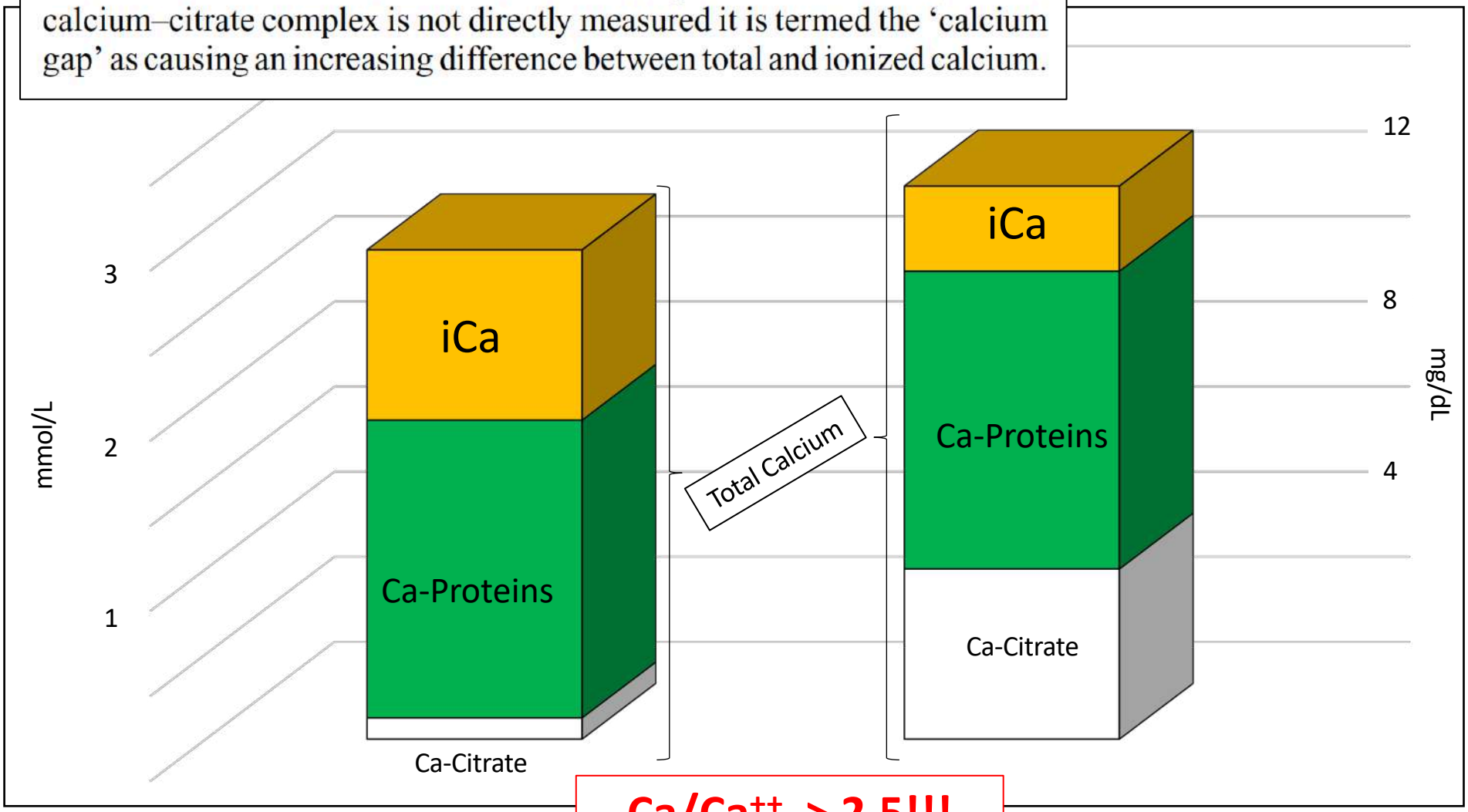
Ci-Ca accumulation ⟶ Metabolic Acidosis


[citrate] pl
Healthy liver
Cellular Oxygenation
Citrate load (mmol/h)


[citrate] pl
Liver failure
Hypoxemia
Shock
Citrate load (mmol/h)

If citrate cannot be metabolized, then the total serum calcium concentration appears to increase, with a corresponding fall in ionized calcium due to the increase in calcium complexed with citrate, as the calcium–citrate complex is not directly measured it is termed the 'calcium gap' as causing an increasing difference between total and ionized calcium.

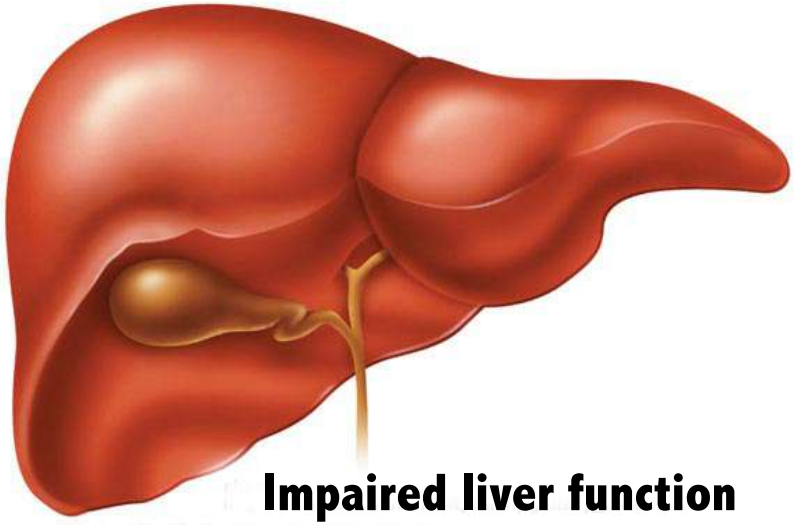
Davenport A et al. NTD (2009)



Ca/Ca^{++} > 2.5!!!

…accurately predict the citrate accumulation (systemic citrate concentration **1 mmol/L**) with high sensitivity and specificity (89 and 100%, respectively)

Bakker AJ, et al. Clin Chem Lab Med (2006)



Impaired liver function

Hypoxemia

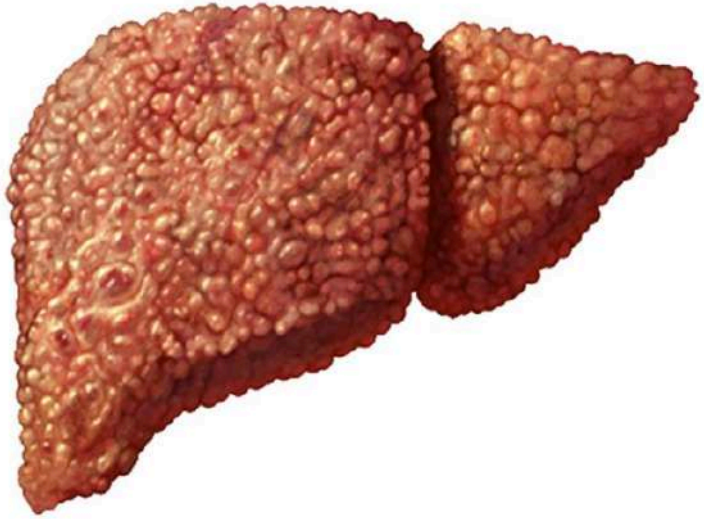
Shock

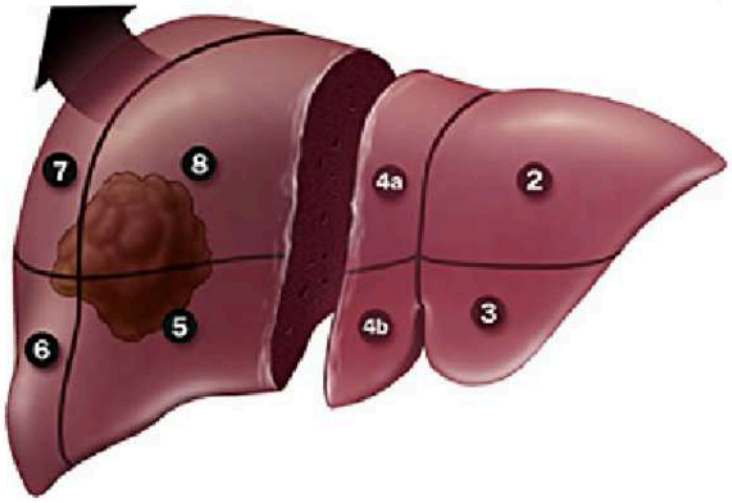
Khadzhynov D, et al J Crit Care (2014)

Ricci D et al. Contrib Nephrol (2017)

However, there is increasing evidence that at least **impaired liver function need not be considered as an absolute contraindication** for RCA.

Several studies have reported that RCA can be safely used even in this population.





Fiaccadori E, et al. J Nephrol 2015; 28: 151–164.
Slowinski T, et al. Crit Care 2015; 19: 349.
Schultheiß C, et al. Crit Care 2012; 16:R162.
Kribben A, et al. 2012; 142: 782–789.e3.

Anticoagulation OPTIONS for CRRT

Rigid Protocol

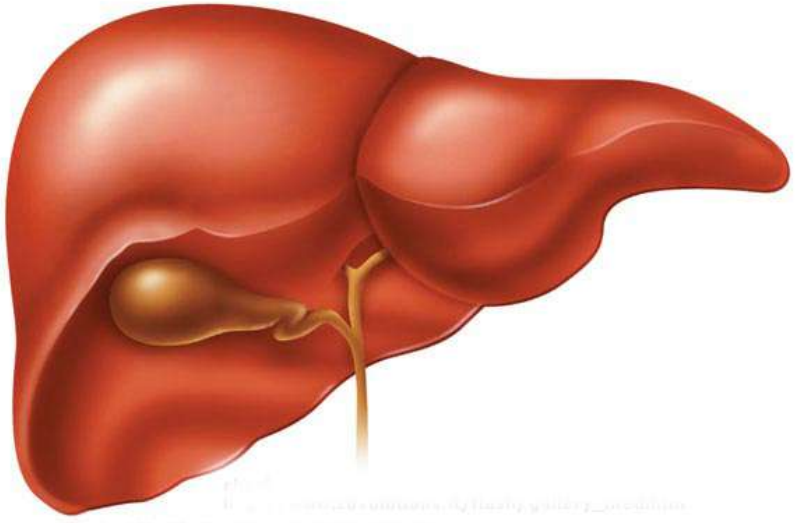
1 **Regional Anticoagulation**

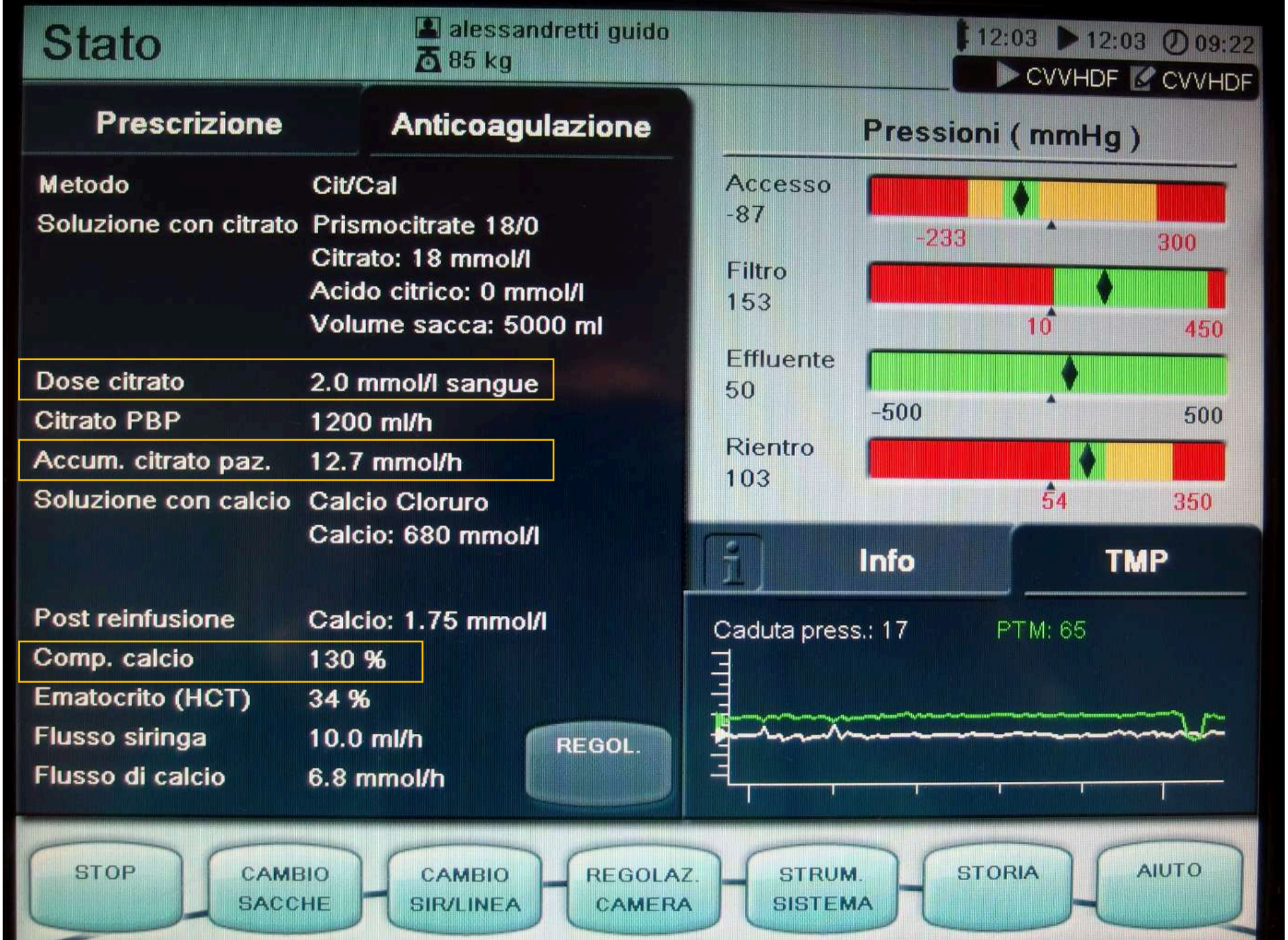
1.5 ***RCA management and handling***

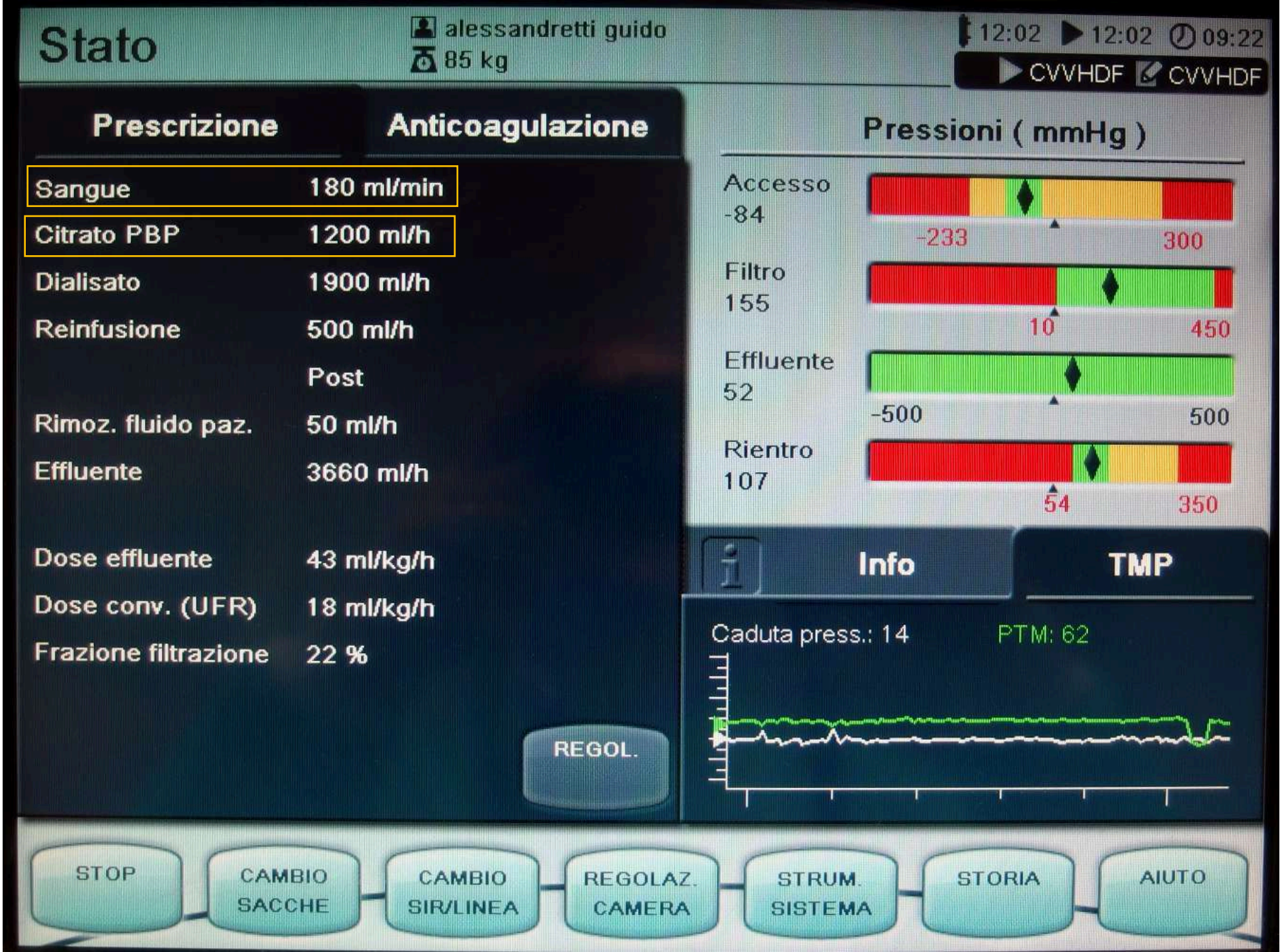
3 **Anticoagulation Free**

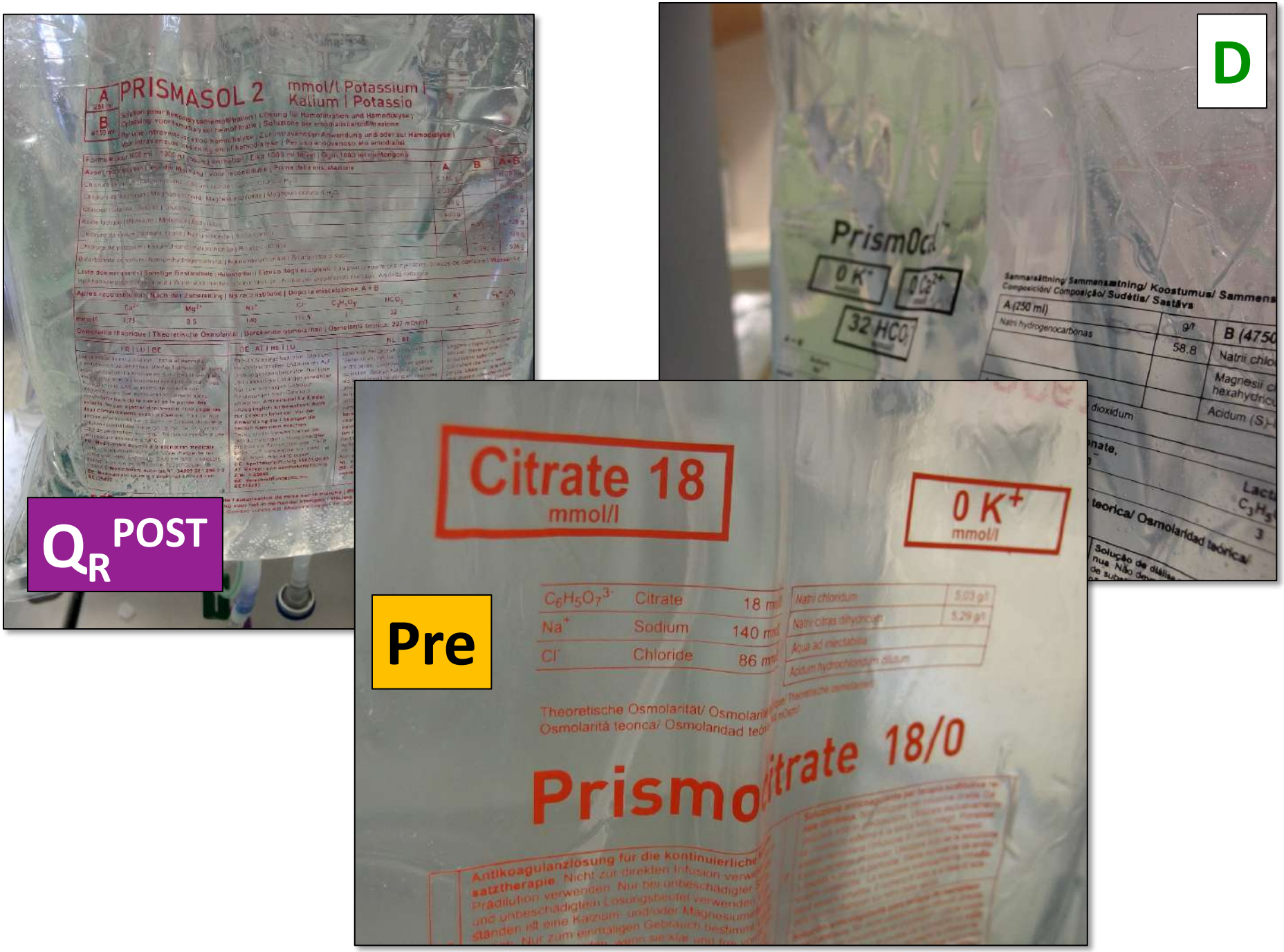

28 Jan 2020


B BRAUN
Ureofix® 500
500 mL
400
300
200
100




Stato
alessandretti guido
85 kg
12:03
12:03
09:22
CVVHDF
CVVHDF
Prescrizione
Anticoagulazione
Metodo
Cit/Cal
Soluzione con citrato
Prismocitrate 18/0
Citrato: 18 mmol/l
Acido citrico: 0 mmol/l
Volume sacca: 5000 ml
Dose citrato
2.0 mmol/l sangue
Citrato PBP
1200 ml/h
Accum. citrato paz.
12.7 mmol/h
Soluzione con calcio
Calcio Cloruro
Calcio: 680 mmol/l
Post reinfusione
Calcio: 1.75 mmol/l
Comp. calcio
130 %
Ematocrito (HCT)
34 %
Flusso siringa
10.0 ml/h
Flusso di calcio
6.8 mmol/h
REGOL.
Pressioni (mmHg)
Accesso
-87
-233
300
Filtro
153
10
450
Effluente
50
-500
500
Rientro
103
54
350
Info
TMP
Caduta press.: 17
PTM: 65
STOP
CAMBIO SACCHE
CAMBIO SIR/LINEA
REGOLAZ. CAMERA
STRUM. SISTEMA
STORIA
AIUTO

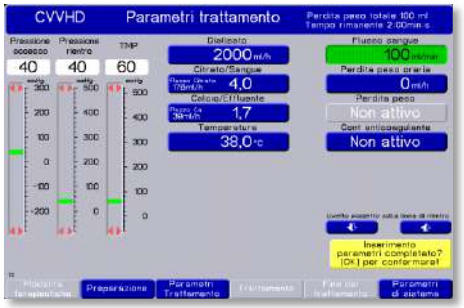

Stato
alessandretti guido
85 kg
12:02
12:02
09:22
CVVHDF
CVVHDF
Prescrizione
Anticoagulazione
Sangue 180 ml/min
Citrato PBP 1200 ml/h
Dialisato 1900 ml/h
Reinfusione 500 ml/h
Post
Rimoz. fluido paz. 50 ml/h
Effluente 3660 ml/h
Dose effluente 43 ml/kg/h
Dose conv. (UFR) 18 ml/kg/h
Frazione filtrazione 22 %
REGOL.
Pressioni (mmHg)
Accesso
-84
-233
300
Filtro
155
10
450
Effluente
52
-500
500
Rientro
107
54
350
Info
TMP
Caduta press.: 14
PTM: 62
STOP
CAMBIO SACCHE
CAMBIO SIR/LINEA
REGOLAZ. CAMERA
STRUM. SISTEMA
STORIA
AIUTO


PRISMASOL 2
mmol/l Potassium | Kalium | Potassio
Q_R POST
D
PrismOcal
0 K+
32 HCO3
Citrate 18
mmol/l
0 K+
mmol/l
Pre
$C_6H_5O_7^{3-}$ Citrate 18 mmol
Na^+ Sodium 140 mmol
Cl^- Chloride 86 mmol
Prismocitrate 18/0


Stato
alessandretti guido
85 kg
22:44
22:44
26:03
CVVHD
CVVHDF
Prescrizione
Anticoagulazione
Metodo
Clt/Cal
Soluzione con citrato
Prismocitrate 18/0
Citrato: 18 mmol/l
Acido citrico: 0 mmol/l
Volume sacca: 5000 ml
Dose citrato
0.0 mmol/l sangue
Citrato PBP
0 ml/h
Accum. citrato paz.
0.0 mmol/h
Soluzione con calcio
Calcio Cloruro
Calcio: 680 mmol/l
Post reinfusione
Calcio: 1.75 mmol/l
Comp. calcio
150 %
Ematocrito (HCT)
34 %
Flusso siringa
0.0 ml/h
Flusso di calcio
0.0 mmol/h
REGOL.
Pressioni (mmHg)
Accesso
-64
-207
300
Filtro
136
450
Effluente
70
500
Rientro
87
350
Caduta press.: 45
PTM: 15
STOP
CAMBIO SACCHE
CAMBIO SIR/LINEA
REGOLAZ. CAMERA
STRUM SISTEMA
STORIA
AIUTO


Stato
alessandretti guido
85 kg
22:44
22:44
20:04
CVVHD
CVVHDF
Prescrizione
Anticoagulazione
Sangue
200 ml/min
Citrato PBP
0 ml/h
Dialisato
1900 ml/h
Reinfusione
500 ml/h
Post
Rimoz. fluido paz.
0 ml/h
Effluente
2400 ml/h
Dose effluente
28 ml/kg/h
Dose conv. (UFR)
6 ml/kg/h
Frazione filtrazione
7 %
REGOL.
Pressioni (mmHg)
Accesso
-52
-207
300
Filtro
138
10
450
Effluente
70
-500
500
Rientro
90
35
350
Info
TMP
Caduta press.: 19
PTM: 27
STOP
CAMBIO SACCHE
CAMBIO SIR/LINEA
REGOLAZ CAMERA
STRUM SISTEMA
STORIA
AIUTO

The **new software** is in fact able to adapt citrate infusion to blood flow changes, thus limiting the risk of an inappropriate citrate/blood flow ratio.



Moreover, with CRRT monitors the citrate dose **can be modified at any time during the treatment** in the event of a documented or suspected citrate overload.

Last, **modulation of the convective and/or diffusive CRRT** dose may prevent the development of citrate accumulation, due to the substantial removal of citrate with the effluent fluid

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

Zaccaria Ricci[a] Stefano Romagnoli[b] Claudio Ronco[c, d]

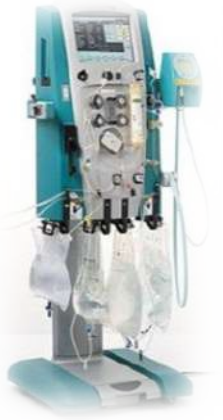
Blood Purif 2017;44:271–275

PrismOcal B22
5000 ml

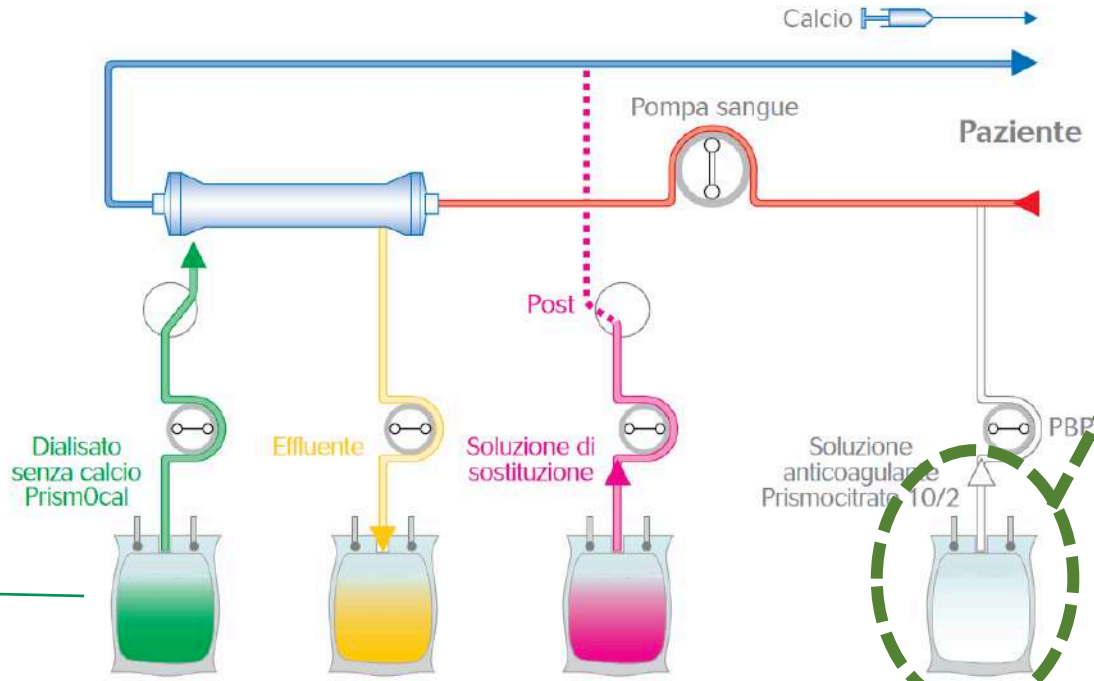
Na^+ 140 mmol/L
K^+ 4 mmol/L
Mg^{++} 0.75 mmol/L
Cl^- 120 mmol/L
HCO_3^- 22 mmol/L
Lattato 3 mmol/L
Glucosio 6.1 mmol/L
Osm 294 mOsm/L

Calcium – Free
$NaHCO_3$ 22 mmol/l

CVVHDF



Baxter



Prismocitrate 18/0
18 mmol/l
5000 ml

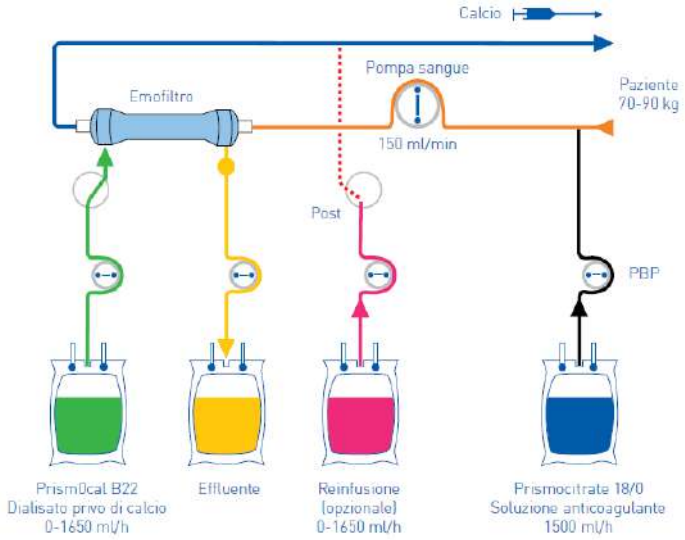
NaCl 5.03 g/L
Sodio citrate 5.29 g/L
Citrato 18 mmol/L
Na^+ 140 mmol/L
Osm 244 mOsm/L

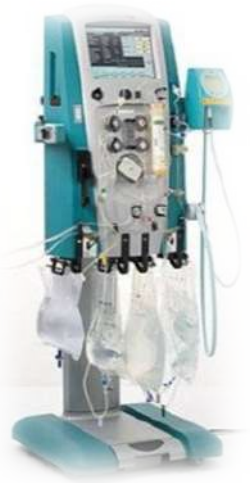
Protocollo CVVHDF con Citrato con Prismaflex

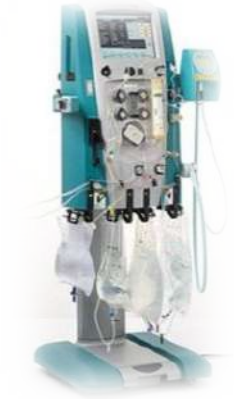
(con Prismocitrate® 18/0)

IMPOSTAZIONE FLUSSI	Peso Paziente [Kg]								
	50	60	70	80	90	100	110	120	130
FLUSSO SANGUE [ml/min]	100	110	120	130	140	150	160	170	180
Infusione PBP (pre diluizione) (1) Prismocitrate® 18/0 o Regiocit [ml/h]	1000	1100	1200	1300	1400	1500	1600	1700	1800
DIALISATO senza calcio Prism0cal® B22 o Biphozyl [ml/h]	1000	1100	1200	1300	1400	1500	1600	1700	1800
REINFUSIONE post diluizione (2) PRISMASOL 2 / 4 , Phoxilium® o Biphozyl [ml/h]	200	400	500	500	500	600	700	800	1000

IMPOSTAZIONE ANTICOAGULANTE	
Dose Citrato	3 mmol/L sangue
Compensazione Calcio (3)	100 %







Calcio ionizzato sistemico Range: 1,00 – 1,20 mmol/L o 4,00 – 4,80 mg/dL	Entro i primi 30 min	A 2 ore dalla partenza	Almeno ogni 6 ore (vedi schema)
Calcio ionizzato post filtro Range: 0,25 – 0,50 mmol/L o 1,00 – 2,00 mg/dL	Entro i primi 30 min		Almeno ogni 24 ore (vedi schema)

COMPENSAZIONE % DELLA CALCEMIA PAZIENTE TRAMITE SIRINGA PRISMAFLEX

Le variazioni si intendono rispetto al valore attualmente impostato

mg/dL	< 3,2	3,6	4,0		4,8	5,4	mg/dL
mmol/L	< 0,8	0,9	1,0		1,2	1,35	mmol/L
+ 30%	+ 20%	+ 10%	COMPENSAZIONE ADEGUATA NESSUNA MODIFICA			- 10%	- 20%
Prossimo controllo dopo 1 ora	Prossimo controllo dopo 2 ore	Prossimo controllo dopo 4 ore	Prossimo controllo dopo 6 ore			Prossimo controllo dopo 4 ore	Prossimo controllo dopo 2 ore

(dopo la seconda ora dall'inizio del trattamento o su richiesta del sistema Prismaflex)

In caso di grave Ipocalcemia si suggerisce di valutare un'ipotetica intolleranza mediante il rapporto Ca Tot. / Ca**

AGGIUSTAMENTO DEL CALCIO IONIZZATO POST FILTRO

mg/dL	< 1,00	1,00 – 2,00	> 2,00	mg/dL
mmol/L	< 0,25	0,25 – 0,50	> 0,50	mmol/L
Impostare Dose Citrato = 2,7 mmol/L		NESSUNA MODIFICA	Impostare Dose Citrato = 3,3 mmol/L (*)	
Prossimo controllo dopo 6 ore		Prossimo controllo dopo 24 ore	Prossimo controllo dopo 6 ore	

(*) Da impostare solo se HCO_3^- < 28 mmol/L

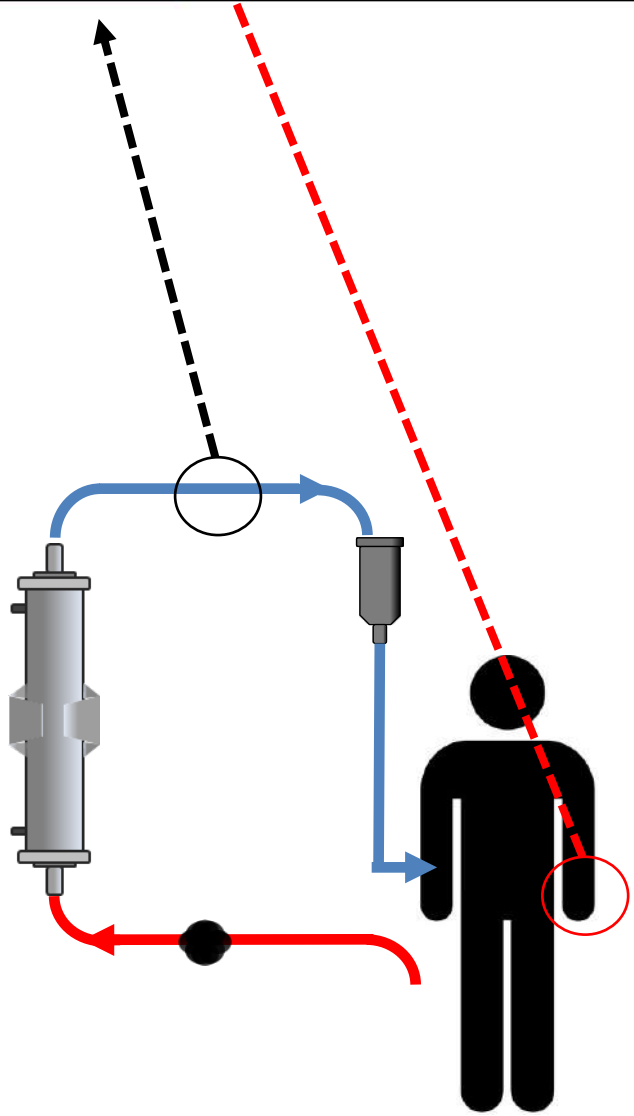
AGGIUSTAMENTO DELL'ACCUMULO DI CITRATO e/o BILANCIO BICARBONATI

(dopo 6 ore dalla partenza)

HCO_3^- mmol/L	22	28	mmol/L
DIALISATO: - 300 ml/h FLUSSO SANGUE: + 10 ml/min	NESSUNA MODIFICA	DIALISATO: + 300 ml/h FLUSSO SANGUE: - 10 ml/min	
Prossimo controllo dopo 6 ore	Prossimo controllo dopo 12 ore	Prossimo controllo dopo 6 ore	

Range consigliati: DIALISATO (900 - 1800) mL/h – FLUSSO SANGUE (100 - 170) mL/min

Applicare possibilmente entrambe le modifiche



OMNI – PROTOCOLLO CITRATO CVVHD (CHUV LOSANNA)

B|BRAUN
SHARING EXPERTISE

Peso paziente (Kg)	Flusso Dialisato (ml/h)	Flusso Sangue (ml/min)
60	1600	80
60 -79	2000	100
80 - 99	2600	130
100 - 119	3000	150
120 -149	3600	180

- Trisodio citrato **4%**
- Siringa B.Braun Omnifix da 50cc contenente:

30 ml Calcio Cloruro 10% (680mmol/l) più **20 ml** di soluzione fisiologica => **408 mmol/l**

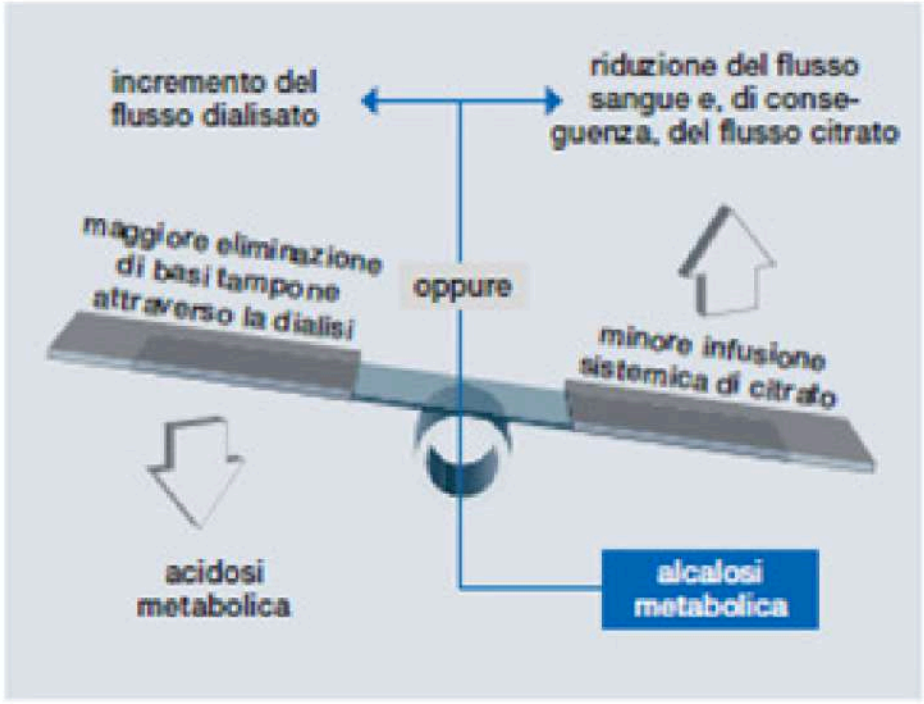
Rapporto Flusso Dialisato/Flusso sangue 20:1

- Dialisato **senza calcio** a 4K+

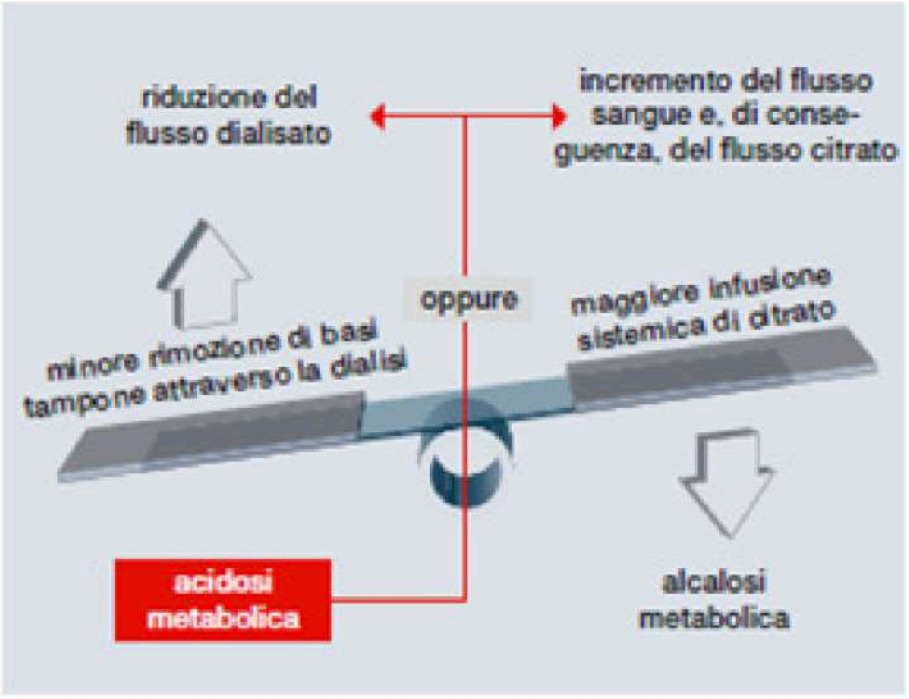
Calcio ionizzato POST FILTRO (mmol/l)	Modifica dose CITRATO (Citrato/Sangue)
> 0,45	**Aumentare di 0,3 mmol/l e informare il medico**
0,41 – 0,45	Aumentare di 0,2 mmol/l
0,35 – 0,40	Aumentare di 0,1 mmol/l
0,25 – 0,34	**Nessuna modifica**
0,20 – 0,24	Ridurre di 0,1 mmol/l
0,15 – 0,19	Ridurre di 0,2 mmol/l
< 0,15	**Ridurre di 0,3 mmol/l**

Calcio ionizzato SISTEMICO (mmol/l)	Modifica dose CALCIO (Calcio/Effluente)
> 1,45	**Diminuire di 0,6 mmol/l e informare il medico**
1,31 – 1,45	Diminuire di 0,4 mmol/l
1,21 – 1,30	Diminuire di 0,2 mmol/l
1,12 – 1,20	**Nessuna modifica**
1,05 – 1,11	Aumentare di 0,2 mmol/l
0,95 – 1,04	Aumentare di 0,4 mmol/l
< 0,95	**Aumentare di 0,6 mmol/l e informare il medico**

ALCALOSI METABOLICA



ACIDOSI METABOLICA

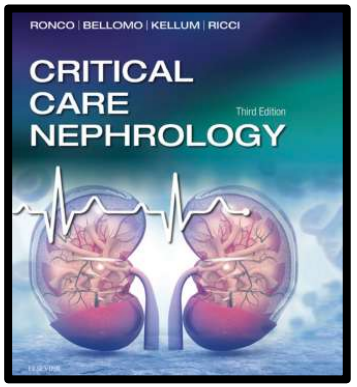


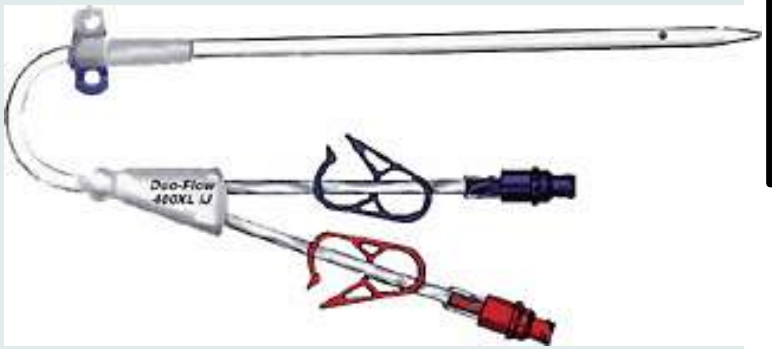
Citrate accumulation or overload

(management)

1) Decreasing Q_B (decreases intake) through blood flow–citrate coupling or
2) Increasing Q_D (CVVHD) or Q_R^{POST} (CVVH) (increases removal), or
3) Decreasing the **targeted citrate** concentration within the filter.

Nonanticoagulant Measures Reducing Circuit and Access Clotting

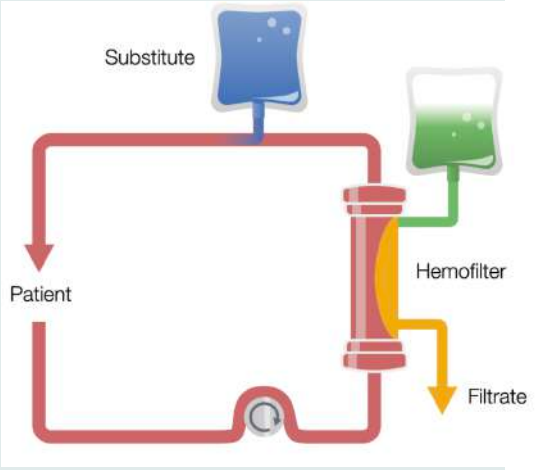




Catheter design
- Increase diameter
- High inner diameter (thin material)
- Avoid side holes
- Use short-gun tip

Catheter position
- Chose individually
- Chose position with lowest pressures
- Choose straight direction : right jugular, left or right femoral vein
- Prevent kinking
- Tip of jugular vein catheter in right atrium
- Tip of femoral vein catheter in inferior caval vein

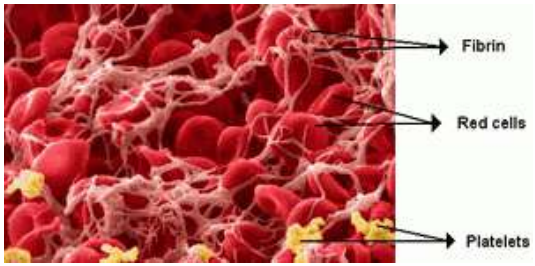
CRRT mode
- Avoid or reduce hemoconcentration
  - Hemodialysis
  - Hemofiltration with low filtration fraction
  - Predilution hemofiltration

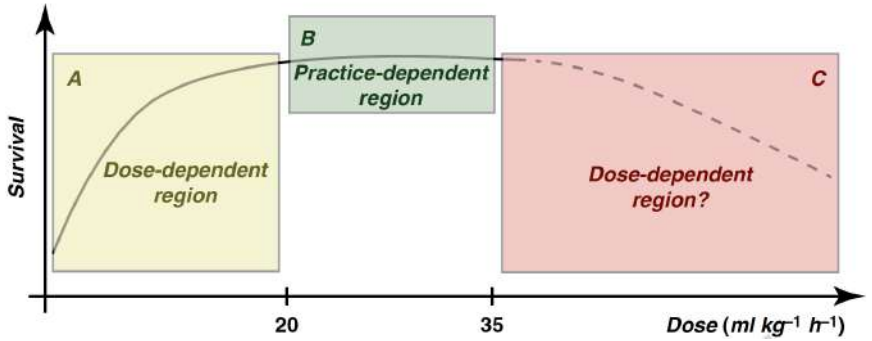


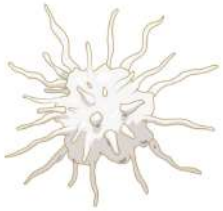
Circuit
- Avoid blood flows < 100mL/min

Venous access during CRRT interruptions
- Use a citrate lock

Ronco, Bellomo, Kellum, Ricci 2018


Fibrin
Red cells
Platelets


A
Dose-dependent region
B
Practice-dependent region
C
Dose-dependent region?
Survival
20
35
Dose (ml kg⁻¹ h⁻¹)

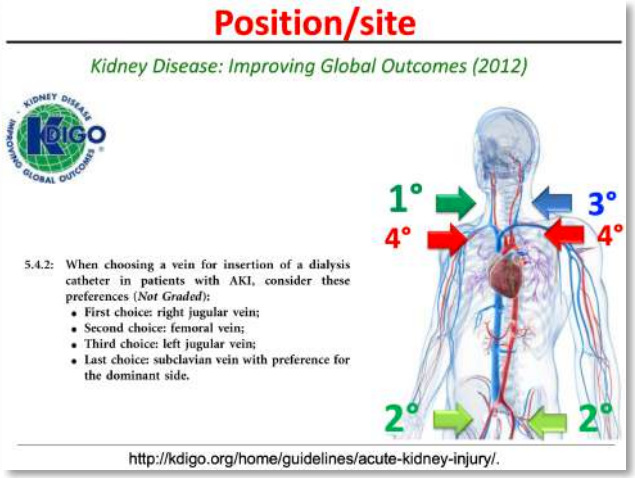


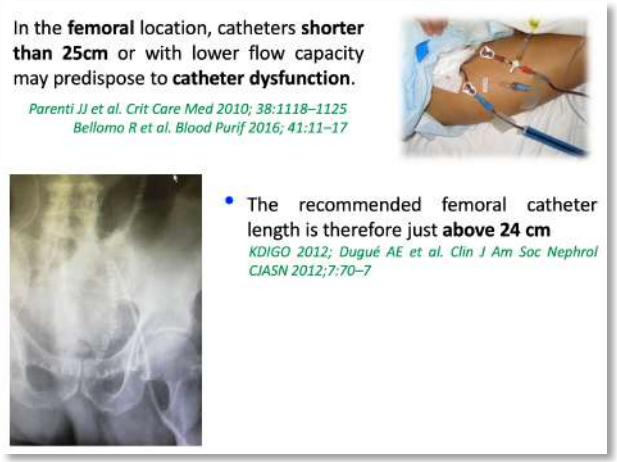
Continuous Renal Replacement Therapy
Who, When, Why, and How

Vascular Access

- In adults, catheter design and position must be sufficient to sustain blood flow rates of 200 to 300 mL/min.

- KDIGO Clinical Practice Guidelines for AKI recommend the right internal jugular vein as the preferred location for catheter placement, followed by the femoral and the left internal jugular veins





Tandukar S; Palevsky PM. Chest (2019)

- Strategies to minimize the risk of clotting of the extracorporeal circuit include the following:
  - Higher **Q_b** rates
  - Minimization of **filtration fraction** (the ratio of ultrafiltration to plasma flow)
  - Minimization of filtration fraction (the ratio of ultrafiltration to plasma flow) by using CVVHD rather than CVVH or infusing replacement fluids **prefilter** during CVVH and CVVHDF (Predilution)
  - **Predilution**: replacement fluids prefilter during CVVH and CVVHDF
  - Ensuring optimal **catheter function**
  - **Responding promptly to machine alarms to minimize interruptions in blood flow**
  - Increasing the frequency of **scheduled replacement** of the extracorporeal circuit

VA/NIH Acute Renal Failure Trial Network, Palevsky PM et al. N Engl J Med (2008)
RENAL Replacement Therapy Study Investigators, Bellomo R, et al. N Engl J Med (2009)

Tandukar S; Palevsky PM. Chest (2019)

Final Thoughts

- **RCA**
  - ✓ Per se is safe and effective
  - ✓ Prolongs filter running time
  - ✓ Decreases bleeding risk (vs. systemic anticoag.)
  - ✓ Decreases workload & associated cost

- Patients at risk for citrate accumulation
  - ✓ Severe liver failure
  - ✓ Severe hypoxemia
  - ✓ Shock

- For patients at **risk** for citrate accumulation (liver failure, hypoxemia, shock) + contraindications to systemic anticoagulation (after surgery, complex endovascular procedures …)
  - ✓ Consider anticoagulation free approach
  - ✓ Personalize the strategies when the clinical scenario changes

CRRT e Anticoagulazione *Una scelta ponderata: come mantenere la pervietà e il perfetto funzionamento del circuito. Diversi regimi di anticoagulazione*

Stefano Romagnoli, MD, PhD

UO di Nefrologia, Dialisi e Trapianto Renale
Ospedale San Bortolo - ULSS 8 Berica
International Renal Research Institute Vicenza (IRRIV)

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