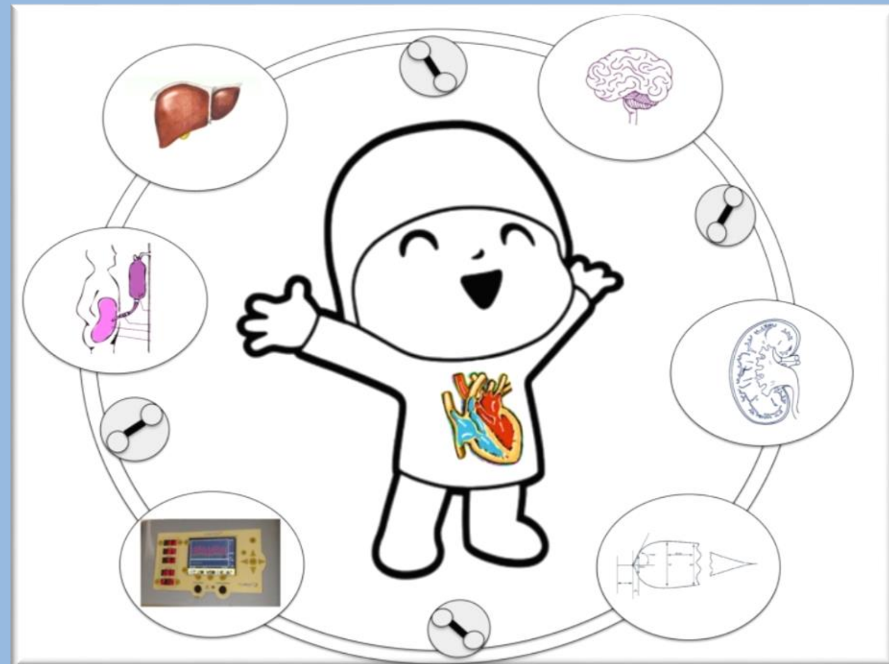
Convection or diffusion? The evidence



37th Vicenza Course on AKI & CRRT

May 28-30, 2019

Zaccaria Ricci

Dipartimento Medico Chirurgico di Cardiologia Pediatrica

Bambino Gesù OSPEDALE PEDIATRICO

Health-e-Child

Comune di Roma

Information Society Technologies

IRRIV International Renal Research Institute Vicenza

Nephrol Dial Transplant (2019) 1–3
doi: 10.1093/ndt/gfz022

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Nephrology Dialysis Transplantation

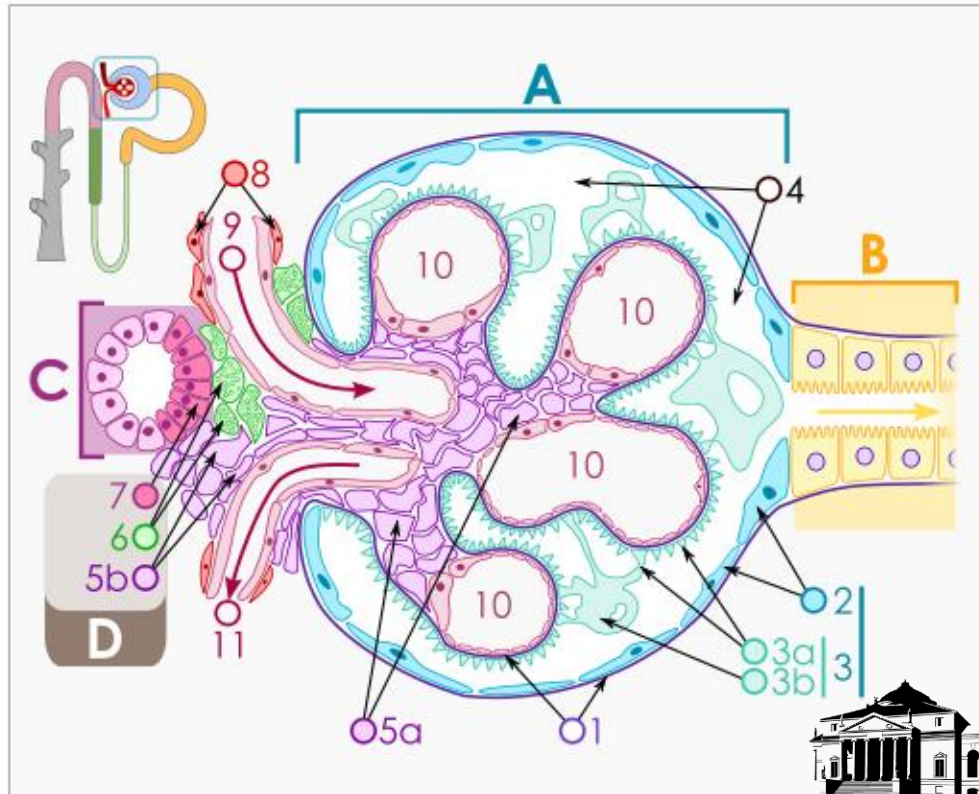
Acute kidney injury: to dialyse or to filter?

Zaccaria Ricci[1,*], Stefano Romagnoli[2] and Claudio Ronco[3,4]

[1]Department of Cardiology and Cardiac Surgery, Pediatric Cardiac Intensive Care Unit, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy, [2]Department of Anesthesiology and Intensive Care, Azienda Ospedaliero-Universitaria Careggi, Largo Brambilla, Florence, Italy, [3]Department of Nephrology, Dialysis and Transplantation, San Bortolo Hospital, Vicenza, Italy and [4]International Renal Research Institute of Vicenza, Vicenza, Italy

- ✓ Blood is filtered and filtrate, except for larger proteins, contains all the substances including some polypeptides in virtually the same concentrations as in plasma.
- ✓ This cell-free filtrate, in which only low-molecular weight solutes appear, is called ultrafiltrate.
- ✓ Around **20% of the plasma is actually filtered**, with the remaining quote being returned to the systemic circulation.

The Vander's Physiology Textbook



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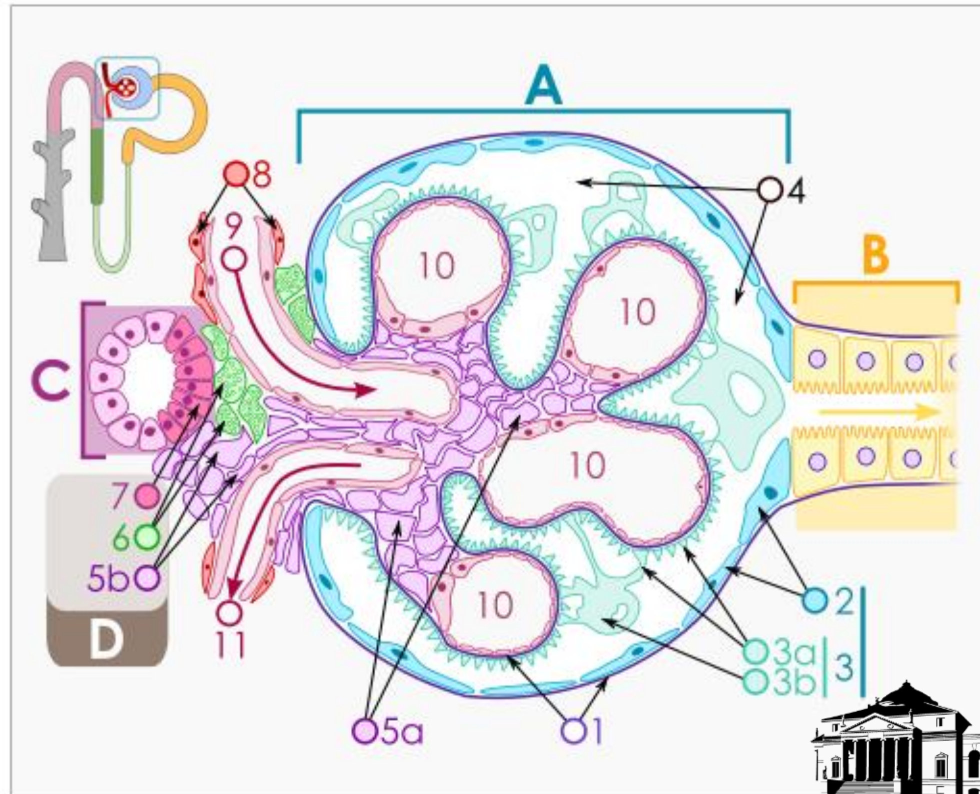
- ✓ Mother nature has chosen continuous hemofiltration (CH), as the primary methodology of blood purification.
- ✓ The "dose" of this "human" blood purification (also known as *creatinine clearance*), in the healthy kidneys of a 70 kg man, ranges from 50 to 100 ml/kg/h.



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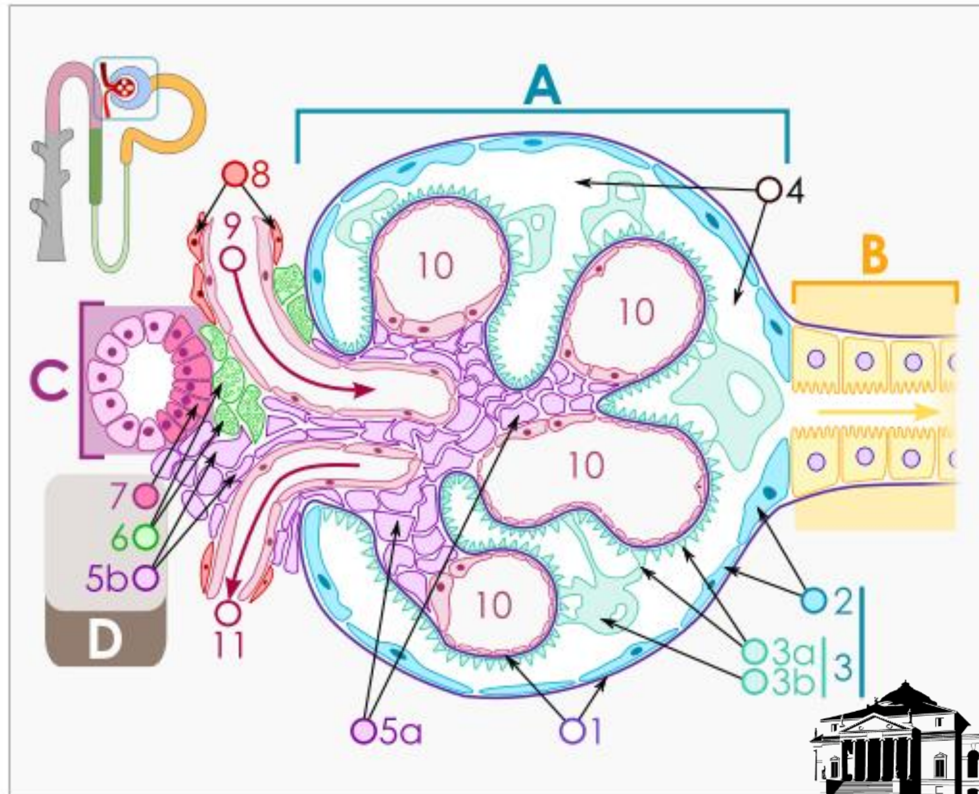
- ✓ A delicate equilibrium between hydrostatic and oncotic pressures regulates the forces involved in the filtration process.
- ✓ About 99% of the filtered flow is eventually restored into the circulation and only the net water removal represents the fluid balance.



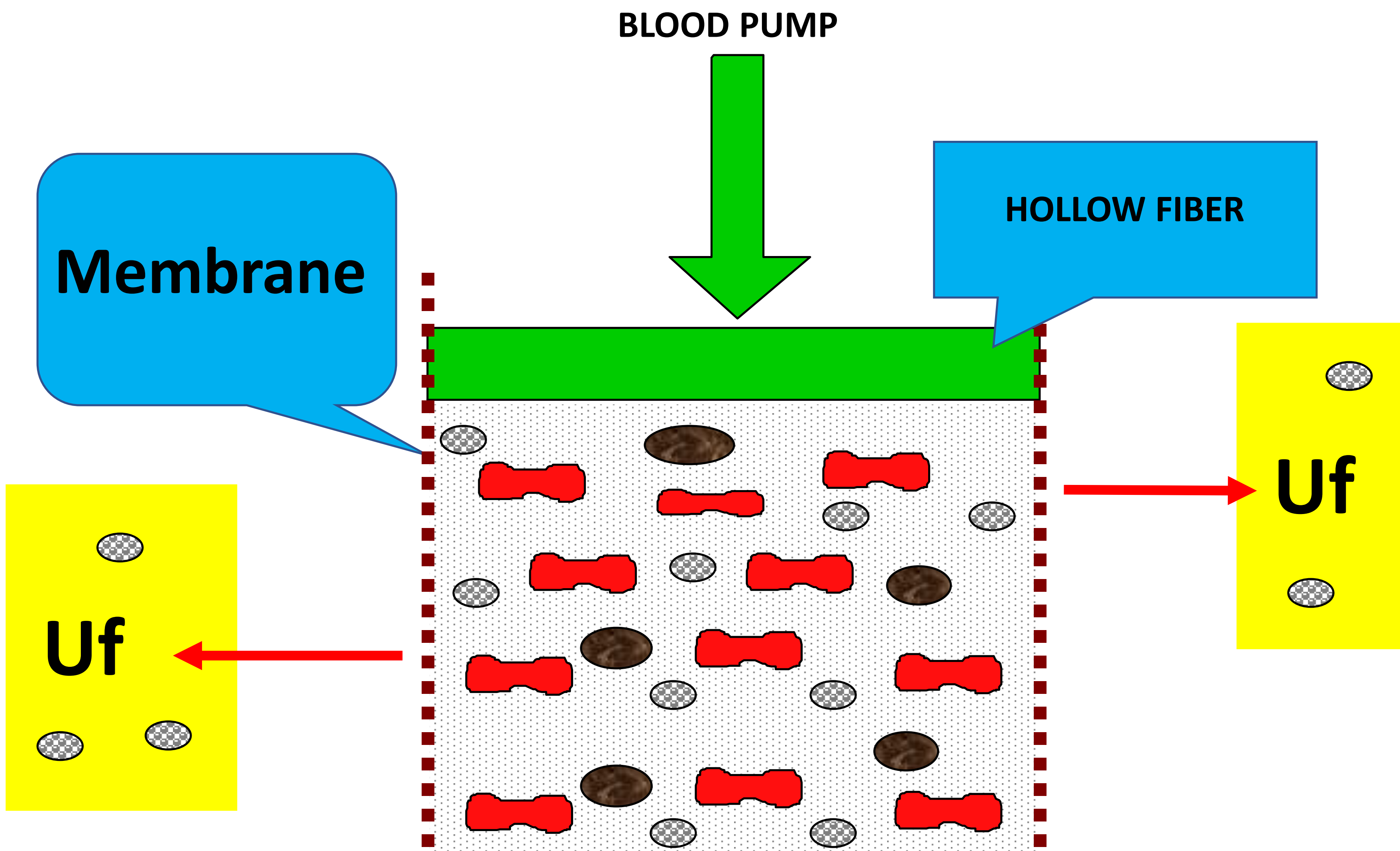
The Vander's Physiology Textbook

OUTLINE

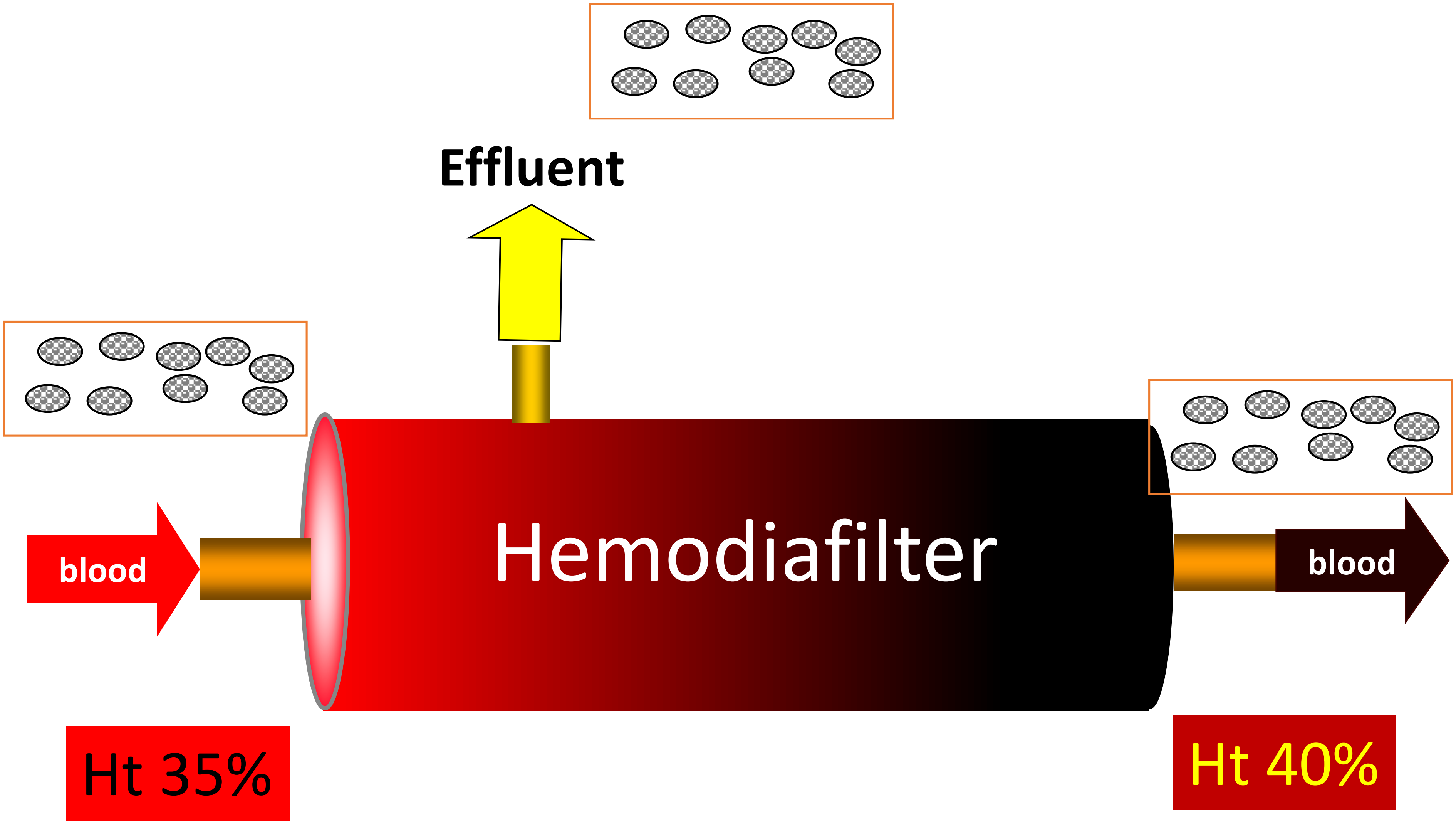
BASICS ON

- Convection and Ultrafiltration
- Pre and post dilution hemofiltration
- Diffusion and Dialysis
- Clearances
- Techniques of monitoring

CONVECTION



ULTRAFILTRATION



The concept of Filtration Fraction

FF = Qef / Qp

The fractional amount of ultrafiltrate produced in relation to the amount of plasma flowing in the hemofilter per unit of time.

Generally expressed as %

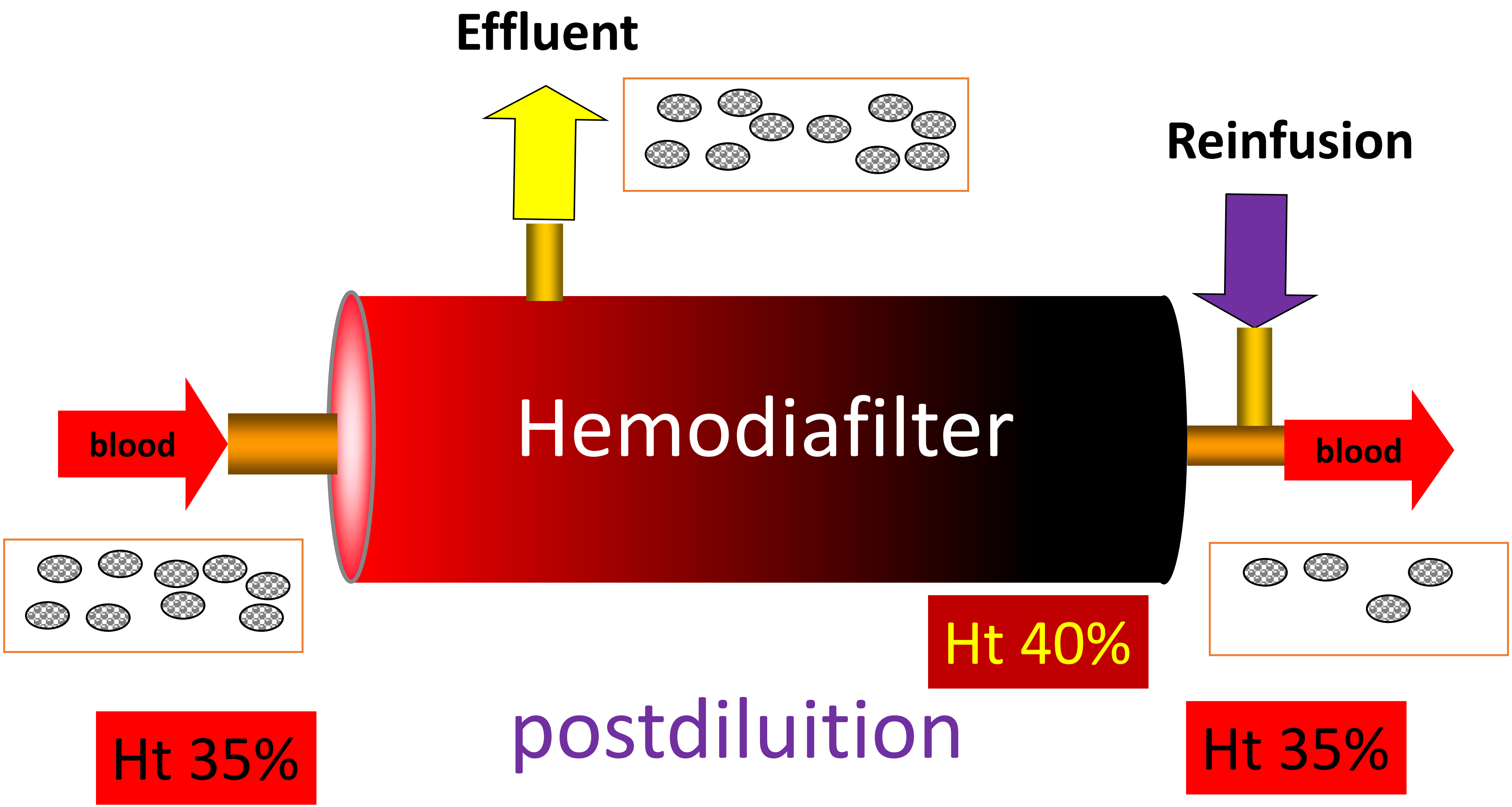
The concept of Filtration Fraction

Qb 160 ml/min and Qrep 20 ml/min
in a 35% Ht patient
FF= 20/[(0.65 x 110)] x 100= 20%

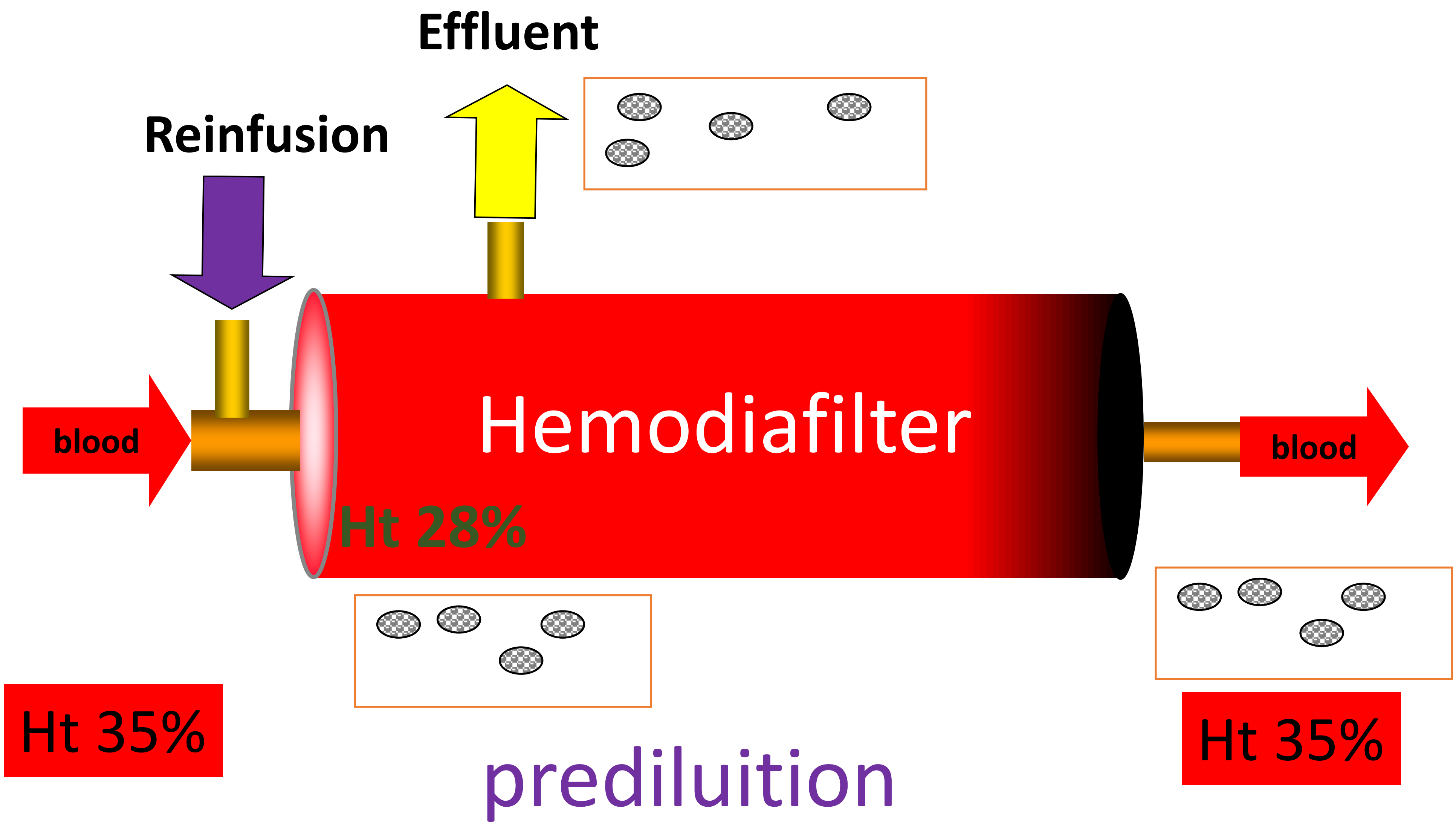
Plasma flow is about 60 to 75% of blood flow,
Depending on hematocrit
(1-Ht) x Qb/100

Optimal Ranges (on Qp) = 20-25%

HEMOFILTRATION



HEMOFILTRATION



PRE DILUTION HEMOFILTRATION

PRO:

- ✓ OPTIMIZATION OF POLARIZATION CONCENTRATION
- ✓ DECREASE OF FILTRATION FRACTION

CONTRA:

- ✓ EFFICIENCY REDUCTION
- ✓ K NO MORE DIRECTLY PROPORTIONAL TO Qeffl

Blood Flow Rate Effects in Pre/Post-Dilution CRRT M

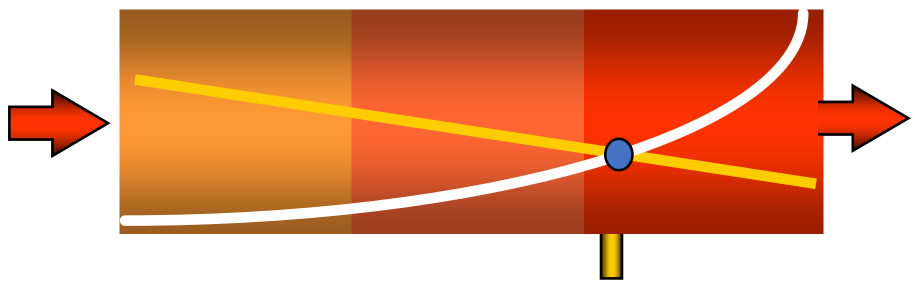
CITRATE?

Low Shear Rate

High Filtration Fraction

EFFECT OF FILTRATION PRESSURE EQUILIBRIUM

a) Part of the filter not used for filtration (high TMP)
b) Distal segment with high resistance (high drop P)
c) Easy clotting due to high Hct and Visc.



SOLUTIONS

1) Optimization of blood flow and Ultrafiltration (FF%)
2) Changes in the structure of the fiber (inner diameter)
3) Changes of filter geometry (Length and n. of fibers)

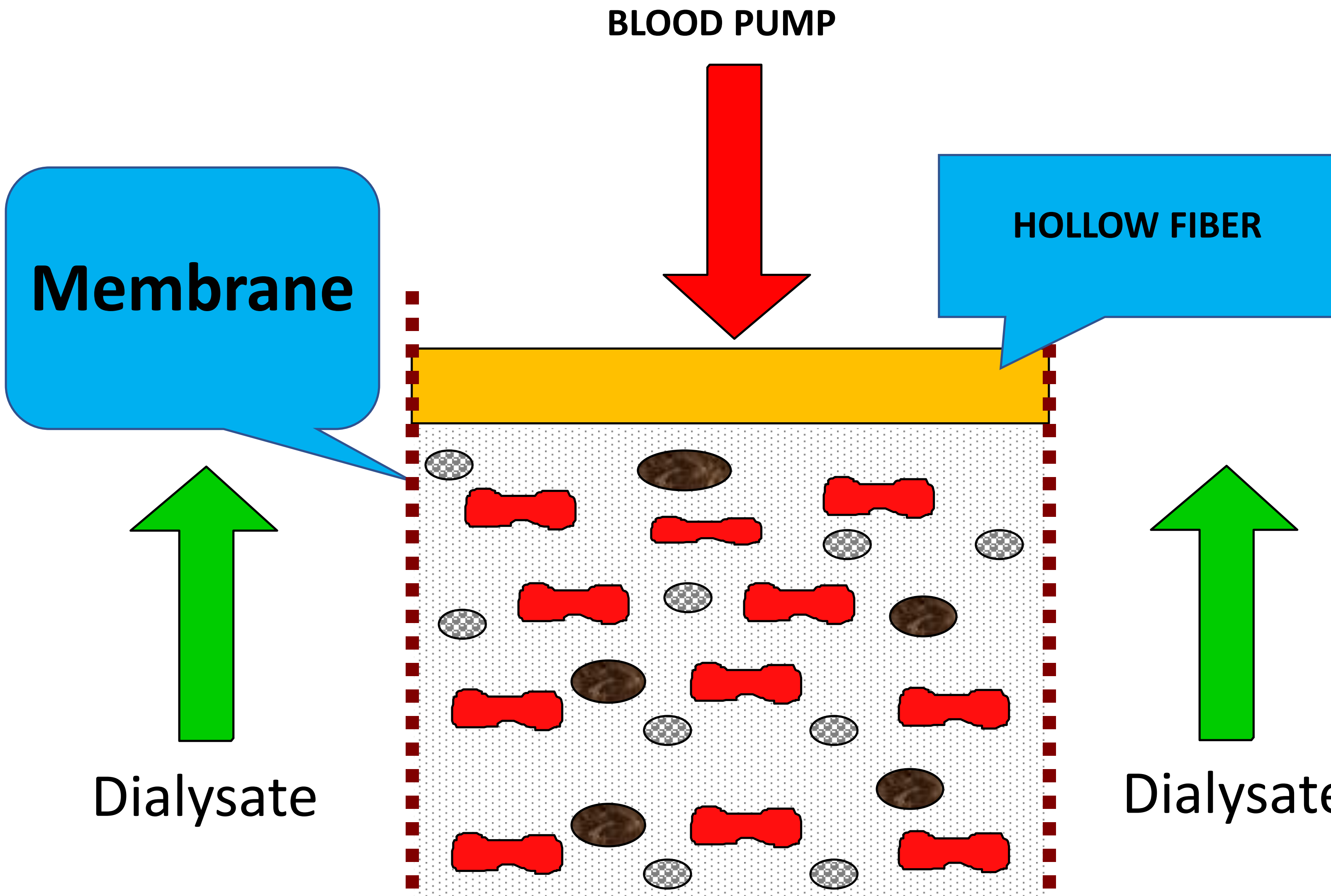
HOW IS FILTRATION FRACTION CALCULATED DURING PRE DILUTION HEMOFILTRATION?

FF = Qef / (Qp+Qrep)

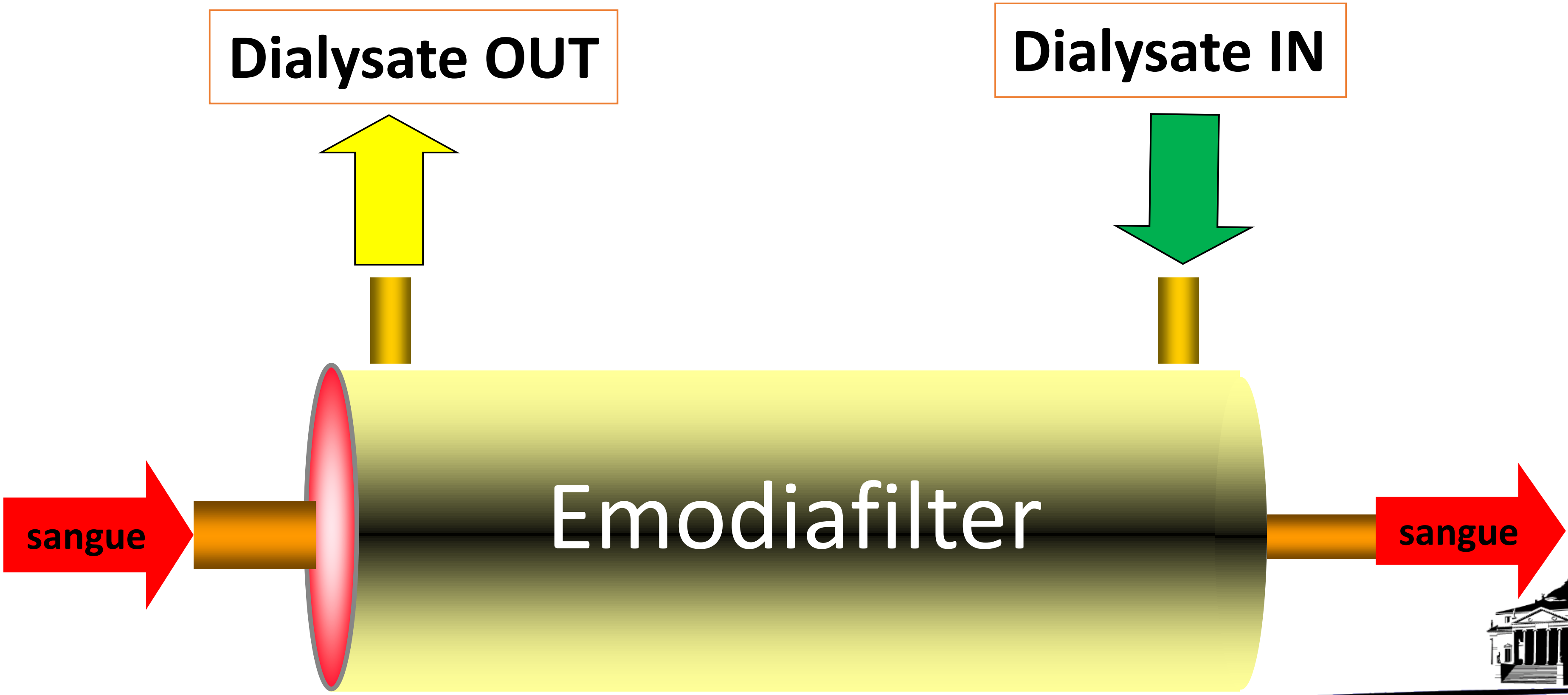
Qb 160 ml/min and Qrep 20 ml/min
in a 35% Ht patient
FF= 20/[(0.65 x 160)+20]= 16%

Optimal Ranges (on Qp) = 25++%

DIFFUSION

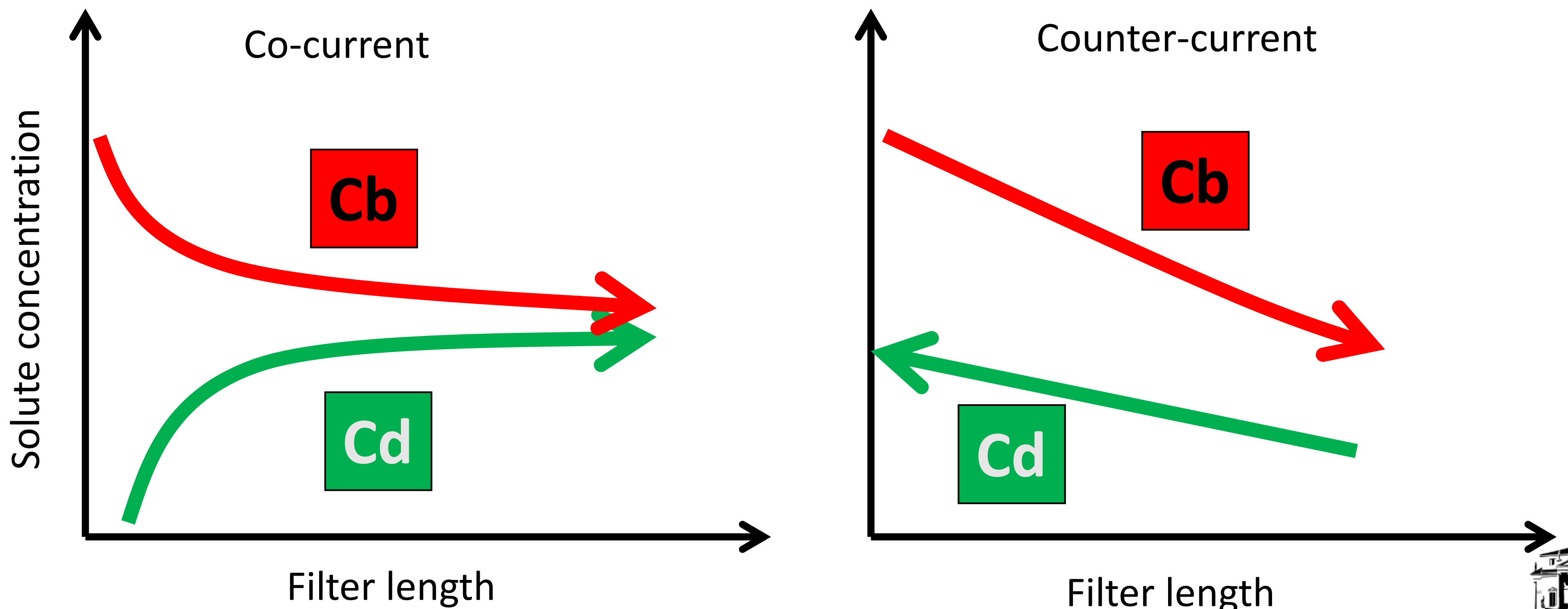


HEMODIALYSIS



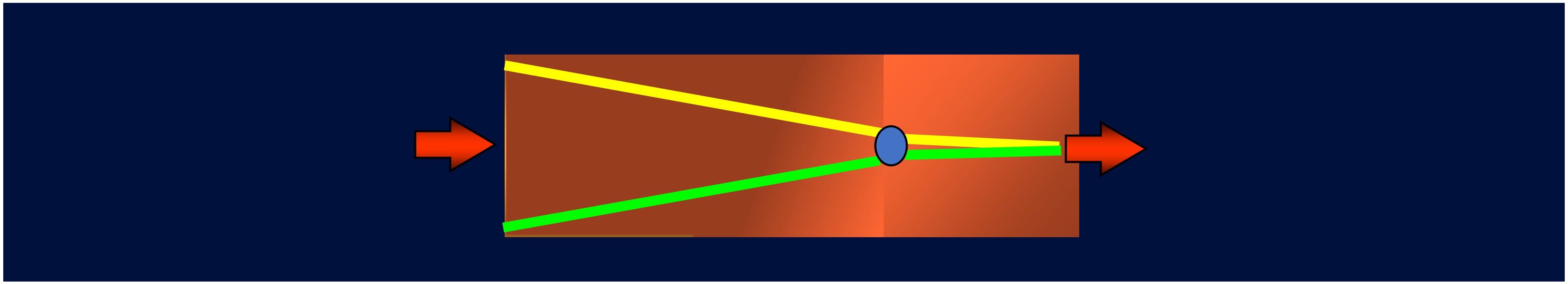
HEMODIALYSIS

Direction of dialysate flow



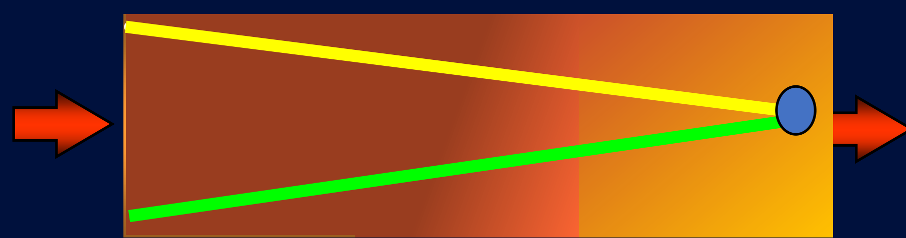
HEMODIALYSIS

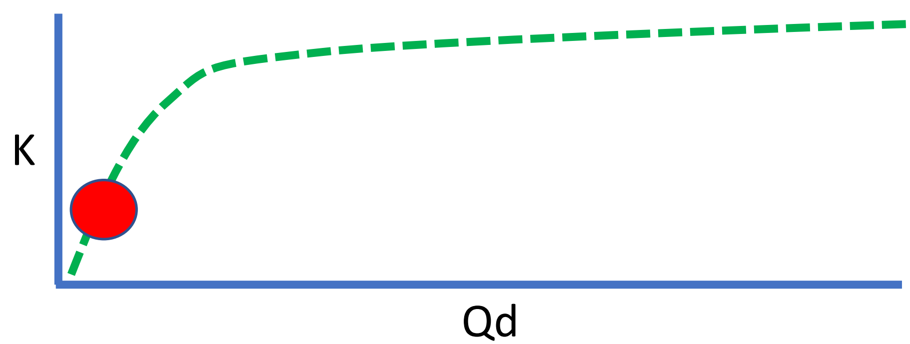
When Qd is low (<25ml/min)
And blood flow rate is relatively high (>150 ml/min),
dialysate be in osmotic equilibrium with plasma
-100% SATURATION-
Before the end of the filter



HEMODIALYSIS

Clearance increases proportionally with dialysate

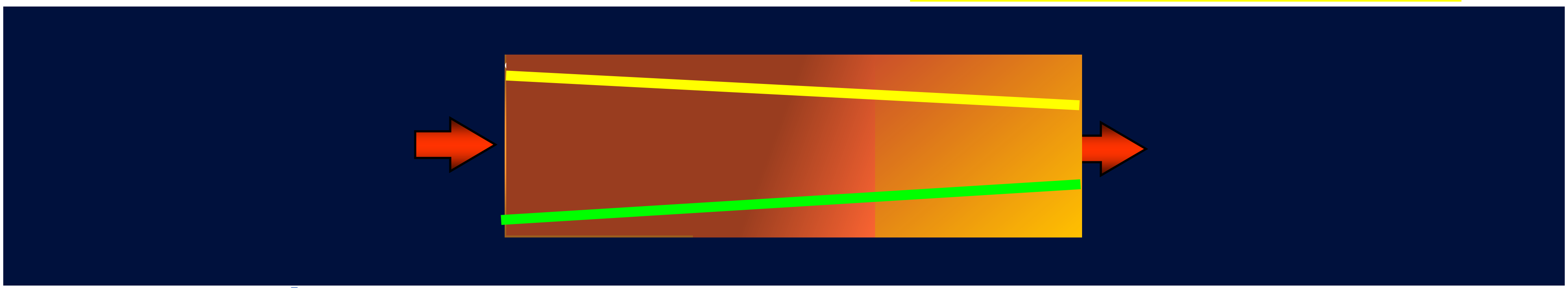


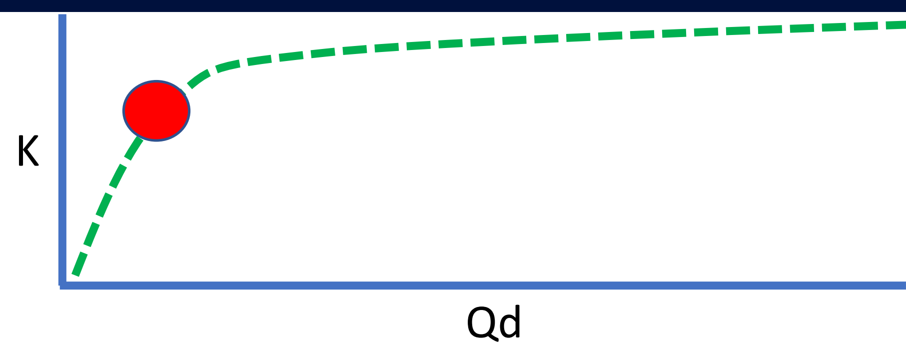


Rule of thumb: 100% saturation is generally achieved up to a Qd/Qb ratio of 0.2-0.3

HEMODIALYSIS

When Qd is relatively high (250 ml/min)
With respect to blood flow rate (150 ml/min),
dialysate will NOT be in osmotic equilibrium with plasma
Before the end of the filter (saturation <100%)





UREA CLEARANCE (K) IS ADEQUATELY ESTIMATED BY EFFLUENT FLOW RATE

K: Qeffl

NOTE:
This is true in postdilution hemofiltration and, for small molecules, for dialysate at low Qd (or in case of 100% saturation)

[UF]≅[P]

Qp 100 ml/min
Qeffl 20 ml/min
K: 20 ml/min

UREA CLEARANCE (K) REQUIRES EFFLUENT FLOW RATE ADJUSTMENTS IN PREDILUTION

[UF]≠[P]

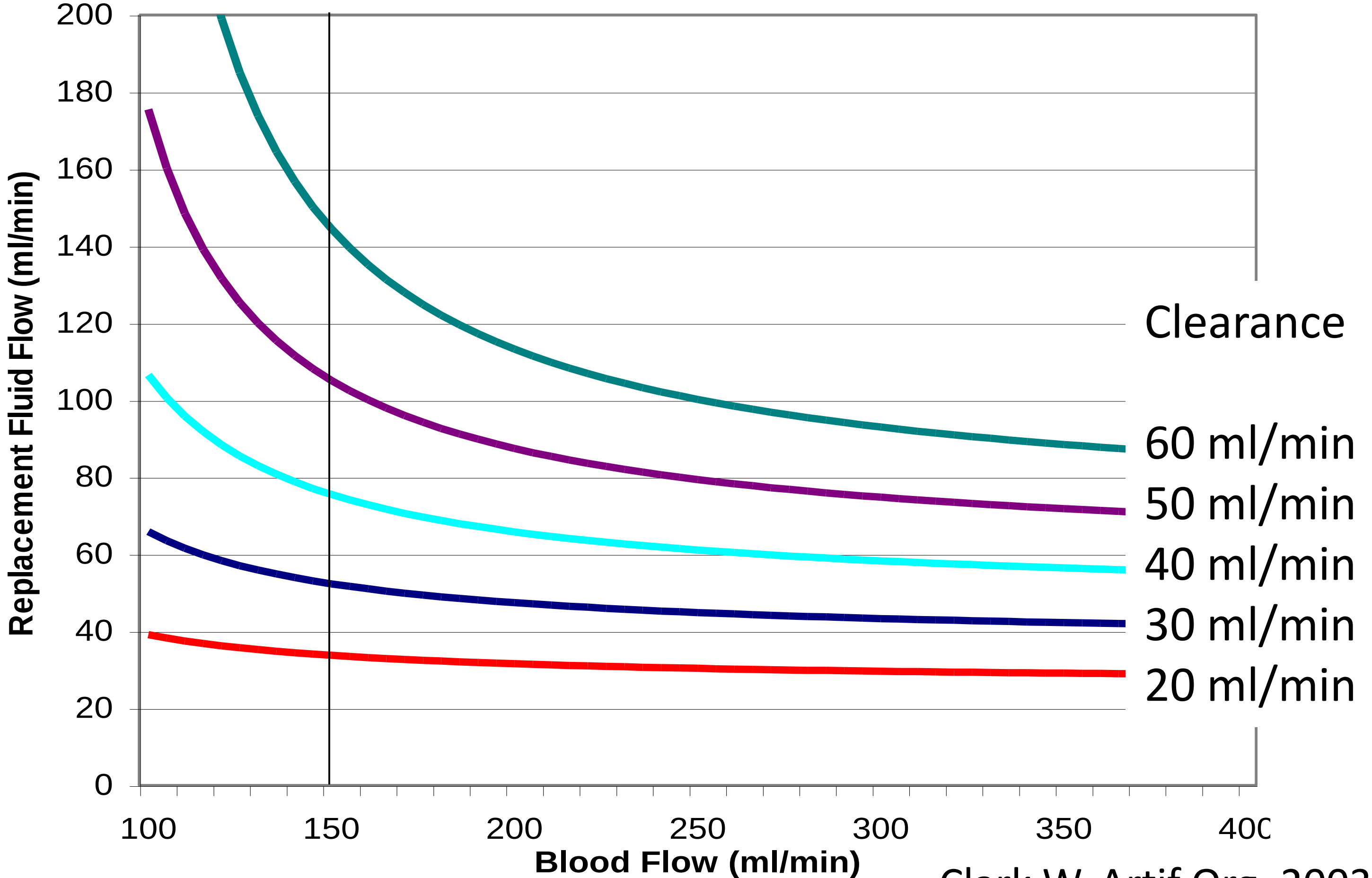
K: Qeffl x Qp/(Qrep+Qp)

Qp 100 ml/min

Qeffl 20 ml/min

K: 20 x 100/120= 16.7 ml/min

In pre-dilution, effluent rate increase does not necessarily causes a (proportional) clearance



Clark W, Artif Org, 2003

Research

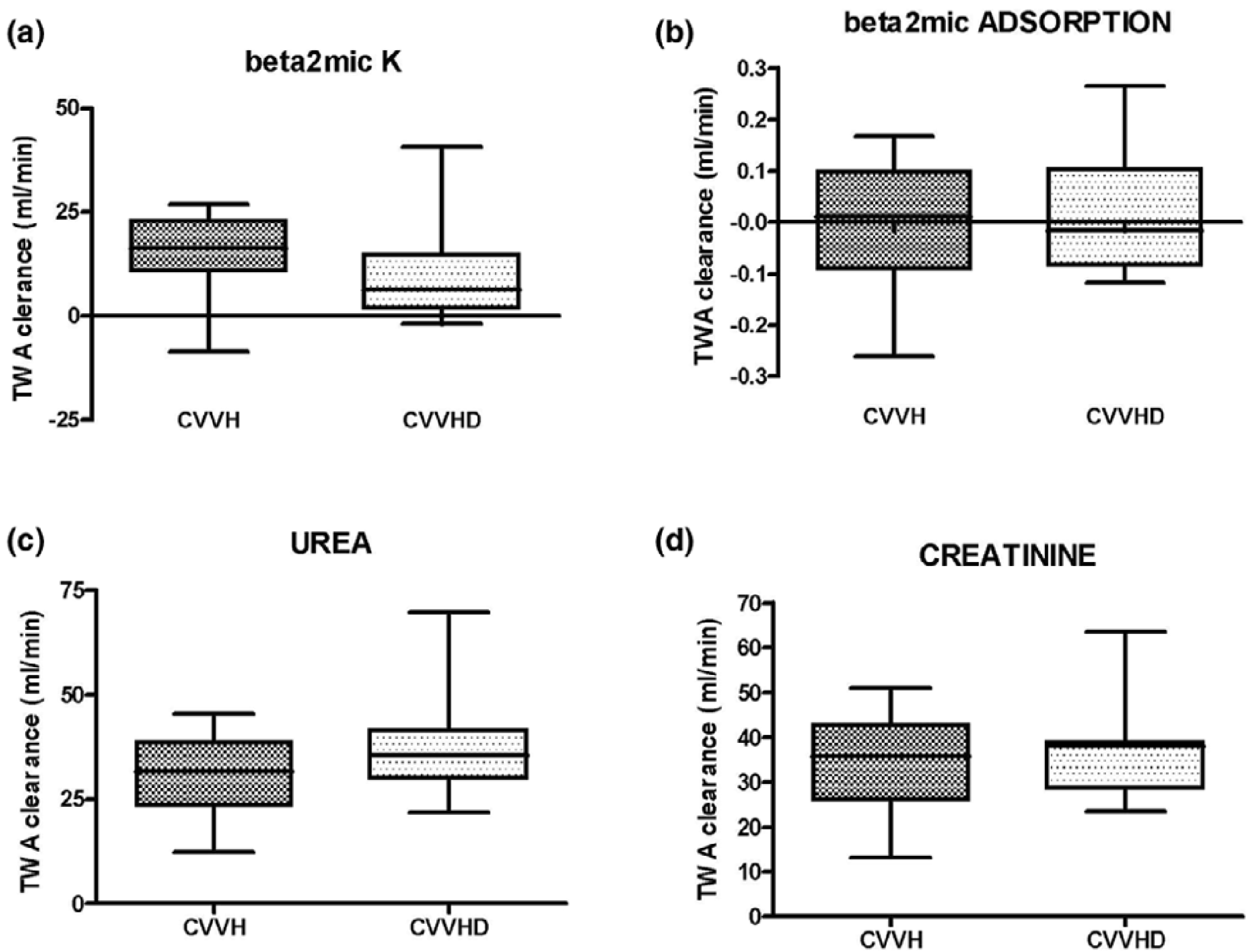
Open Access

Solute removal during continuous renal replacement therapy in critically ill patients: convection versus diffusion

Zaccaria Ricci[1], Claudio Ronco[2], Alessandra Bachetoni[3], Giuseppe D'amico[4], Stefano Rossi[4], Elisa Alessandri[1], Monica Rocco[1] and Paolo Pietropaoli[5]

CC2006

β_2m is an 11,600 Dalton molecule that is normally present in most biological fluids; it is filtered by glomeruli and is catabolised after proximal tubular reabsorption.

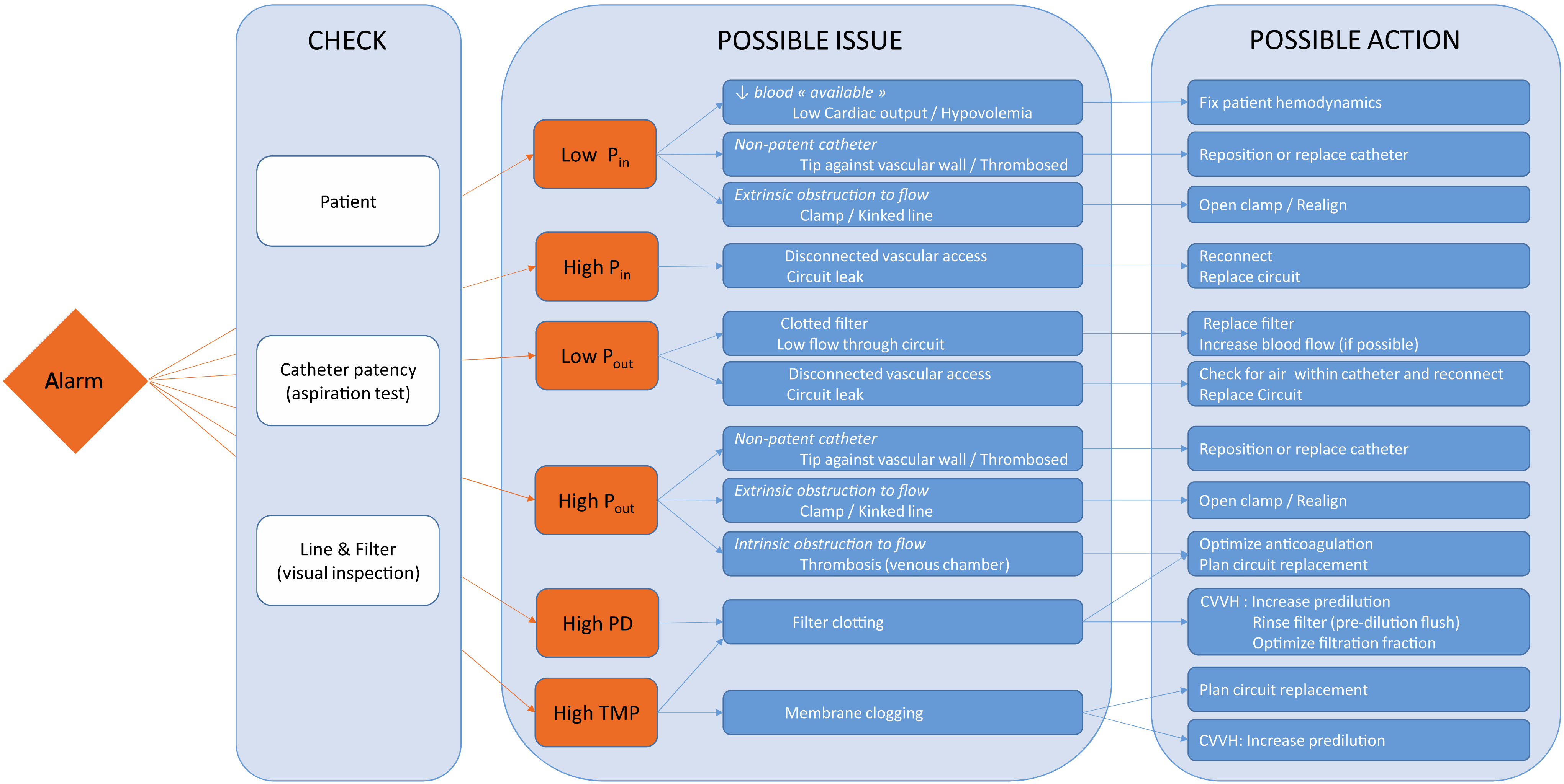


CURRENT OPINION

2018

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

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



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

SOME COMMENTS

What is probably currently lacking is:

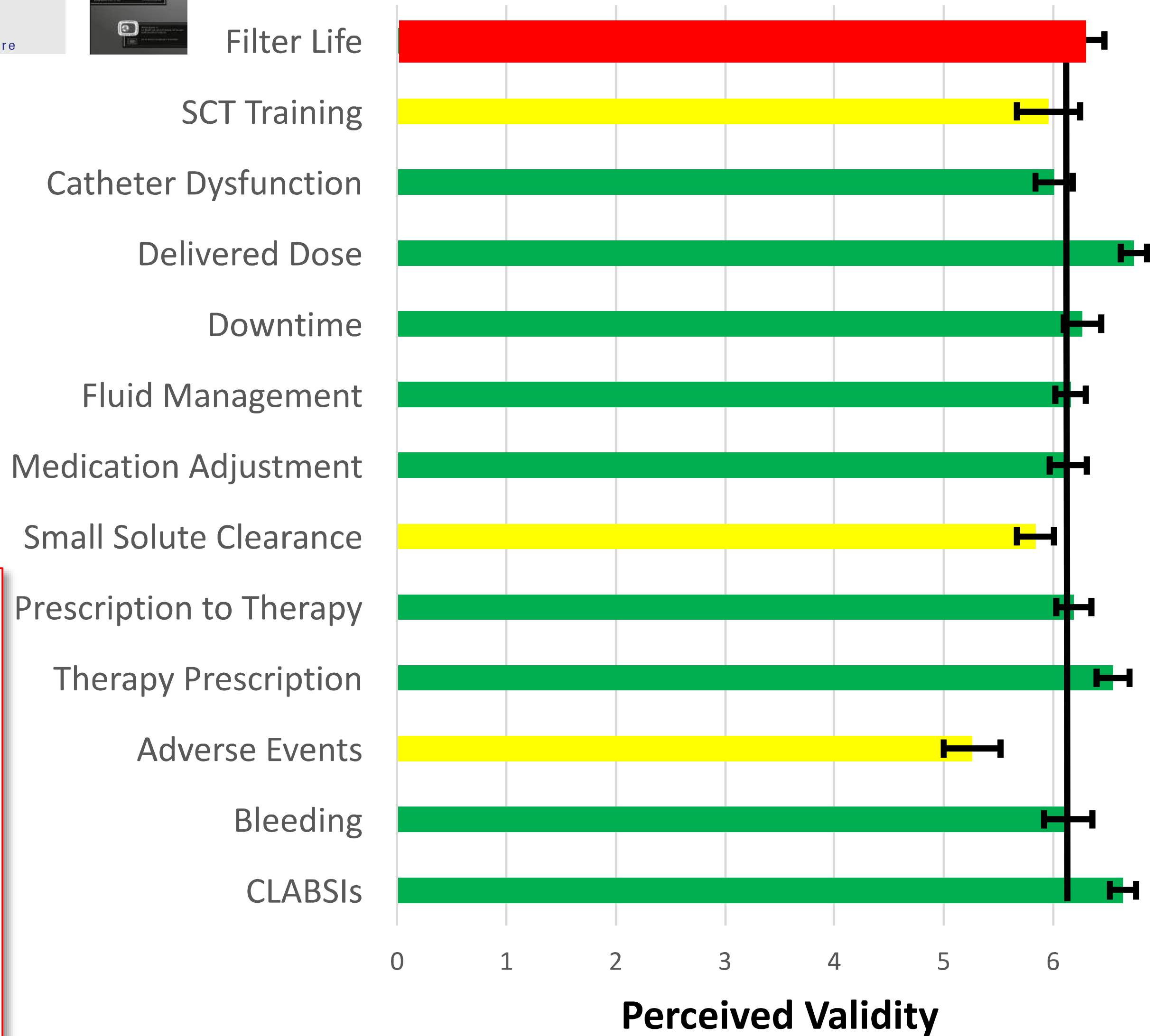
- A standard benchmark of circuit patency duration
- A standard TMP level or a trend of TMP when to start managing filter clogging
- A standard method to calculate, report and monitor TMP

Contents lists available at ScienceDirect

2018 Journal of Critical Care

journal homepage: www.journals.elsevier.com/journal-of-critical-care

QUALITY INDICATORS



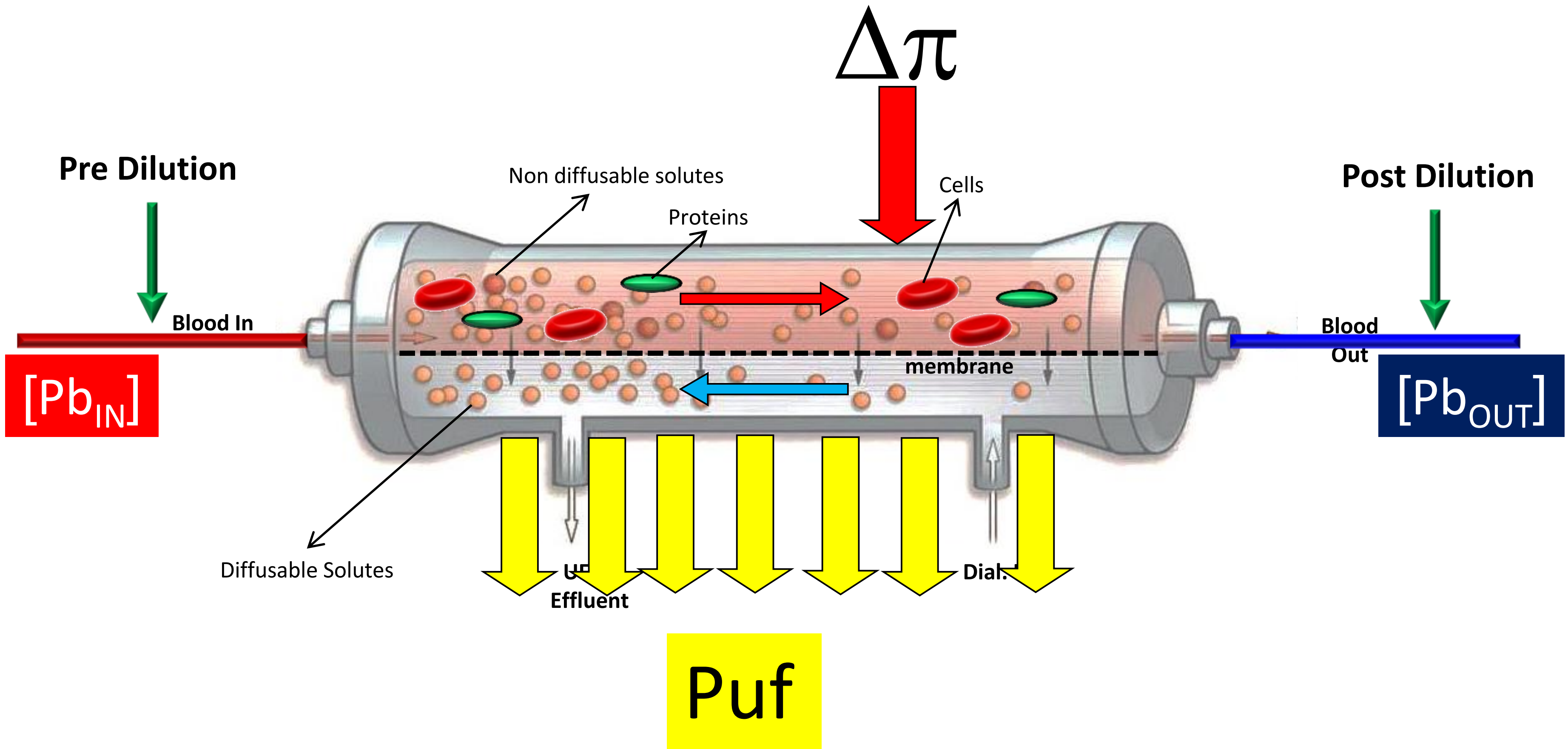
The duration of patency of each CRRT filter: Number of filter lasting 72 hrs / total number of filters used. Benchmark 50%

Filter change is dictated by consistently elevated transmembrane pressures of over 250 mm Hg for greater than 5 min
(ref Fealy, Ren Fail 2013, Catheter comparison)

A modified Delphi process to identify, rank and prioritize quality indicators for continuous renal replacement therapy (CRRT) care in critically ill patients☆

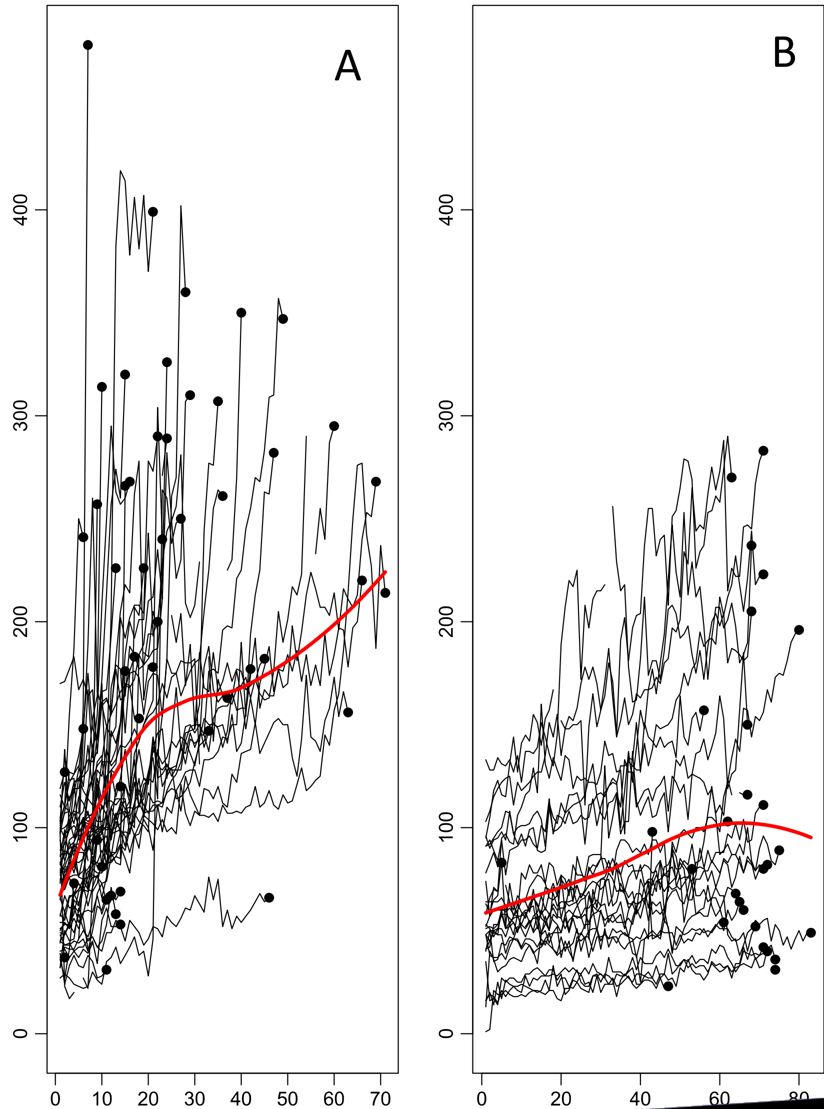
Oleksa G. Rewa, MD, MSc [a,*], Dean T. Eurich, BSP, PhD [b], R.T. Noel Gibney, MD [a], Sean M. Bagshaw, MD, MSc [a]

TMP = Filter - Dπ - Puf



1. PUF is proportional to convection rate
2. If PUF is positive TMP is low; if PUF is negative TMP increases
3. During dialysis PUF is low

TMP monitoring



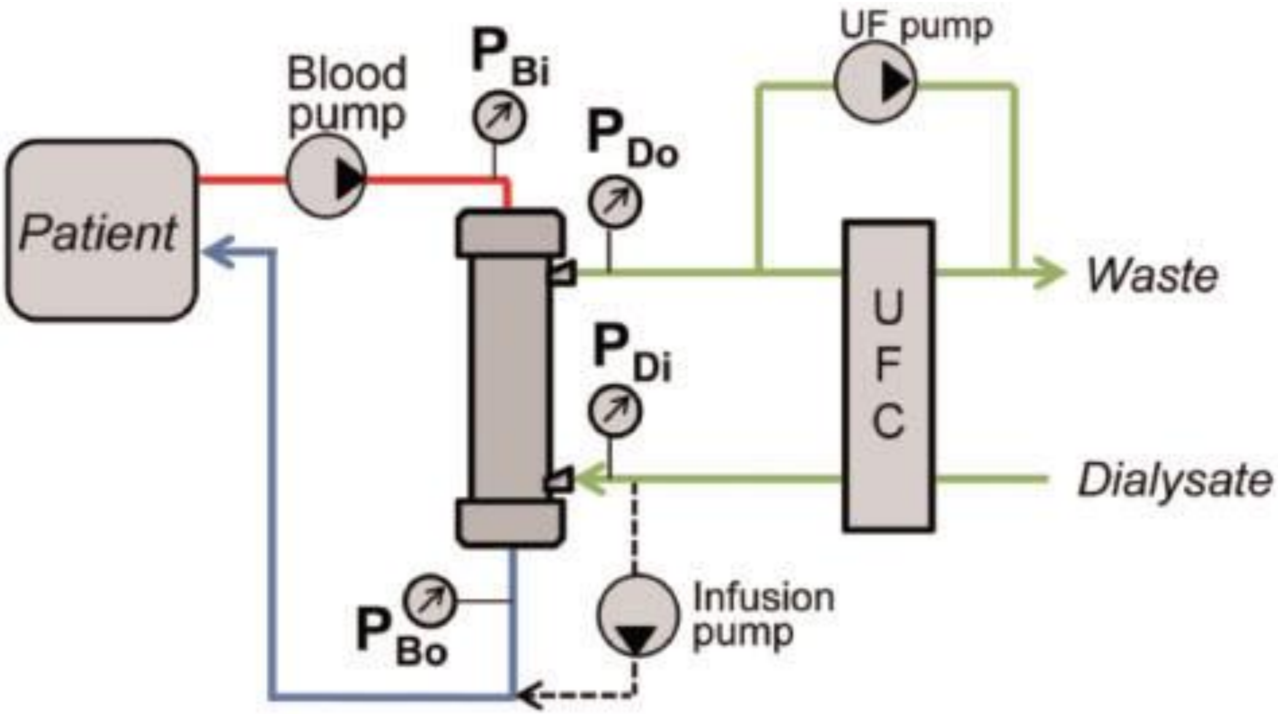
Panel A: clotted prematurely
Panel B: clotted after 72 hours
TMP on y axes
Hours on x axes

1. Should we really wait for TMP to increase up to the pressure limit for indicating a circuit change?
2. What is the limit?
3. Is the trend more important than absolute levels?

Kakajiwala A, et al Ped Neph 2017

Measuring intradialyser transmembrane and hydrostatic pressures: pitfalls and relevance in haemodialysis and haemodiafiltration

Ficheux A et al, CKJ 2019



Estimating TMP from 2, 3 and 4 points:

(1) $TMP2 = P_{Bo} - P_{Do}$

(2) $TMP3 = ([P_{Bi} + P_{Bo}]/2) - P_{Do}$

(3) $TMP4 = ([P_{Bi} + P_{Bo}]/2) - ([P_{Di} + P_{Do}]/2)$

Measuring intradialyser transmembrane and hydrostatic pressures: pitfalls and relevance in haemodialysis and haemodiafiltration

Ficheux A et al, CKJ 2019

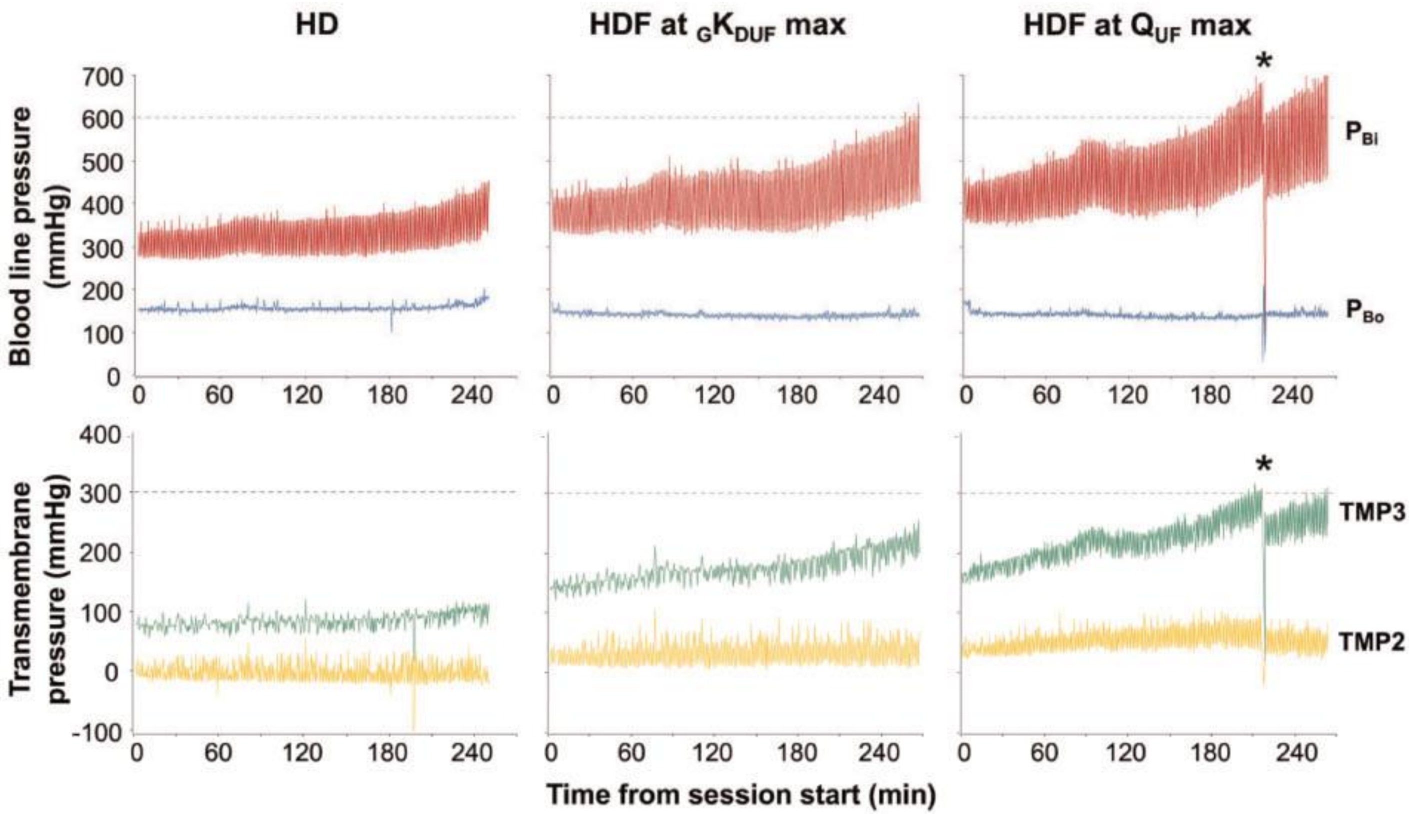
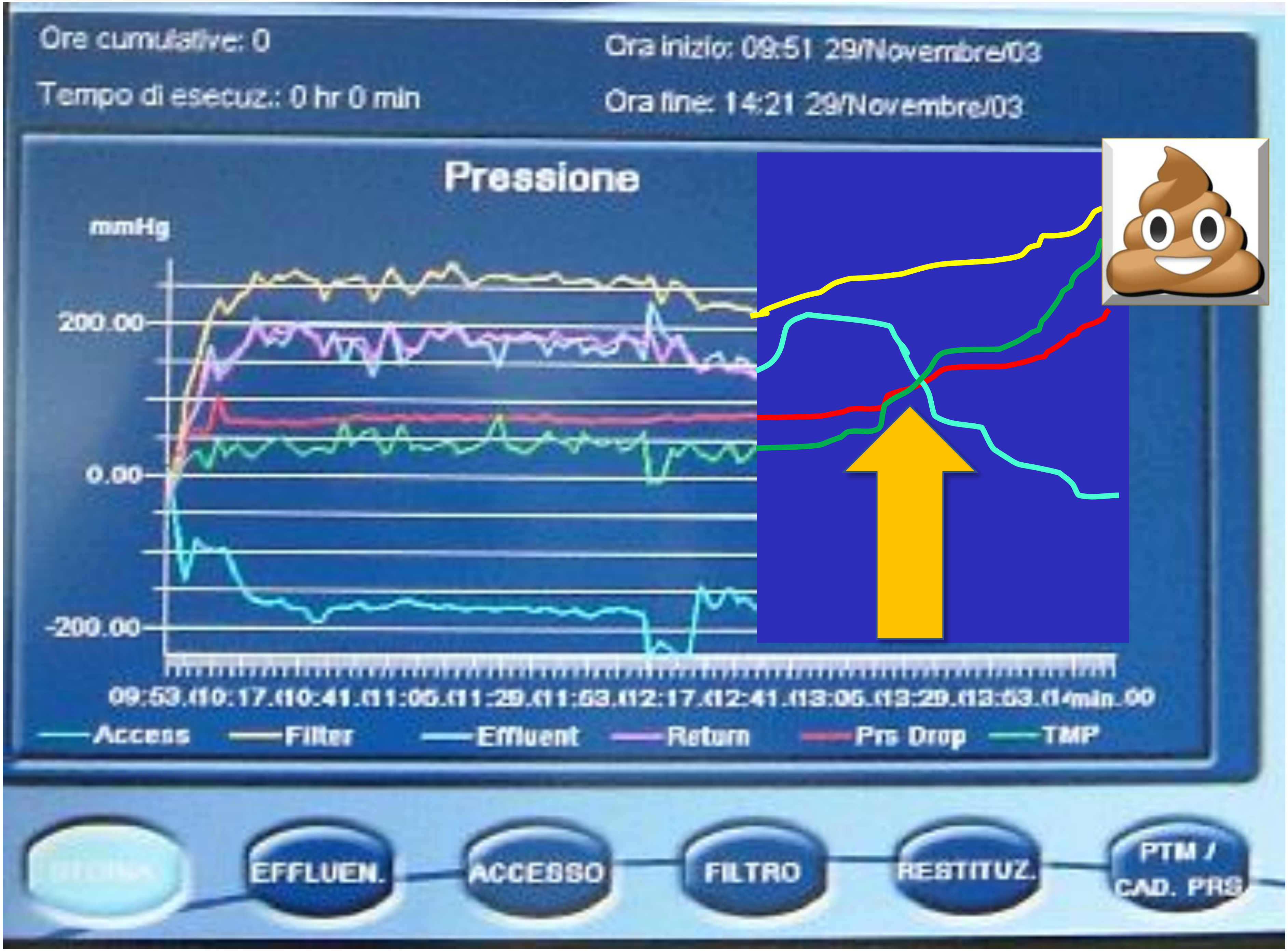


Table 2. Observed characteristics of different dialysis conditions

Dialysis condition	HD	Q_{UF} at $_GK_{D\text{-}UF}$ max	Q_{UF} max	P-value
Number of sessions	26	27	26	–
Session duration (min)	234 ± 3	237 ± 3	236 ± 4	0.51
Blood flow (mL/min)	362 ± 7	360 ± 7	365 ± 6	0.50
Dialysate flow (mL/min)	601 ± 2	601 ± 1	601 ± 1	0.38
Ultrafiltration volume for weight loss (L)	2.6 ± 0.2	2.8 ±0.2	2.9 ± 0.2	0.74
Ultrafiltration volume for infusion (L)	0	17.8 ± 0.3	22.2 ± 0.5	<0.001*
Total ultrafiltration volume (L)	2.6 ± 0.2	20.6 ± 0.4	25.1 ± 1.0	<0.001*
Total ultrafiltration flow over blood flow (%)	3.0 ± 0.2	24.0 ± 0.3	28.7 ± 0.3	<0.001*


Ore cumulative: 0
Tempo di esecuz.: 0 hr 0 min
Ora inizio: 09:51 29/Novembre/03
Ora fine: 14:21 29/Novembre/03
Pressione
mmHg
200.00
0.00
-200.00
09:53.10:17.10:41.11:05.11:29.11:53.12:17.12:41.13:05.13:29.13:53.14min.00
Access
Filter
Effluent
Return
Prs Drop
TMP
EFFLUEN.
ACCESSO
FILTRO
RESTITUZ.
PTM /
CAD. PRS

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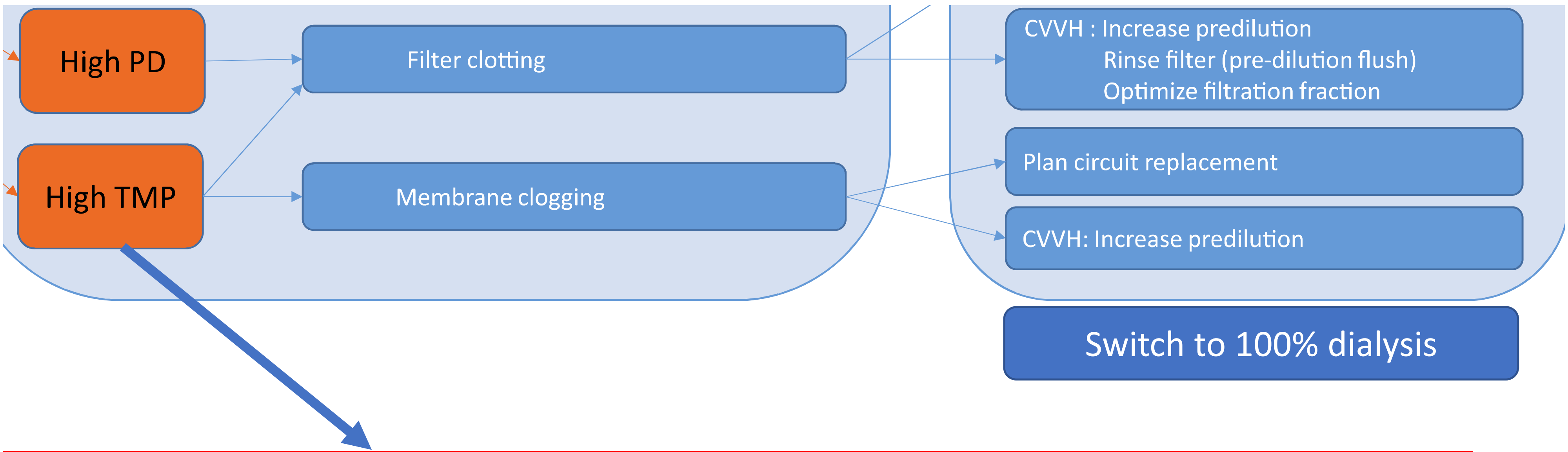

Consider that filter efficiency at this time is likely significantly compromised!!

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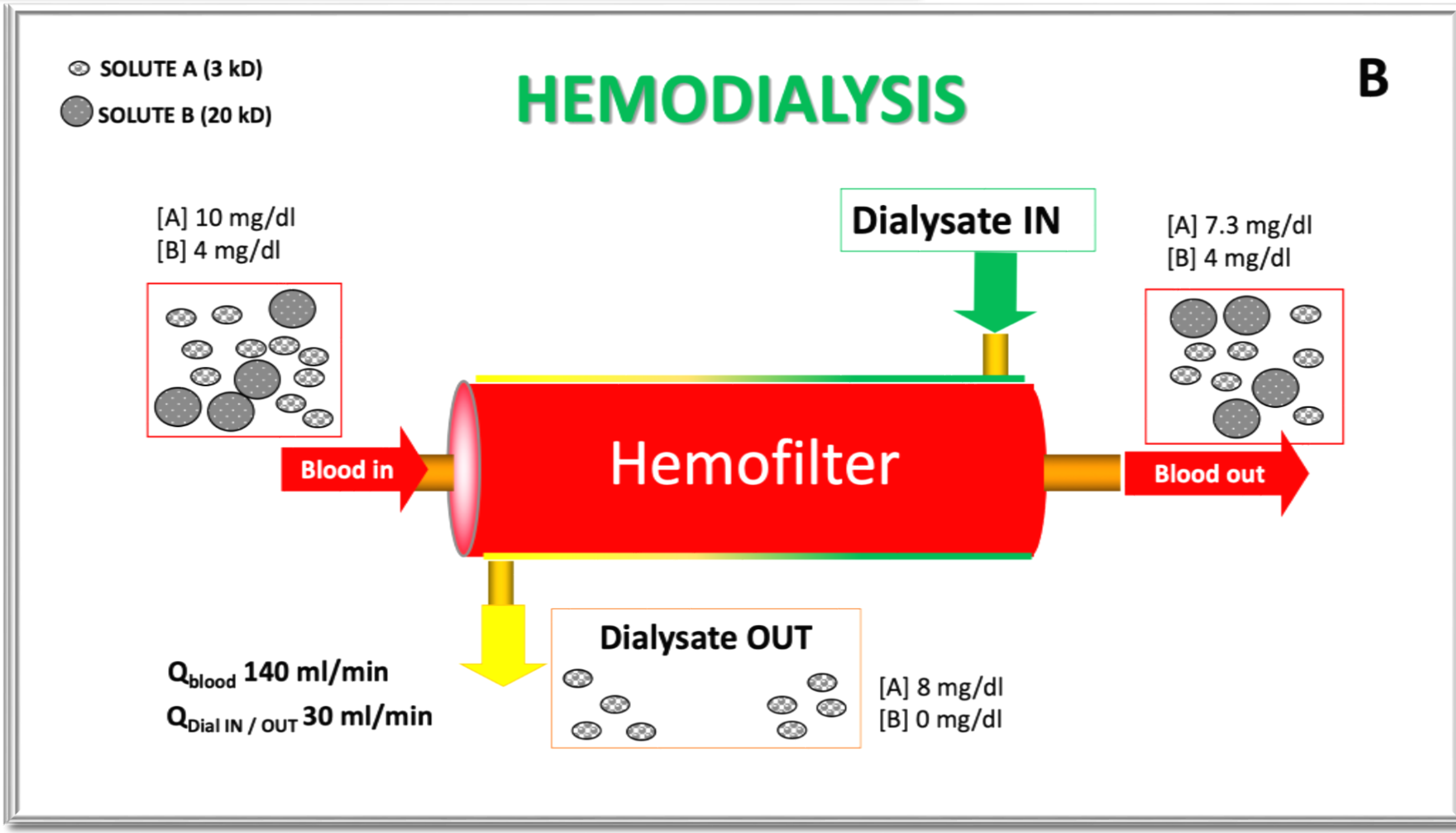
IN CONCLUSION....



IN CONCLUSION

1. By convection, ultrafiltration hemofiltration are delivered
2. By diffusion, dialysis
3. Convection implies filtration fraction control
4. Diffusion requires knowledge of dialysate saturation
5. Filter hemodynamics is probably challenged by convection>diffusion
6. TMP is the parameter to monitor filter conditions
7. Standardized benchmarks (TMP monitoring method, TMP threshold, TMP slope) are lacking