CRRT
Review and Refresh

Pam Waters, RN

Acute Field Mentor-West US Region

Baxter-Gambro Renal

Los Angeles, CA

June 11, 2014

Prismaflex 5.1 SW only

GAMBRO®

Course Objectives

By the end of the Gambro CRRT training course the participant will be able to:

- Discuss the basic CRRT principles
- Discuss the basic principles of the solute transport mechanisms
- Identify the clinical indications for administering CRRT, including an overview of patient selection and therapy application
- Discuss evidence based practice and supporting research
- Describe the CRRT machine's safety management features, pressure monitoring and fluid balance principles.

Continuous Renal Replacement Therapy (CRRT)

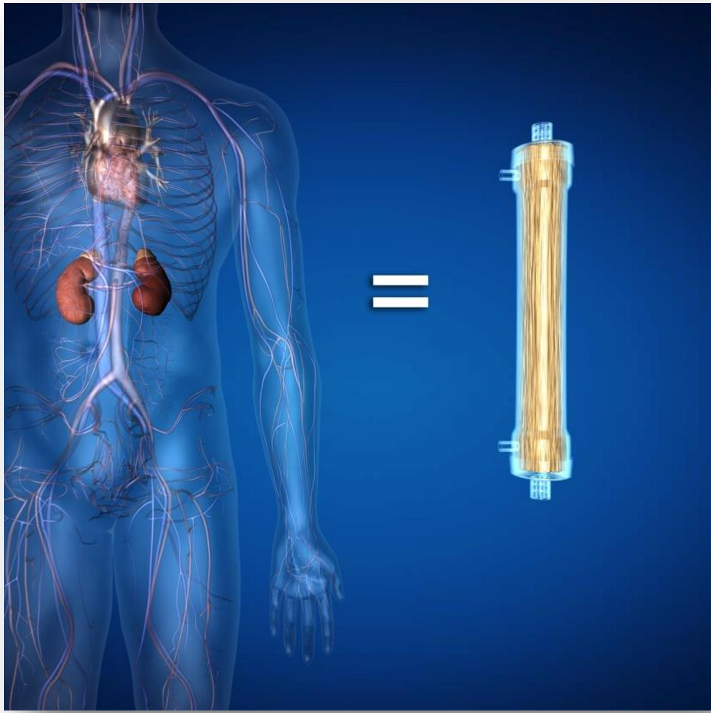
"Any extracorporeal blood purification therapy intended to substitute for impaired renal function over an extended period of time and applied for or aimed at being applied for 24 hours/day."

Bellomo R., Ronco C., Mehta R, Nomenclature for Continuous Renal Replacement Therapies, AJKD, Vol 28, No. 5, Suppl 3, Nov 1996

Why CRRT?

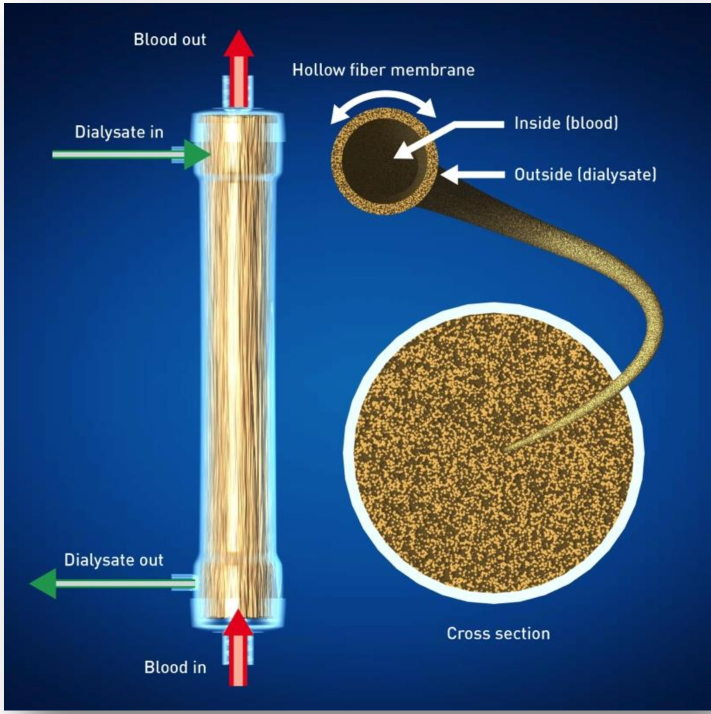
CRRT closely mimics the native kidney in treating AKI and fluid overload

- Removes large amounts of fluid and waste products (urea, creatinine) over time
- Re-establishes electrolyte and pH balance
- Tolerated well by hemodynamically unstable patients



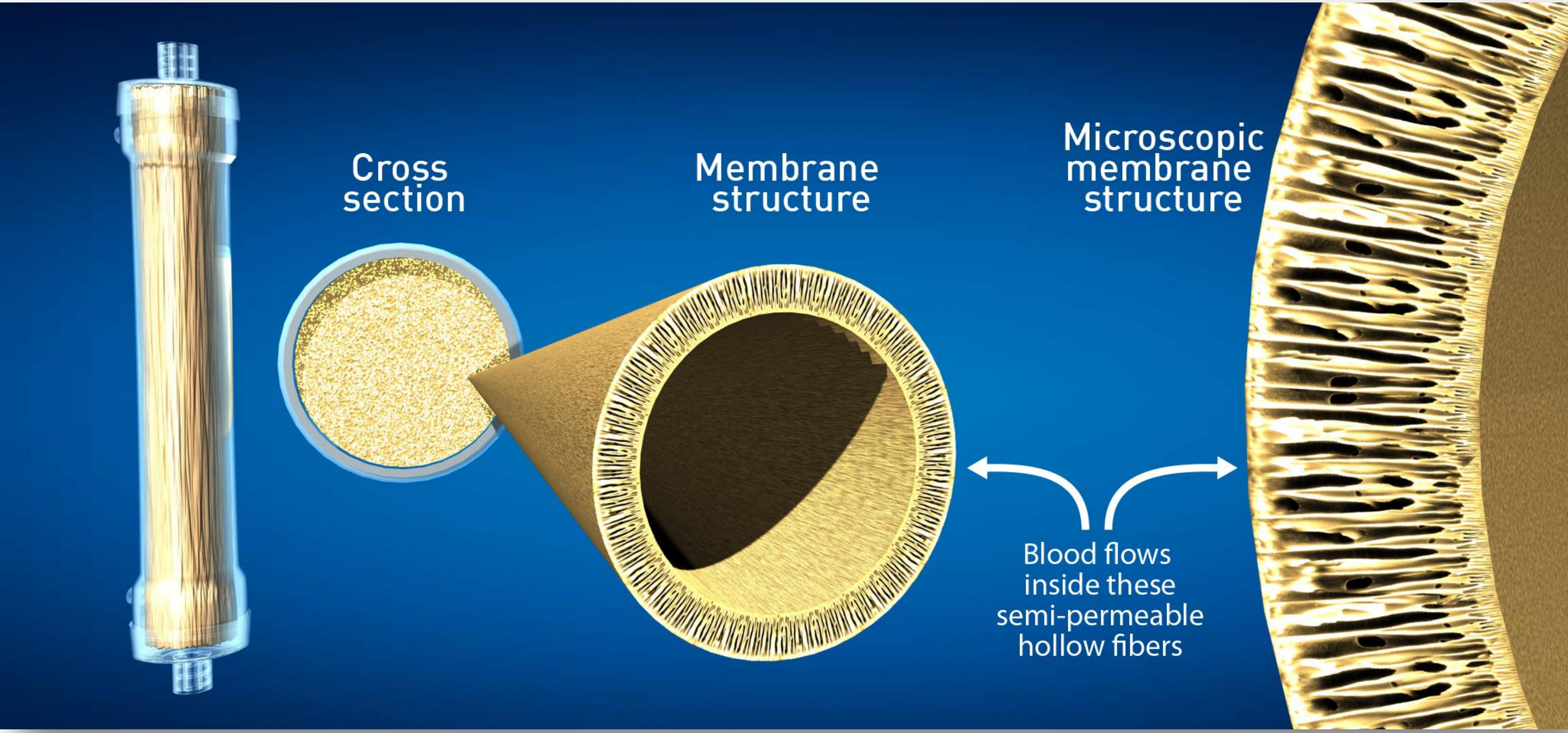
Anatomy of a Hemofilter

- 4 External ports
  - Blood and dialysis fluid
- Potting material
  - Support structure
- Hollow fibers
  - Semi-permeable membrane
- Outer casing



Hemofilter: Semi-permeable membrane

Allows solutes (molecules or ions) up to a certain size to pass through



CRRT Transport Mechanisms

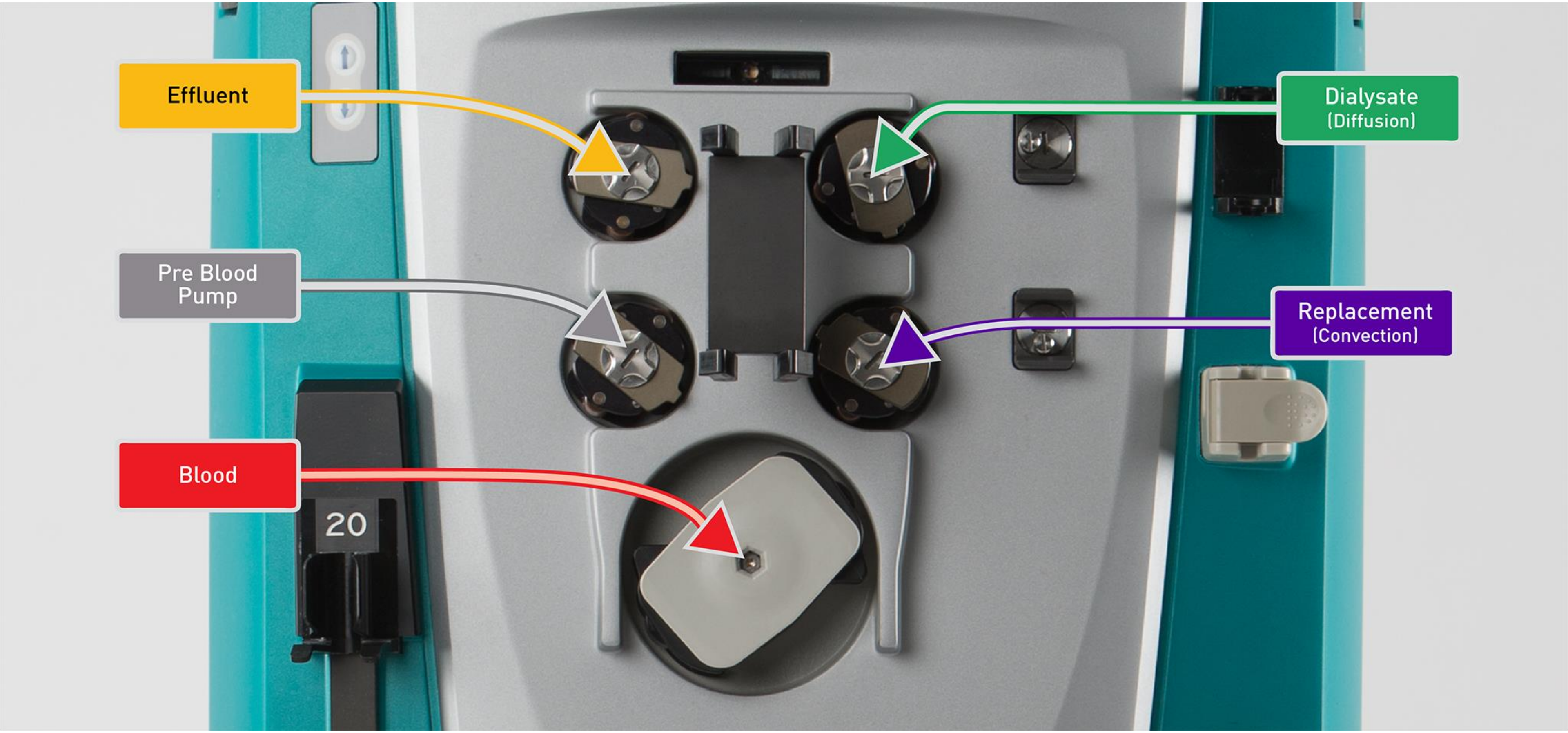
CRRT Modes of Therapy

- **SCUF:** Slow Continuous Ultrafiltration. Primary goal is to remove patient fluid
- **CVVH:** Continuous Veno-Venous Hemofiltration. Primary goal is to achieve small, medium and large molecule clearance, remove patient fluid
- **CVVHD:** Continuous Veno-Venous HemoDialysis. Primary goal is to achieve small molecule clearance, remove patient fluid
- **CVVHDF:** Continuous Veno-Venous HemoDiaFiltration. Primary goal is to achieve highly effective small, medium and large molecule clearance, remove patient fluid

All modes will assist in maintaining hemodynamic stability due to the gentle and gradual fluid removal as tolerated by the patient MAP.

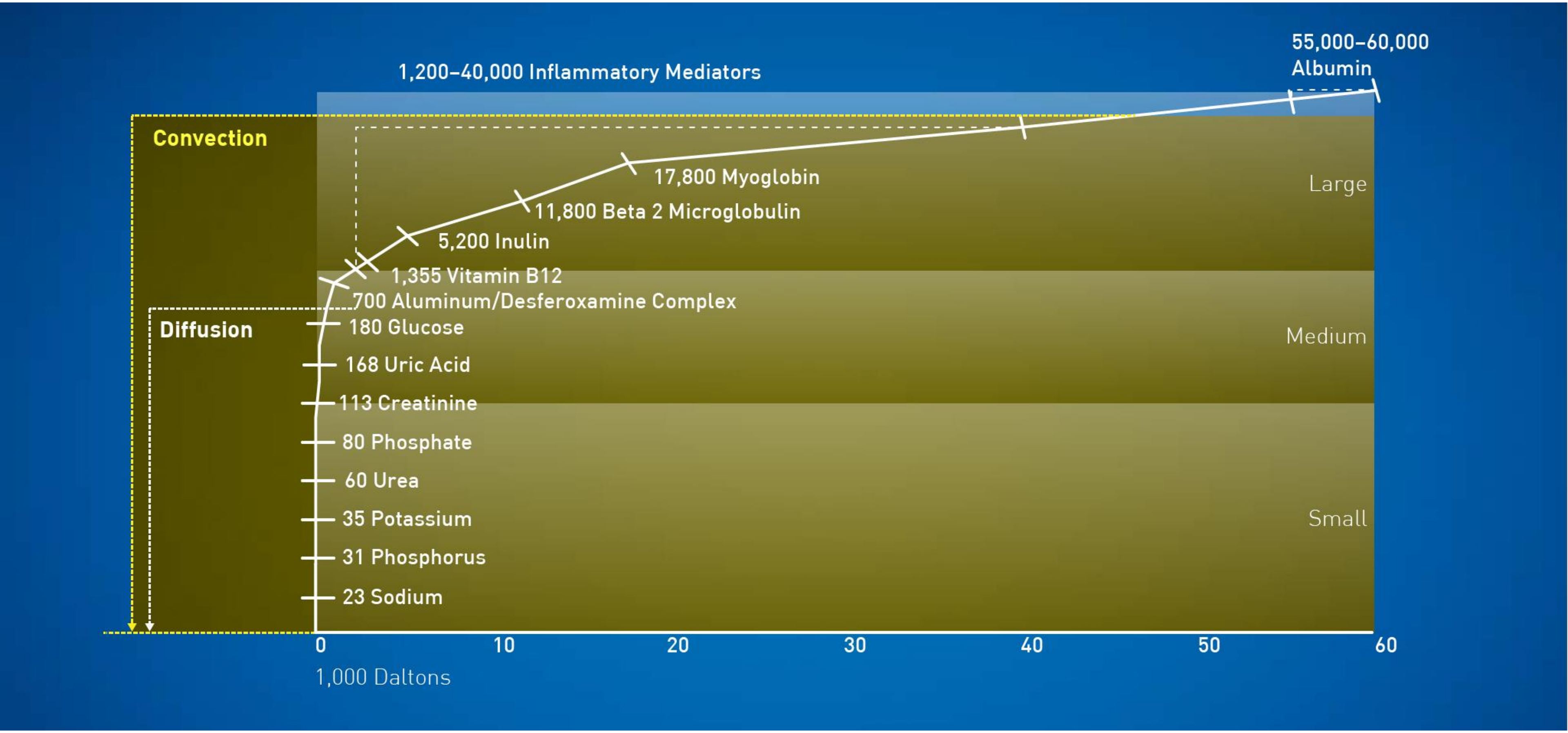
GAMBRO®

Flow Control Unit – Pumps



GAMBRO

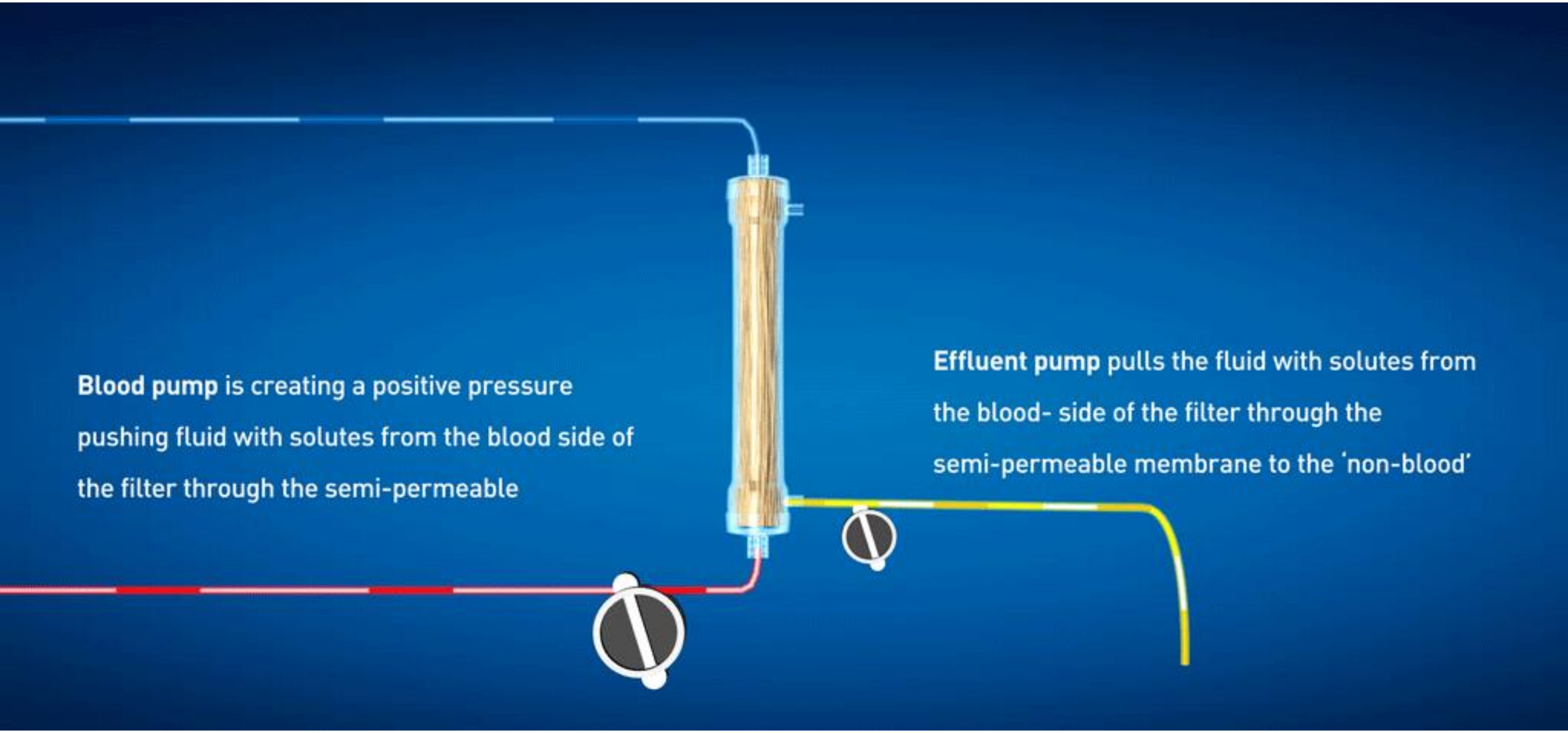
Molecular Weights



* Filter has a 50K cut off

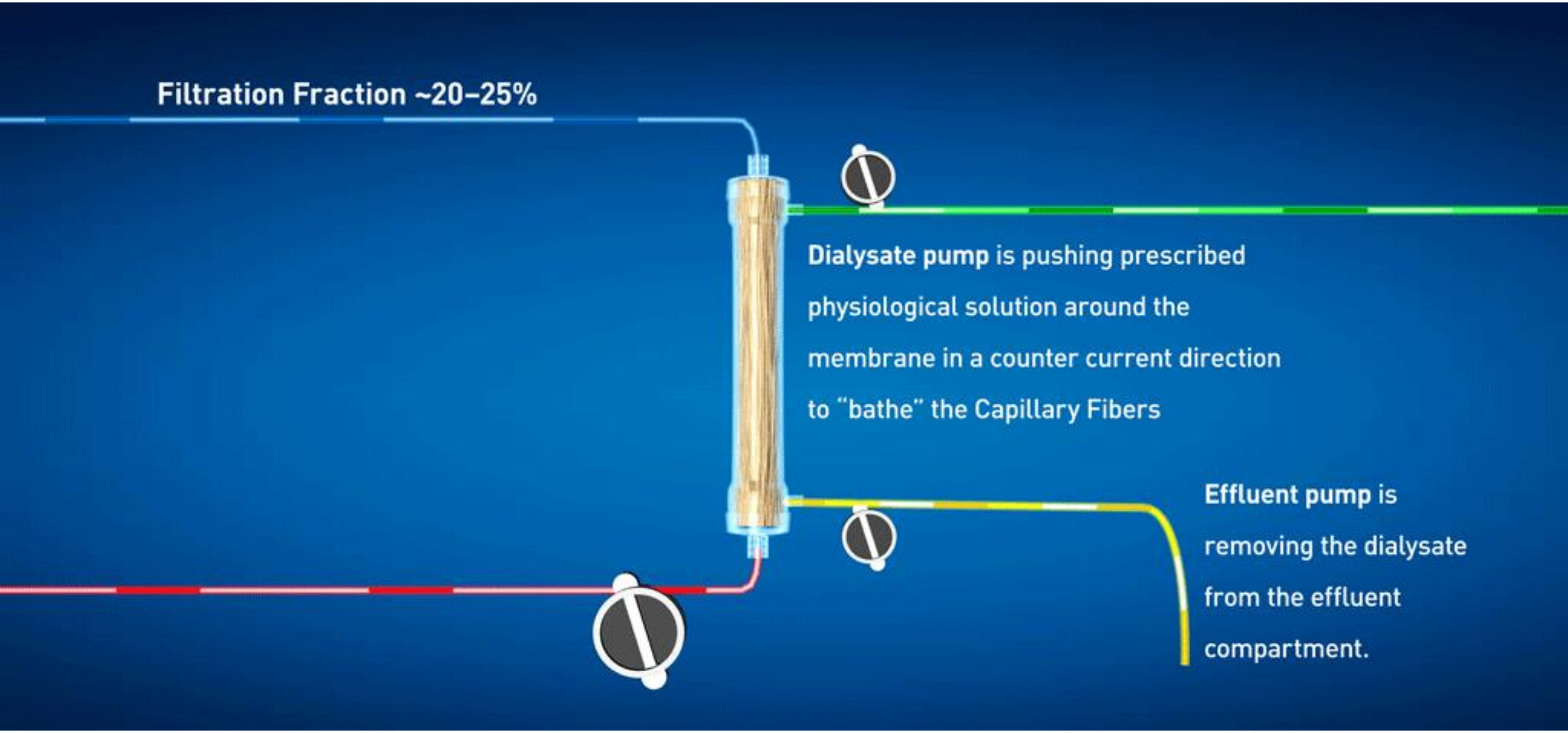
Ultrafiltration

The movement of fluid through a semi-permeable membrane driven by a pressure gradient (hydrostatic pressure)



Diffusion = Hemodialysis

The movement of solutes only from an area of higher concentration to an area of lower concentration



* Filter has a 50K cut off

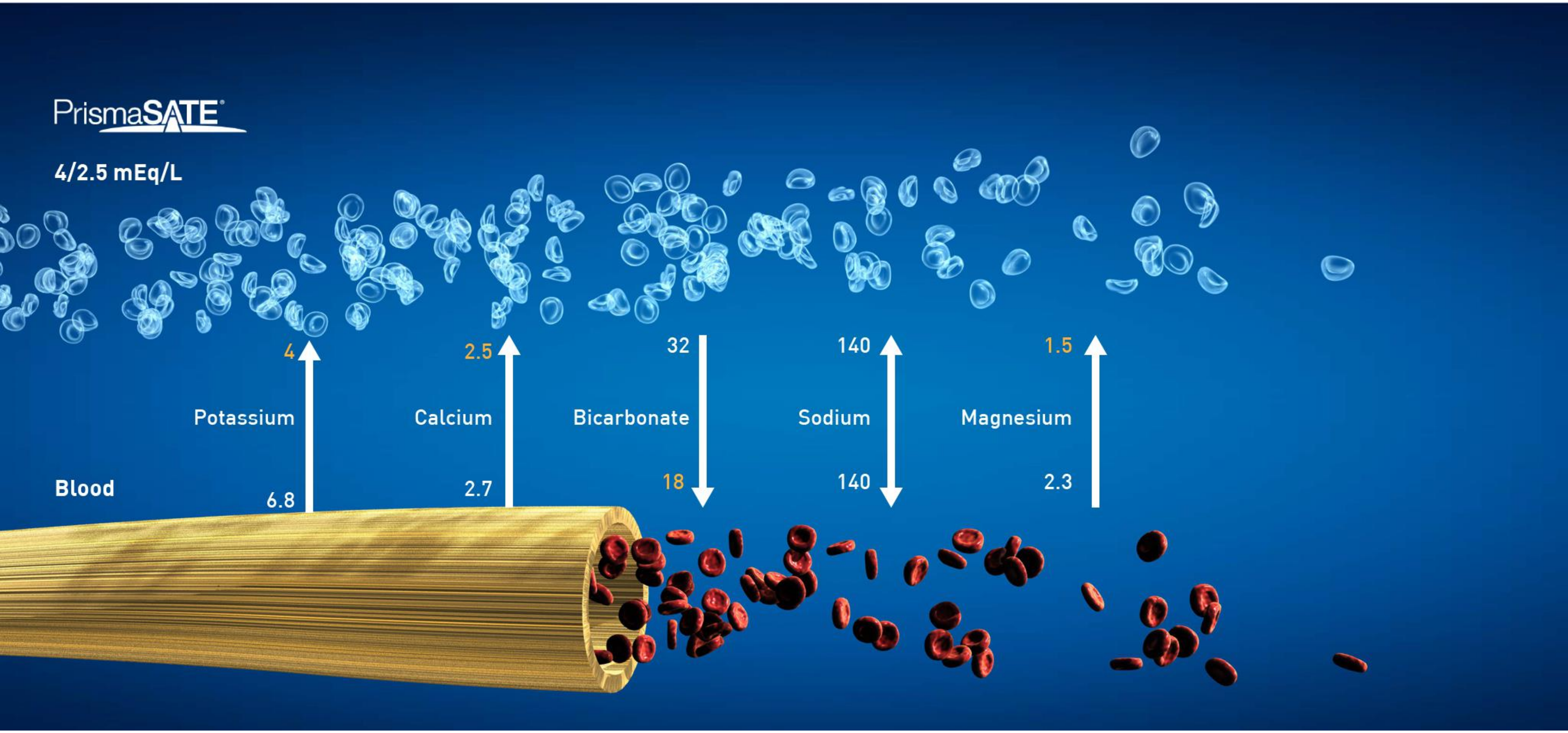
Major factors affecting diffusion

Solute removal by diffusion depends on:

- Concentration gradient blood / dialysis
- Dialysate flow rate
- Molecular size – diffusion clears small molecules
- Permeability of the membrane

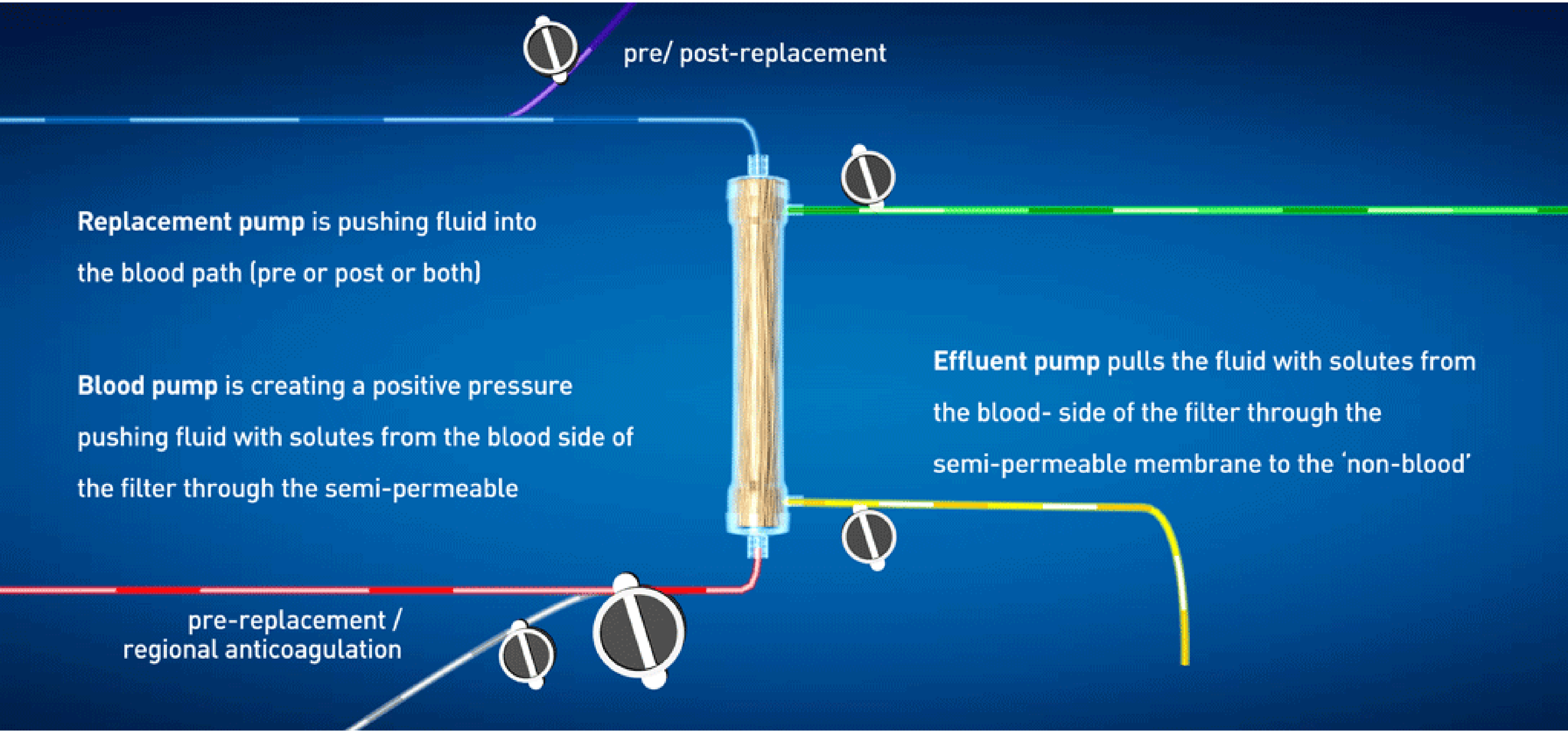
GAMBRO®

How does diffusion work???



Convection "Solute drag"= hemofiltration

The forced movement of fluid with dissolved solutes
(the fluid will drag the solutes)



Major factors affecting convection

Solute removal by convection depends on:

- High Membrane permeability
- Molecular size
- Degradation of filter membrane (can decrease performance)
- Replacement fluid flow rate (pressure gradient)

How Pre or Post Replacement works!

Pre Replacement

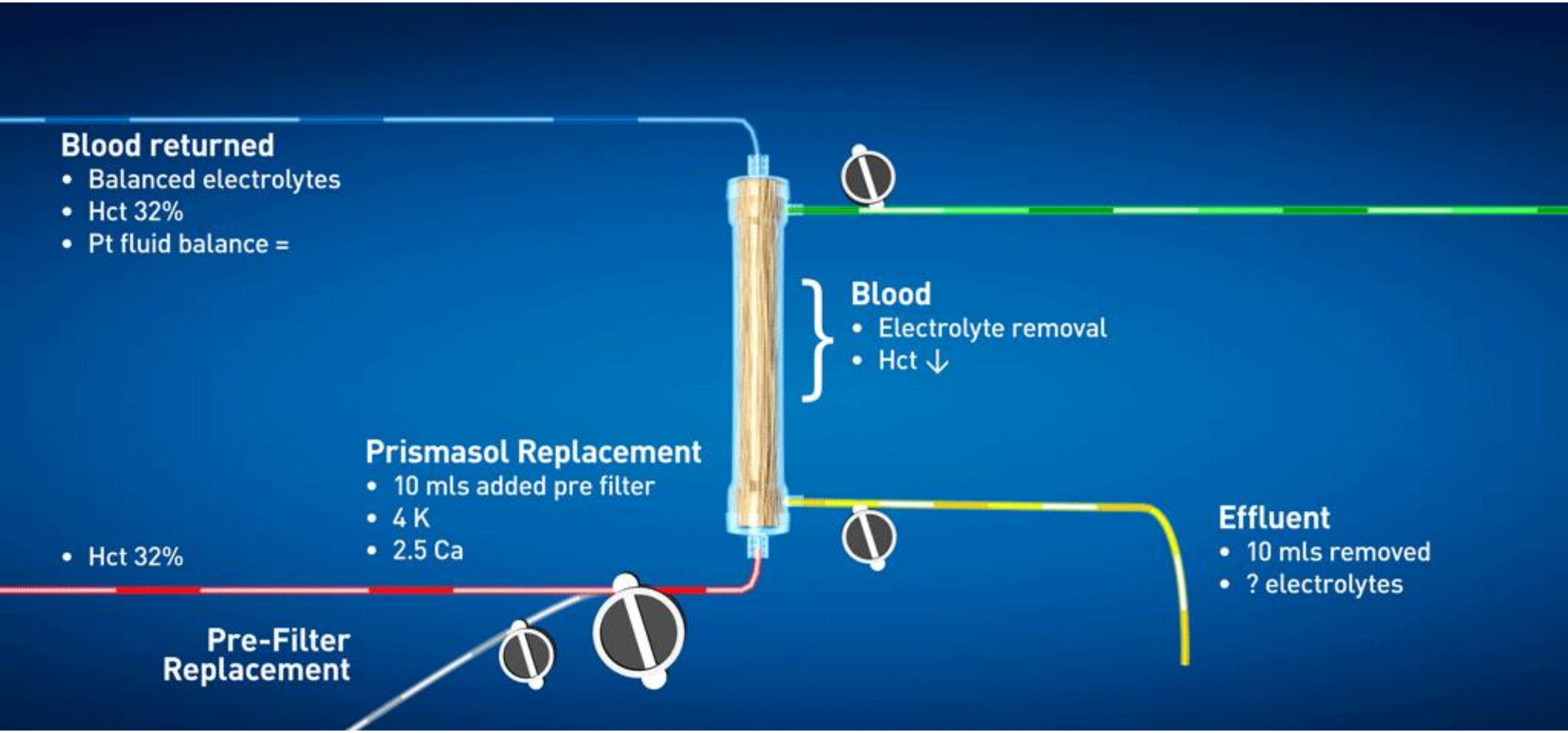
- Pre-filter replacement solution will deliver into the blood flow at set rate.
- Blood will be diluted ↓Hct.
- The replacement "fluid volume" will be removed by the effluent pump.

Post Replacement

- The replacement "fluid volume" will be removed by the effluent pump.
- Blood will be concentrated ↑Hct.
- Post-filter replacement solution will deliver replacement solution to "replace" the removed "volume" and replenish lost electrolytes.

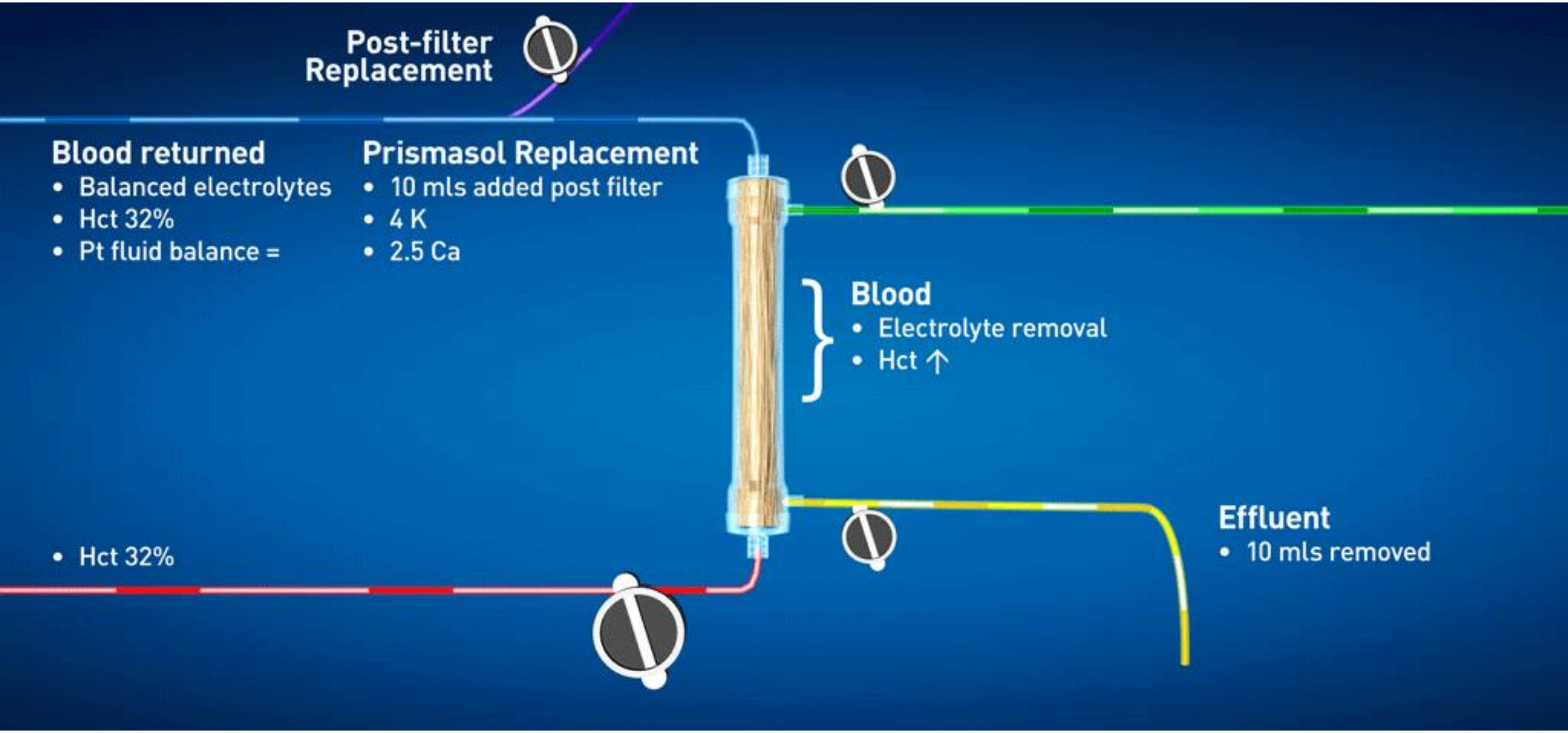
GAMBRO®

Pre-filter replacement



Reference #3

Post-filter replacement

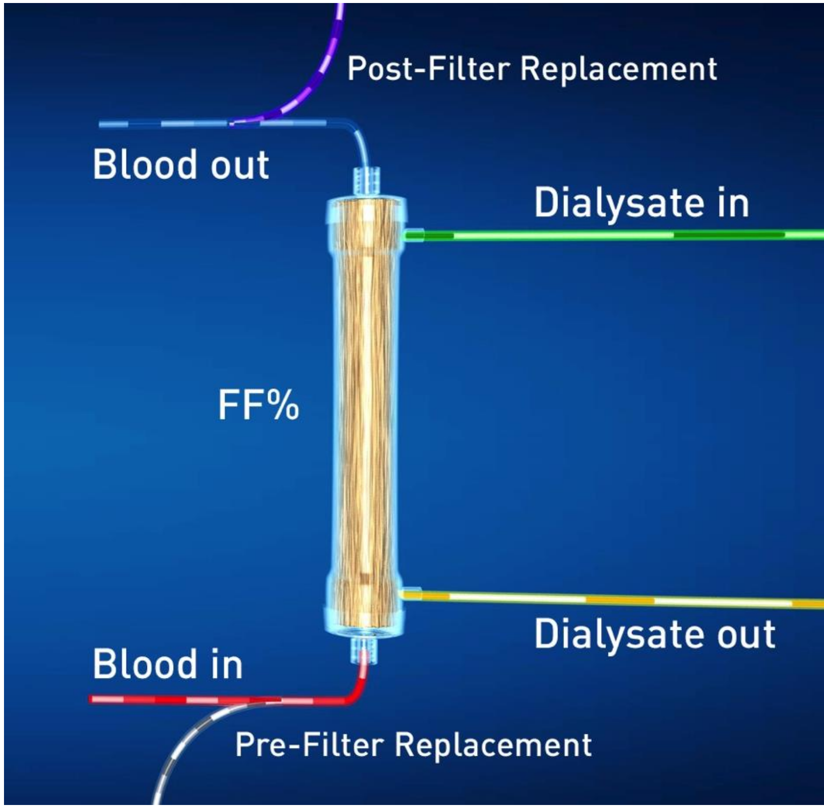


Reference #3

GAMBRO

Why do we need to monitor Filtration Fraction percentage (FF%)?

- A FF > 25% can lead to premature filter degradation
- To decrease the FF%, prescribed fluid delivery strategies may need to be initiated such as a mix of pre- and post-dilution.
- For accurate Filtration Fraction percentage monitoring, the patient's hematocrit should be updated once a day.



Most hospitals use 2–3 solutions

Initiation Solution:

- Used for the first 24-48 hours
- Typically has lower levels of electrolytes to help balance the patient.
  - PrismaSATE/SOL BK 0/3.5
  - PrismaSATE/SOL BGK 2/0
  - PrismaSOL BGK 0/2.5
  - PrismaSOL BK 0/0/1.2

20%

Maintenance Solution:

- Used after the 24-48 hours to CRRT treatment completion.
- Physiologic levels to maintain the patient's electrolyte balance.
  - PrismaSATE/SOL BGK 4/2.5
  - PrismaSATE B22GK 4/0
    BGK 4/0/1.2
  - PrismaSOL B22GK 2/0

80%

GAMBRO®

Considerations for solution choice

Which mode of therapy?

- CVVH: PrismaSOL
- CVVHD: PrismaSATE
- CVVHDF: Both Solutions
- Be aware: 0.9% saline average P_h is 5.0 to 5.6. frequent bag changes

Which anticoagulant prescribed?

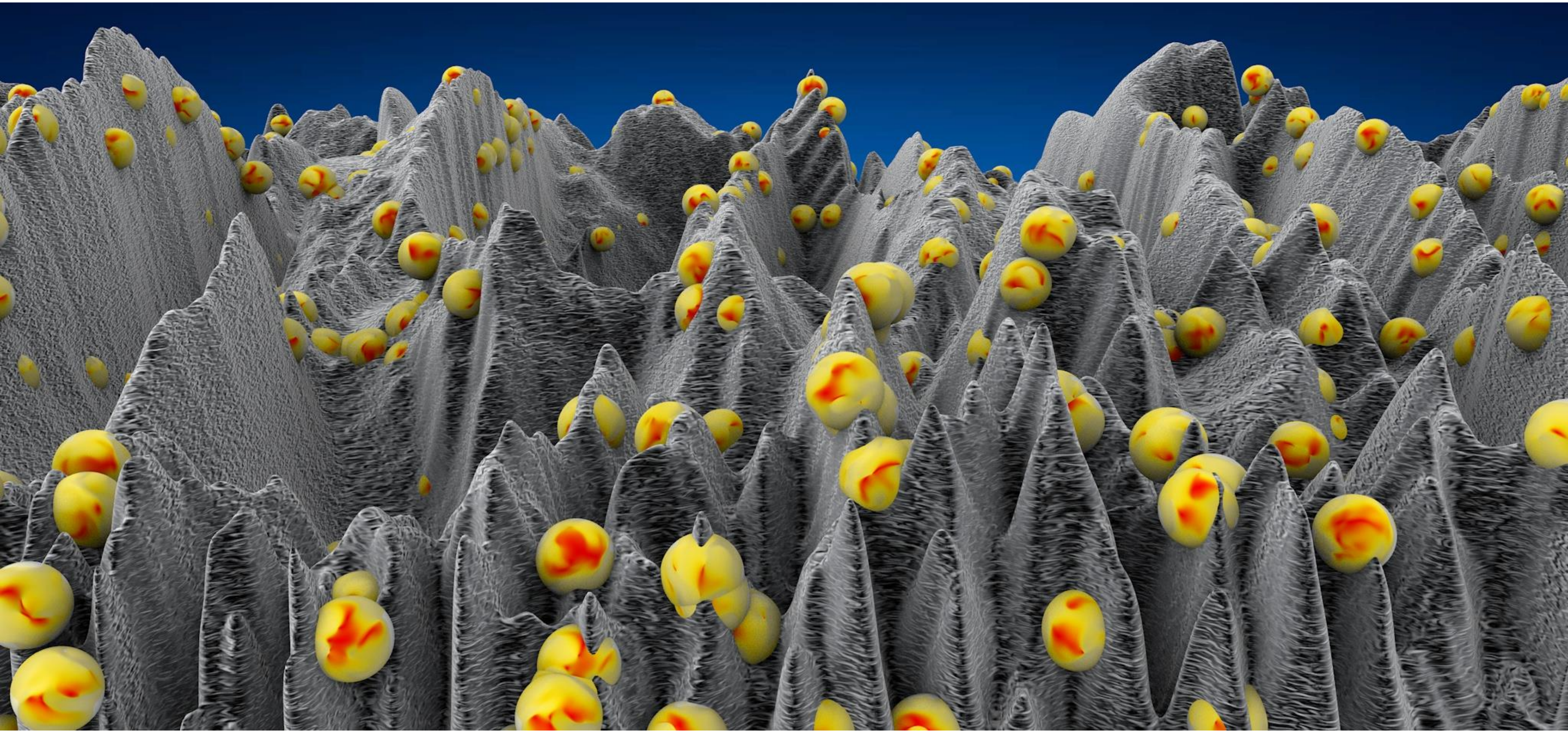
- Systemic, regional or none

What else is happening to the patient?

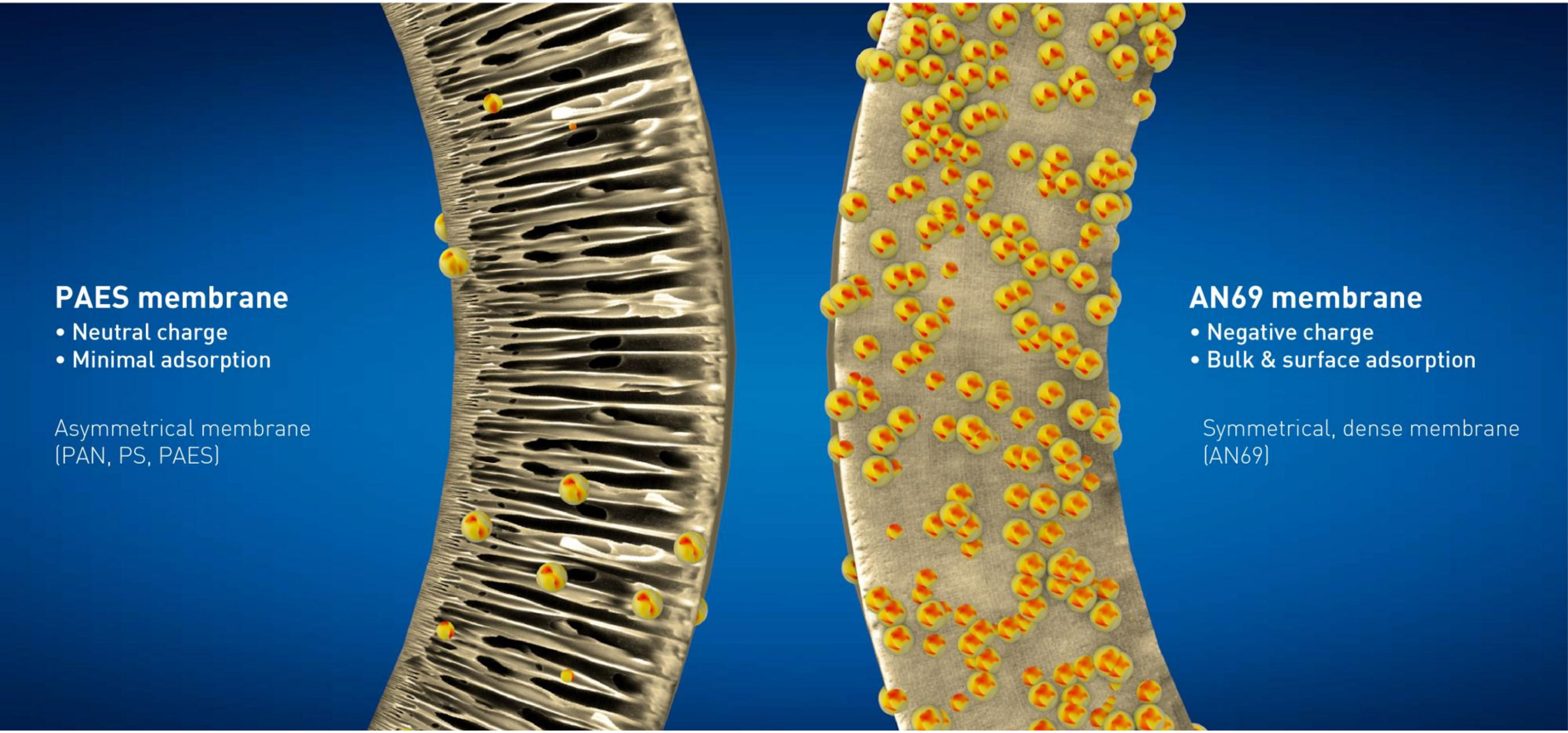
- Ventilatory settings, vasoactive drugs etc

Adsorption

Molecular adherence to the surface or interior of the membrane.

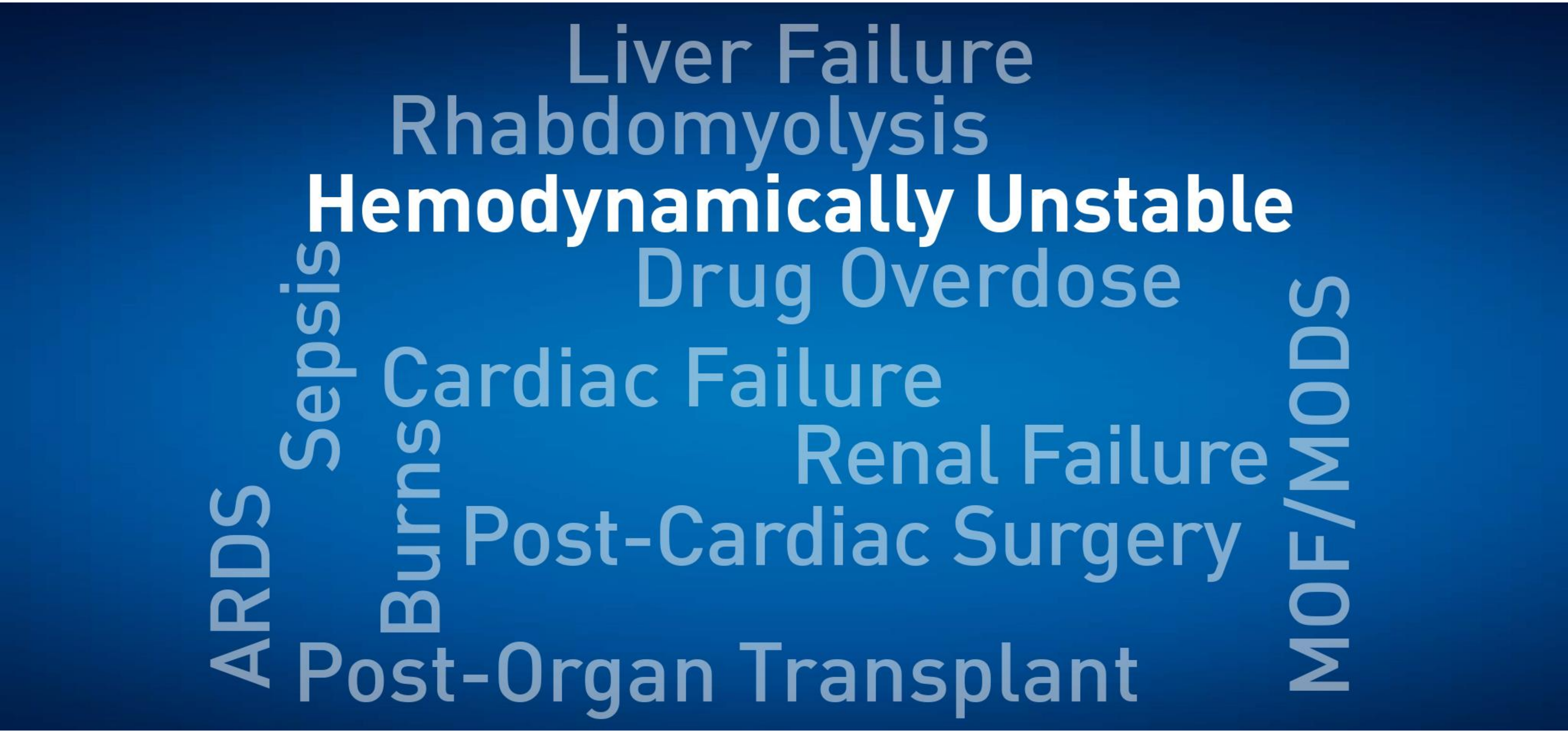


Different membrane performance



Who should be treated with CRRT?

AKI patient conditions



Reference #16

GAMBRO

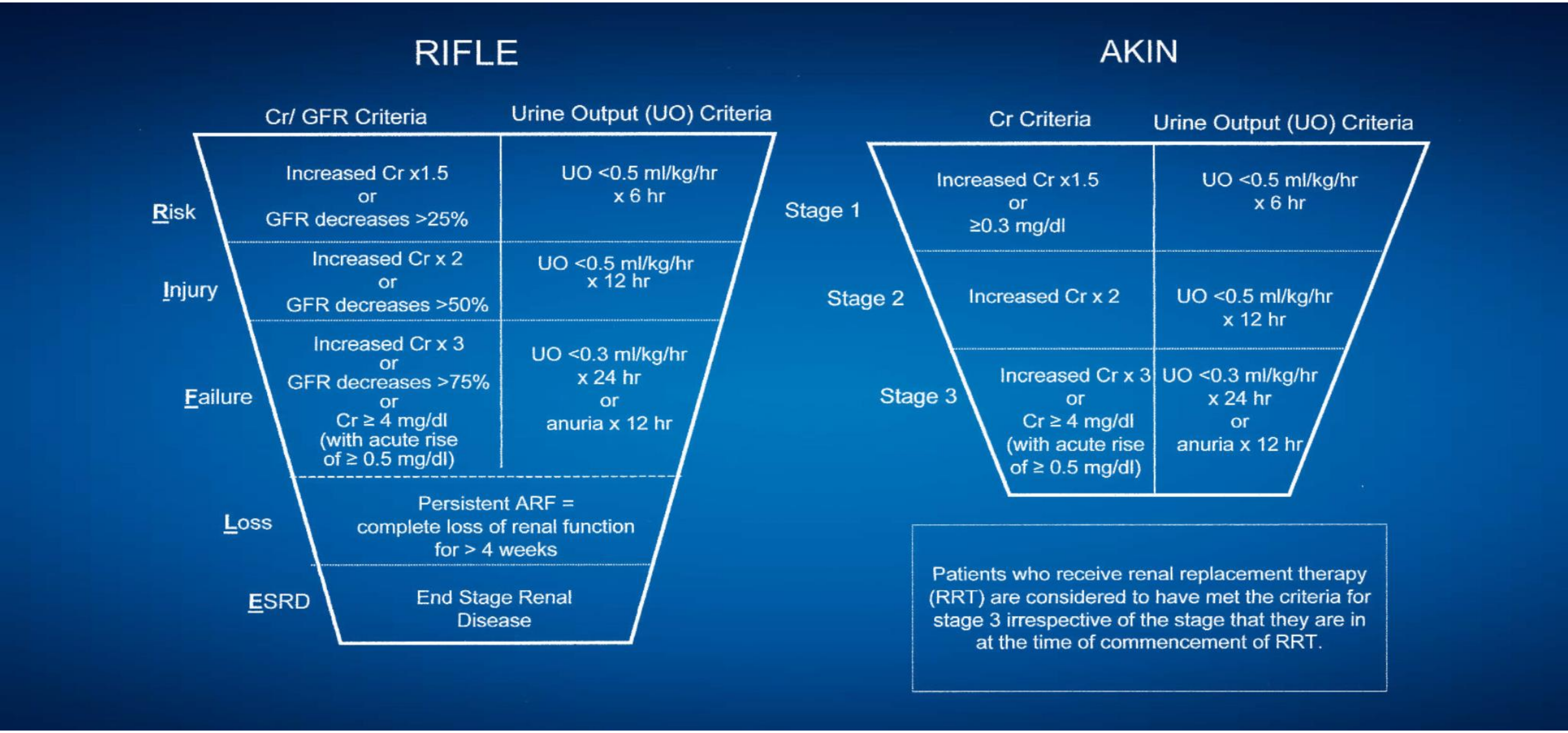
Definition of AKI

2.1.1: Acute kidney injury (AKI) is defined as any of the following:

- Increase in SCr by ≥ 0.3 mg/dl within 48 hours; or
- Increase in SCr to ≥ 1.5 times baseline, which is known or presumed to have occurred within prior 7 days; or
- Urine volume <0.5 ml/kg/h for 6 hours

Reference #13

RIFLE and AKIN Criteria

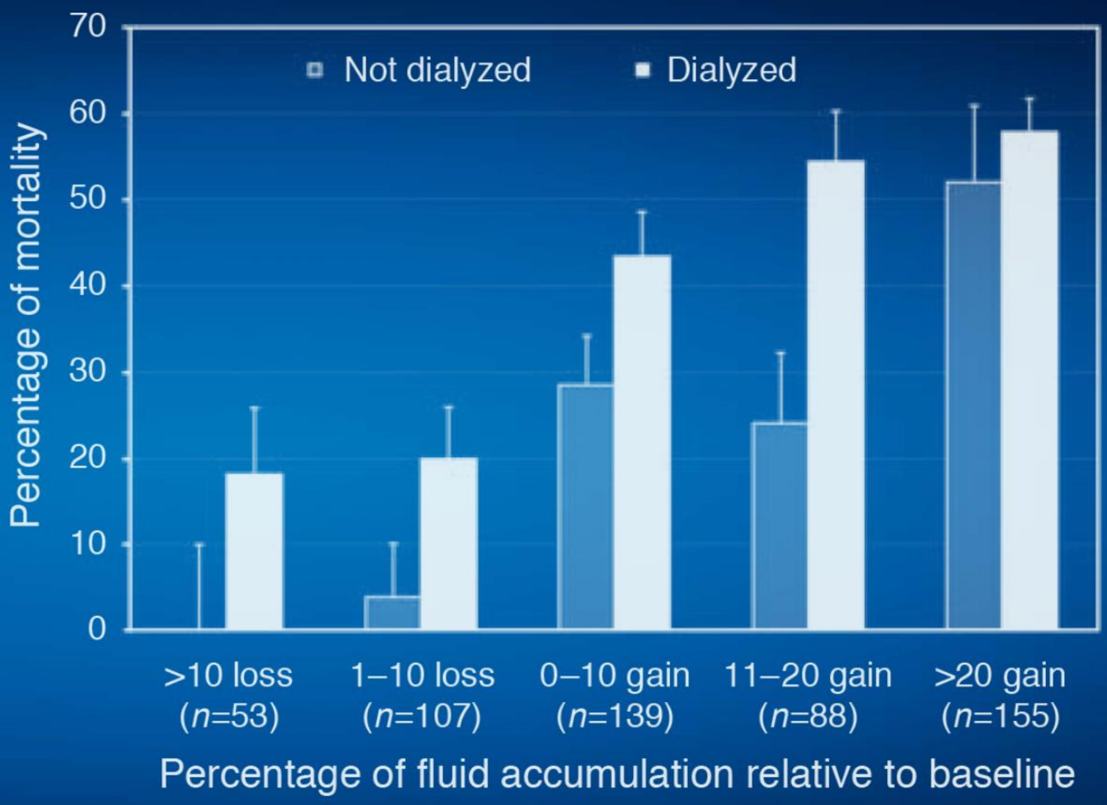


Reference #4

Fluid overload

A biomarker for treatment initiation?

Fluid overload with AKI was independently associated with mortality.



Reference #10

How to calculate % FO

$$\left(\frac{\text{total fluid input (L)} - \text{total fluid output (L)}}{\text{baseline body weight (kg)}}\right) \times 100$$

0–10% = Fluid accumulation

>10% = Fluid overload

Reference #10

GAMBRO®

Chapter 3.1:

Prevention and Treatment of AKI

3.4.1: We recommend not using diuretics to prevent AKI (1B)

Reference #13

Chapter 5.6:

Modality of RRT for Patients with AKI

5.6.1: Use continuous and intermittent RRT as complementary therapies in AKI patients. (Not Graded)

5.6.2: We suggest using CRRT rather than standard intermittent RRT, for hemodynamically unstable patients. (2B)

5.6.3: We suggest using CRRT, rather than intermittent RRT, for AKI patients with acute brain injury or other causes of increased intracranial pressure or generalized brain edema. (2B)

Reference #13

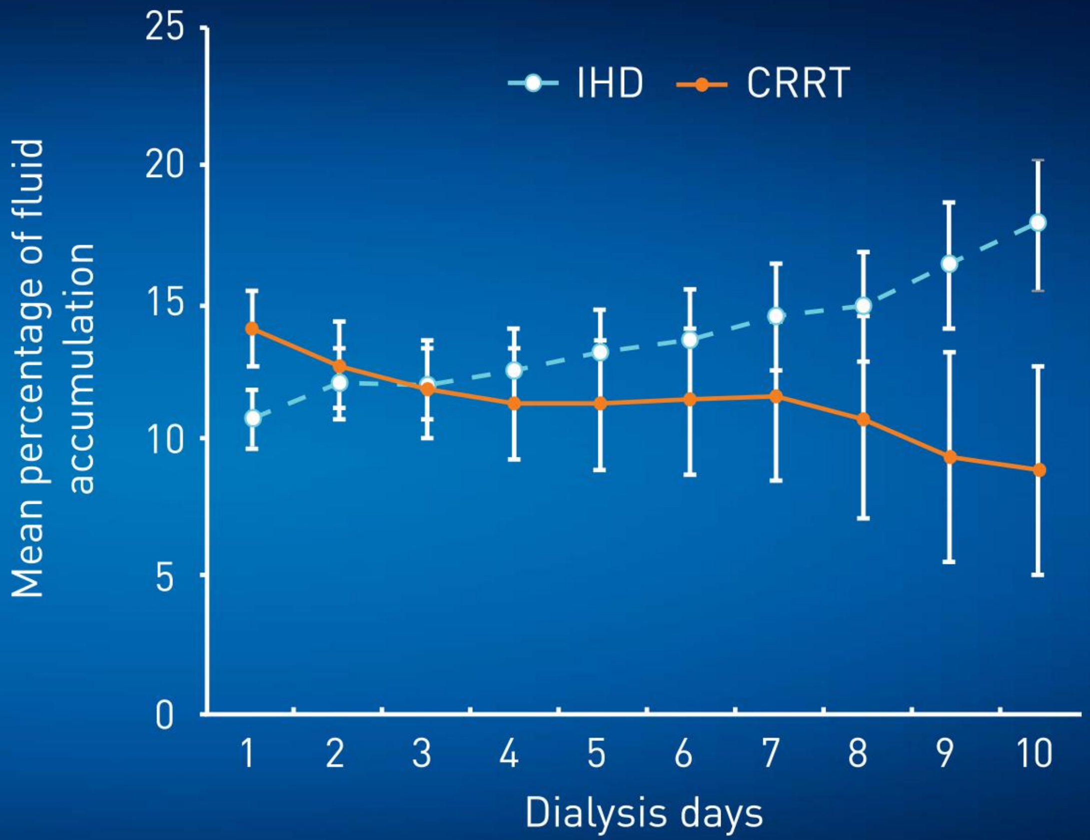
Comparison of IHD, SLEDD and CRRT

Intermittent Hemodialysis	SLEDD	CRRT
Duration = 4 hours	Duration = 6–12 hours	Duration = 24 hours
Blood Flow = around 400 ml/min	Blood Flow = 150–300 ml/min	Blood Flow = 150–250 ml/min
Fluid used = Dialysate only	Fluids used = Dialysate only	Fluids used = Dialysate & Replacement solutions
Fluid Rates = 500–800 ml/min	Fluid Rates = 100-300 ml/min	Fluid Rates = 34–68 ml/min (2–4 L/hr)
Non Sterile Dialysate	Non Sterile Dialysate	Sterile Dialysate & Replacement solutions
Typical Net Fluid Removal = 0–1000 ml/hr	Typical Net Fluid Removal = 0–500 ml/hr	Typical Net Fluid Removal = 0–200 ml/hr

GAMBRO®

Correction of Fluid Overload:
CRRT vs IHD

PICARD Study group says CRRT is better than IHD for fluid removal!



Reference #10

Timing of RRT initiation:

Starting RRT early may be associated with improved outcomes!

“Early” initiation of RRT has been associated with better outcomes for AKI patients.

The published studies assessing the effect of timing of RRT initiation are largely observational and have used variable definitions of “early” vs. “late.” Nevertheless, two meta-analyses involving critically ill AKI patients treated with RRT showed that “early” RRT initiation was associated with significantly reduced mortality risk compared to “late” initiation.

Reference #14, 15

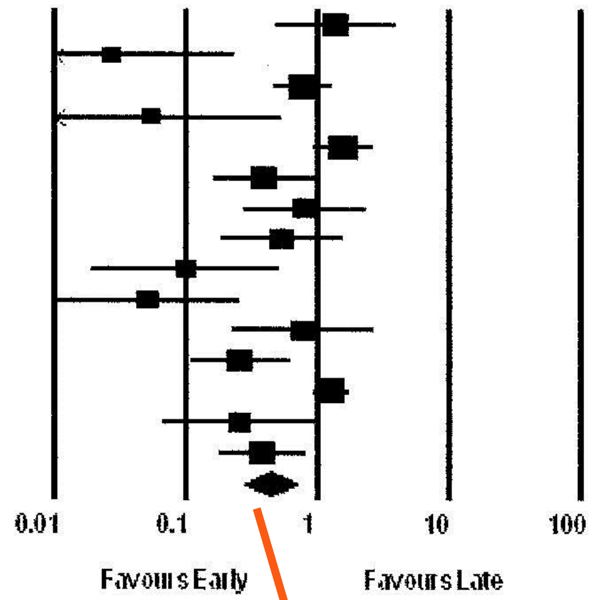
Timing of RRT Initiation: Meta-Analysis

Karvellas et al, Crit Care 2011

Meta Analysis: All 15 studies

Study name	Subgroup within study	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
Bouman 2002	Mixed	1.375	0.487	3.884	0.601	0.548
Sugahara 2004	Surgery	0.028	0.003	0.231	-3.318	0.001
Liu 2006	Mixed	0.773	0.460	1.298	-0.974	0.330
Sabater 2008	Mixed	0.055	0.006	0.524	-2.520	0.012
Bagshaw 2010*	Mixed	1.563	0.933	2.619	1.697	0.090
Gettings 1999	Surgery	0.399	0.164	0.973	-2.019	0.043
Elahi 2004	Surgery	0.800	0.273	2.341	-0.407	0.684
Demirkilic 2004	Surgery	0.533	0.183	1.552	-1.154	0.249
Andrade 2007	Mixed	0.100	0.019	0.515	-2.752	0.006
Manche 2008	Surgery	0.051	0.010	0.256	-3.623	0.000
Iyem 2009	Surgery	0.778	0.229	2.644	-0.403	0.687
Shiao 2009	Surgery	0.260	0.110	0.614	-3.075	0.002
Bagshaw 2009 adj	Mixed	1.250	0.915	1.708	1.401	0.161
Wu 2007 adj	Surgical	0.259	0.068	0.988	-1.977	0.048
Carl 2010 adj	Mixed	0.380	0.177	0.816	-2.482	0.013
		0.446	0.276	0.723	-3.279	0.001

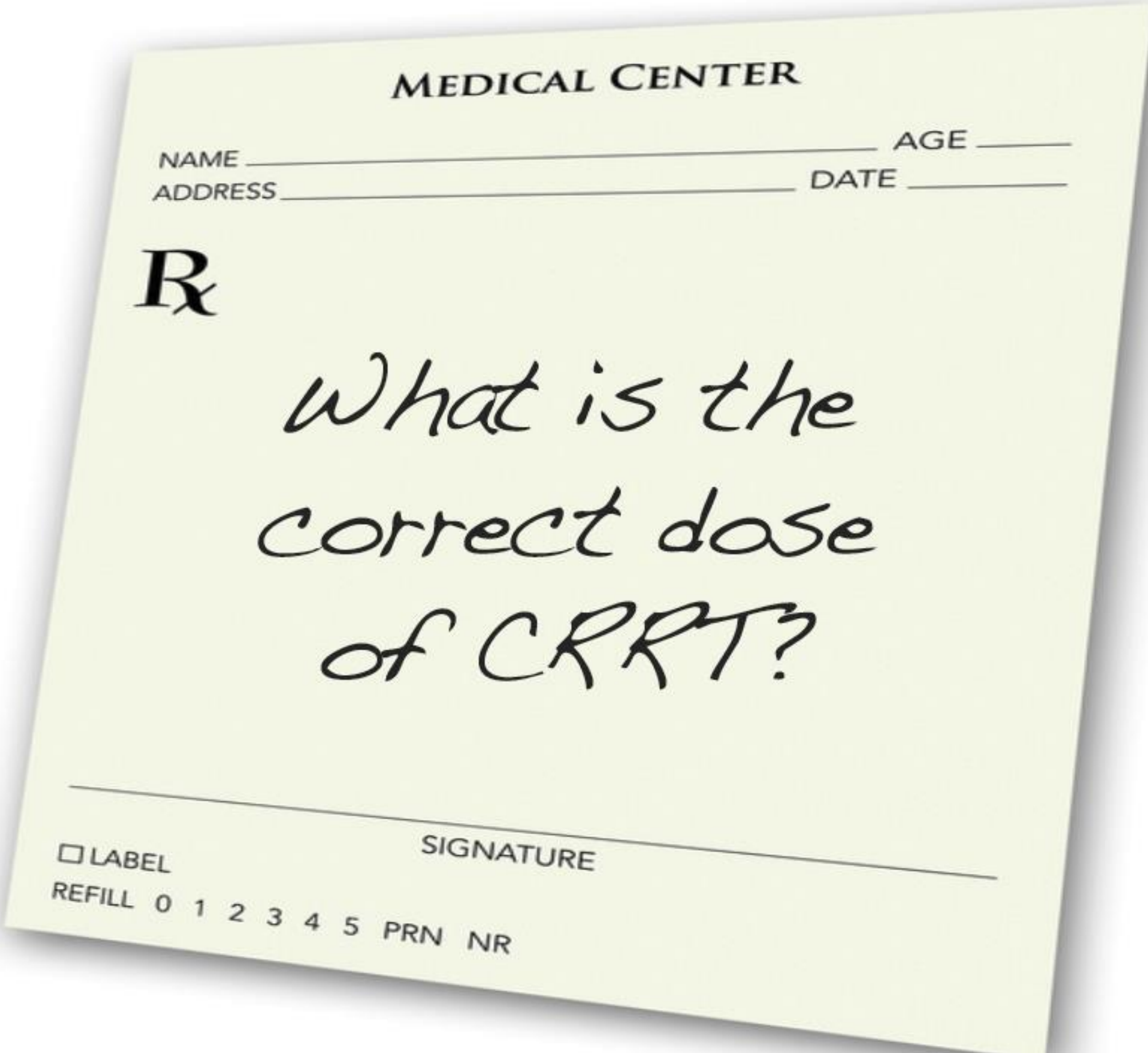
(Statistics for each study)



Meta Analysis

Figure 2 Forest plot of all 15 studies (Random Effects Model, OR, 95% CI).

Pooled OR of 0.45 for early start


MEDICAL CENTER
NAME
AGE
ADDRESS
DATE
R
What is the correct dose of CRRT?
SIGNATURE
LABEL
REFILL 0 1 2 3 4 5 PRN NR

KDIGO Clinical Practice Guideline Chapter 5.8: Dose of RRT in AKI

5.8.4: We recommend delivering an effluent volume of 20-25 ml/kg/hr for CRRT in AKI (1A). This will usually require a higher prescription of effluent volume. (Not Graded)

Reference #13

Prescribed vs Delivered

5.8.4: We recommend delivering an effluent volume of 20–25 ml/kg/hr for CRRT in AKI (1A). This will usually require a higher prescription of effluent volume. (Not Graded)

5.8.1: The dose of RRT to be delivered should be prescribed before starting each session of RRT.(Not Graded). We recommend frequent assessment of the actual delivered dose in order to adjust the prescription. (1B)

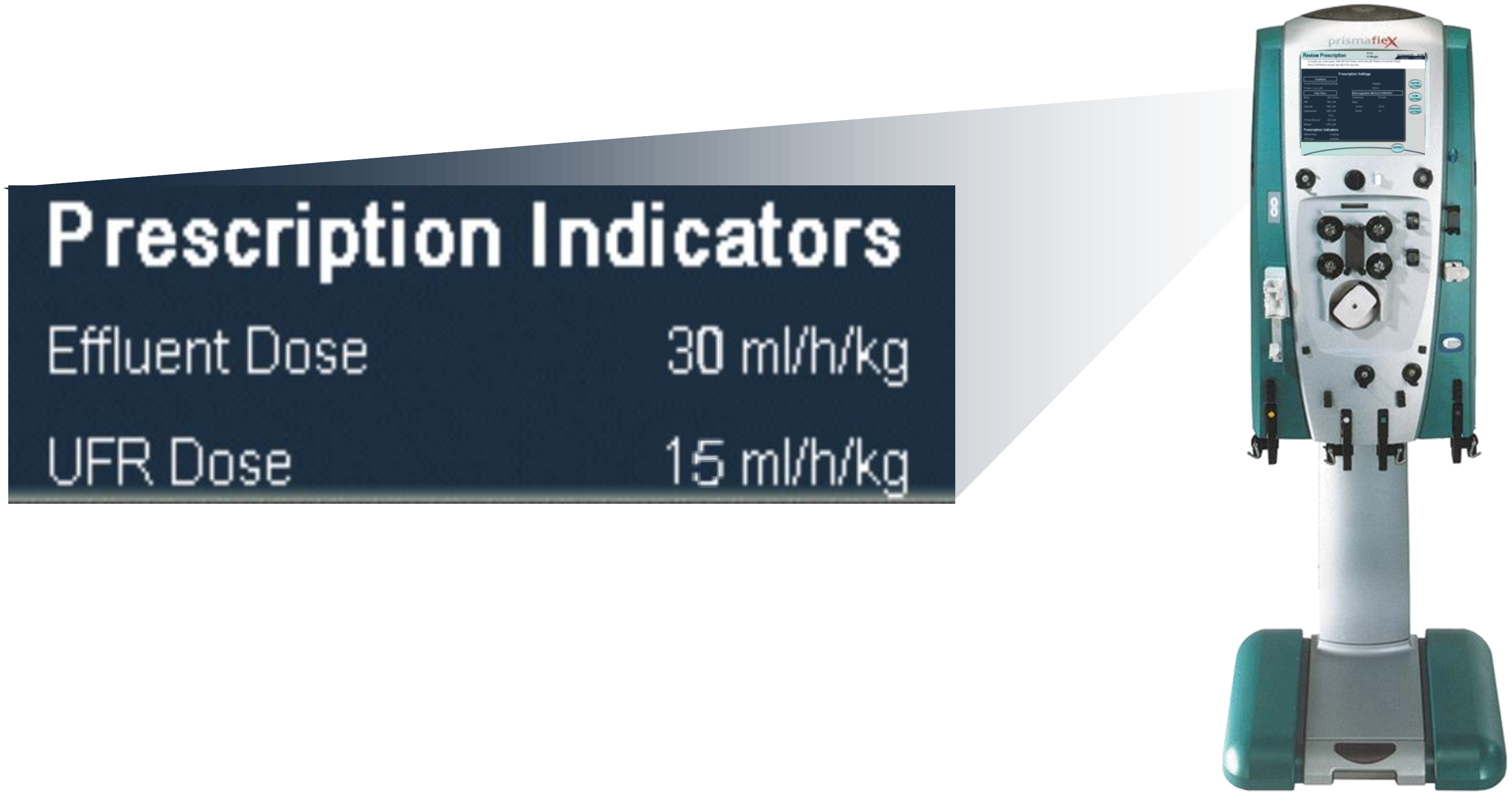
5.8.2: Provide RRT to achieve the goals of electrolyte, acid-base, solute, and fluid balance that will meet the patient's needs. (Not Graded)

Reference #13

Key Take-aways

- Ensure your CRRT dose prescription is delivered!
- Urea is a traditional marker for chronic dialysis efficacy, CRRT provides benefits above and beyond urea clearance
- Major contributors to under-delivery of CRRT dose can be patient or treatment related
- CRRT provides slow, continuous and gentle replacement of renal function…as close to native kidney function as possible!

Prescription screen on set up



Case study

- Patient: 82kg Female
- ICU LOS: 3 days
- Previously fit and well with no comorbidity
- Diagnosis: Pneumonia & Sepsis
- Labs
  - Creatinine 1.1 mg/dL
  - BUN = 67 mg/dL
  - K+ = 5.9 mEq/L
  - WBC's = 31,000
- Intake in last 48 hrs = 11, 545 ml
- Output in last 48 hrs = 1,350 mls
- Ventilated
- MAP of 59 mmHg on
  - Norepinephrine at 12 mcgs/min
  - Dopamine at 20 mcgs/kg/min
- Urine output 0.2 mls/hr/kg with lasix

Questions:

Is the patient hemodynamically stable?

NO. Patient is on vasopressors and MAP is still low, which means the patient is hemodynamically unstable. KDIGO suggests using CRRT, rather than intermittent RRT, for hemodynamically unstable patients (2B)

What is % FO?

11.545L – 1.350L = 10.1.95 / 82kg = 0.12432927 X 100% = 12.4% FO which is associated with increased mortality per PICARD

Is staging of AKI appropriate?

Yes, because with increased stage of AKI, the risk of death and need for renal replacement therapy (such as CRRT) increases.

Can we remove fluid in this patient?

Yes, if done over 24 hours per KDIGO

What dose of CRRT should the patient be given?

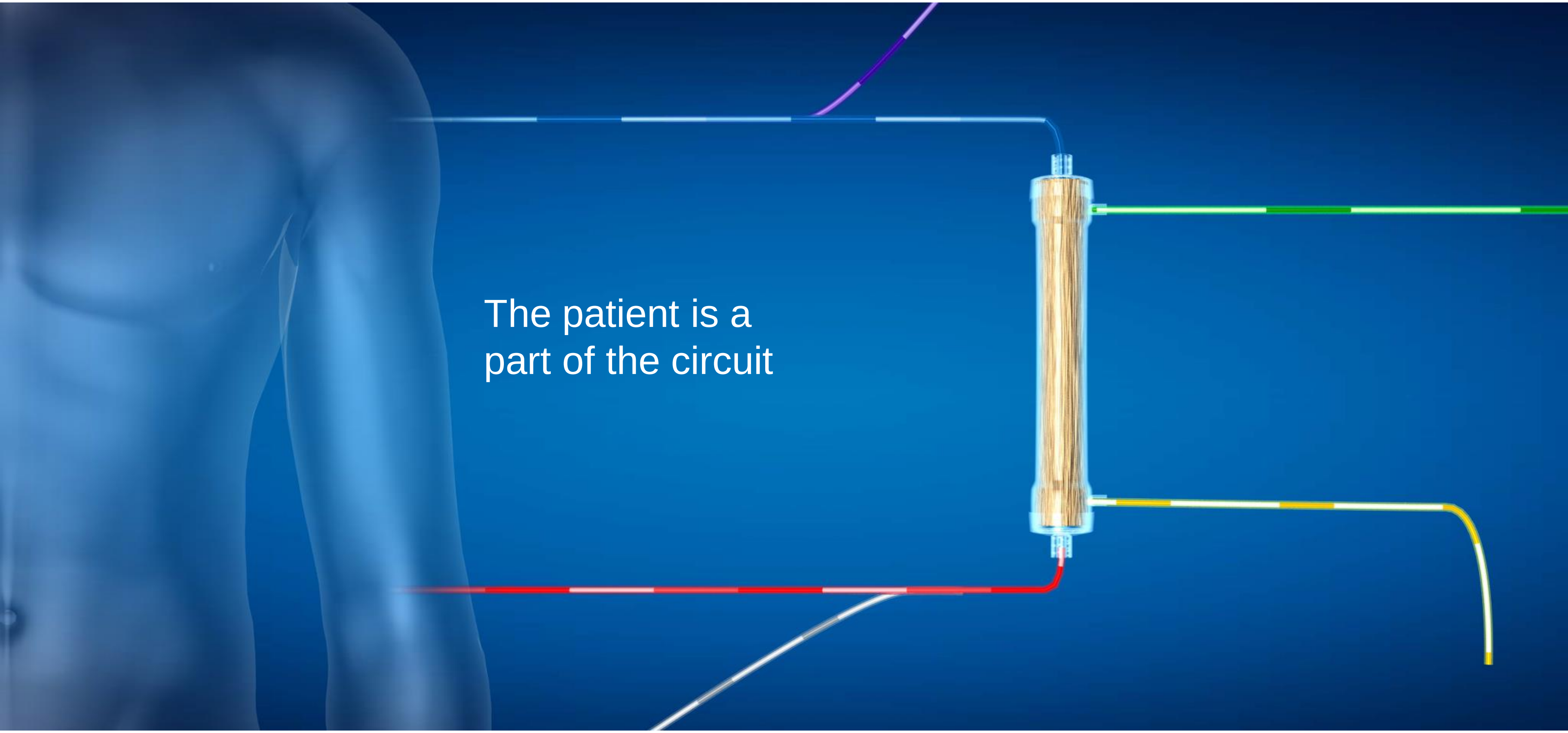
82kg X 25mls/hr/kg effluent (minimum) = 2050mls/hr of replacement and dialysate combined.

Add in estimated downtime of 20% = 2050mls/hr + 410mls/hr = 2460mls/hr = 30mls/hr/kg effluent dose.

Reference #10, 13

PACE: Applying what we know

Patient, Access, Circuit, Equipment



Check the patient!

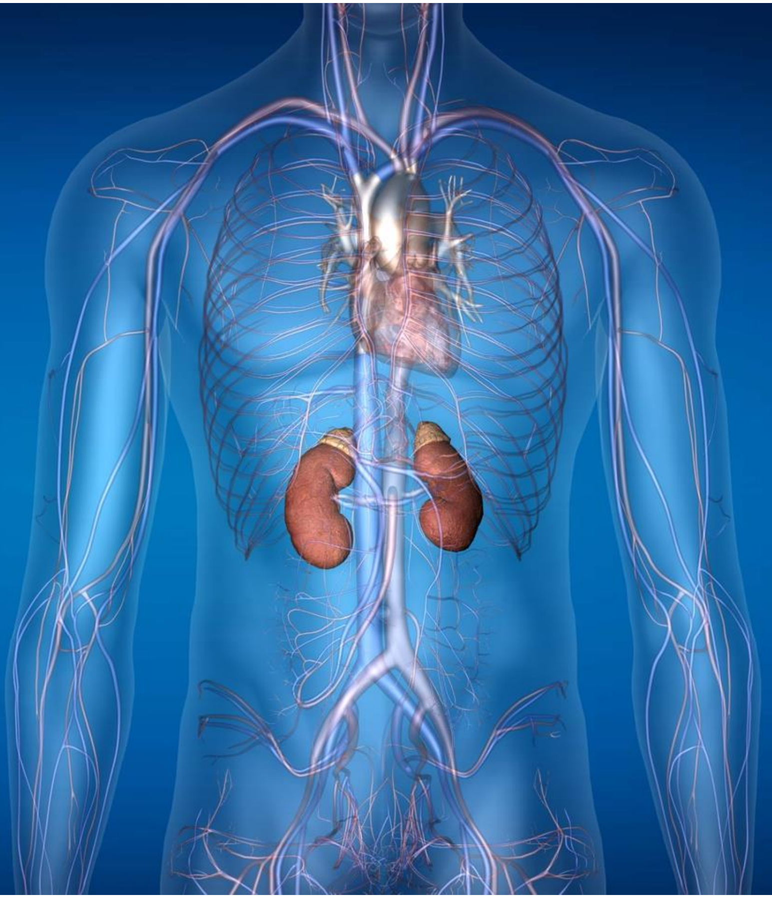
Cardiac status	Patient weight
Patient temperature	Patient labs
Hemodynamic status – vital signs	Sedation Level
Intravascular volume	Chest tubes
Ventilator Status - Mode, reverse I:E ratio, Positive pressure ventilation, oscillator	Abdominal Pressure
Patient position – HOB 30º, prone, rotation etc	Intra-aortic Balloon pump
Compartment syndrome	

GAMBRO®

PACE: Applying what we know

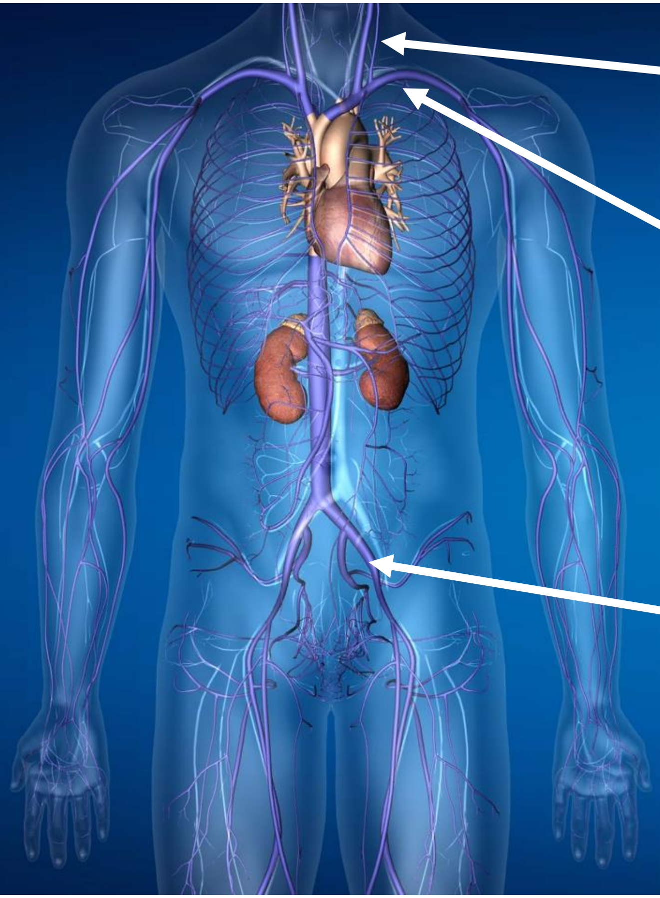
Patient, **Access,** Circuit, Equipment

Vascular Access Catheter



Vascular access: Location

A veno-venous double or two single lumen venous catheters



Internal Jugular Vein

- Lower risk of complication
- Simplicity of catheter insertion

Subclavian Vein

- Higher risk of pneumo/hemothorax
- Associated with central venous stenosis

Femoral Vein

- Optimal site for immobilized patient
- Easiest site for insertion

GAMBRO®

Vascular access catheter:

Important considerations

Desired characteristics:

see KDIGO guideline pg 101

- Size: Adults 11 french or larger
- Adequate Length
- Optimal Placement

Number ONE Circuit Management Issue

Refer to and follow the hospital protocol for specific guidelines

Vascular Access recommendations:

- Aspirate and discard anticoagulant before flushing
- 10ml to 30ml syringe to assess patency
- Check for kinks/ clamps

Reference #13

GAMBRO®

CRRT Blood Flow Rate

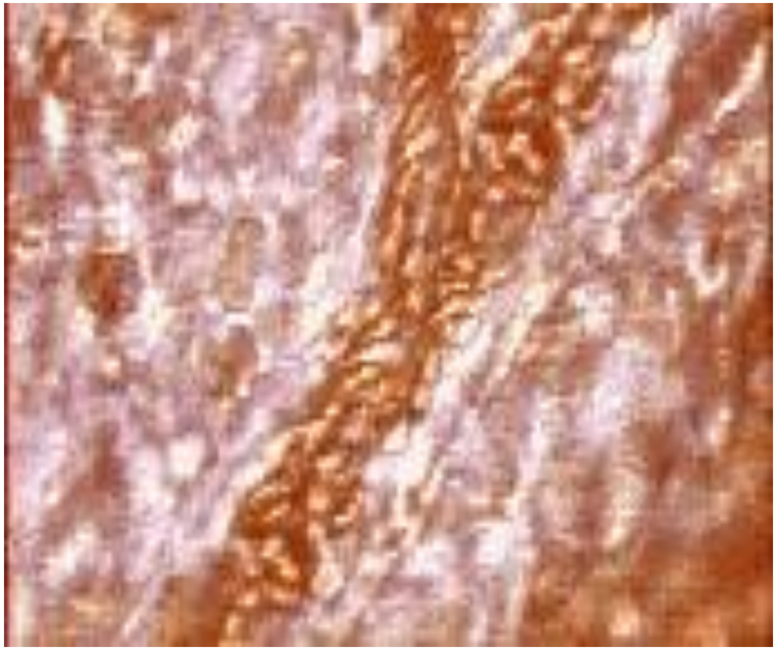
Blood Flow Rate:

Machine Limits:

10ml/min - 450ml/min

Recommended: adults:

- Minimum 100 ml/min
- Preferred: Blood flow rate must be adequate for the fluid removal rate



Considerations:

Vascular Access

- Size and patency

Hemofilter selection

Anticoagulation

Patent catheter

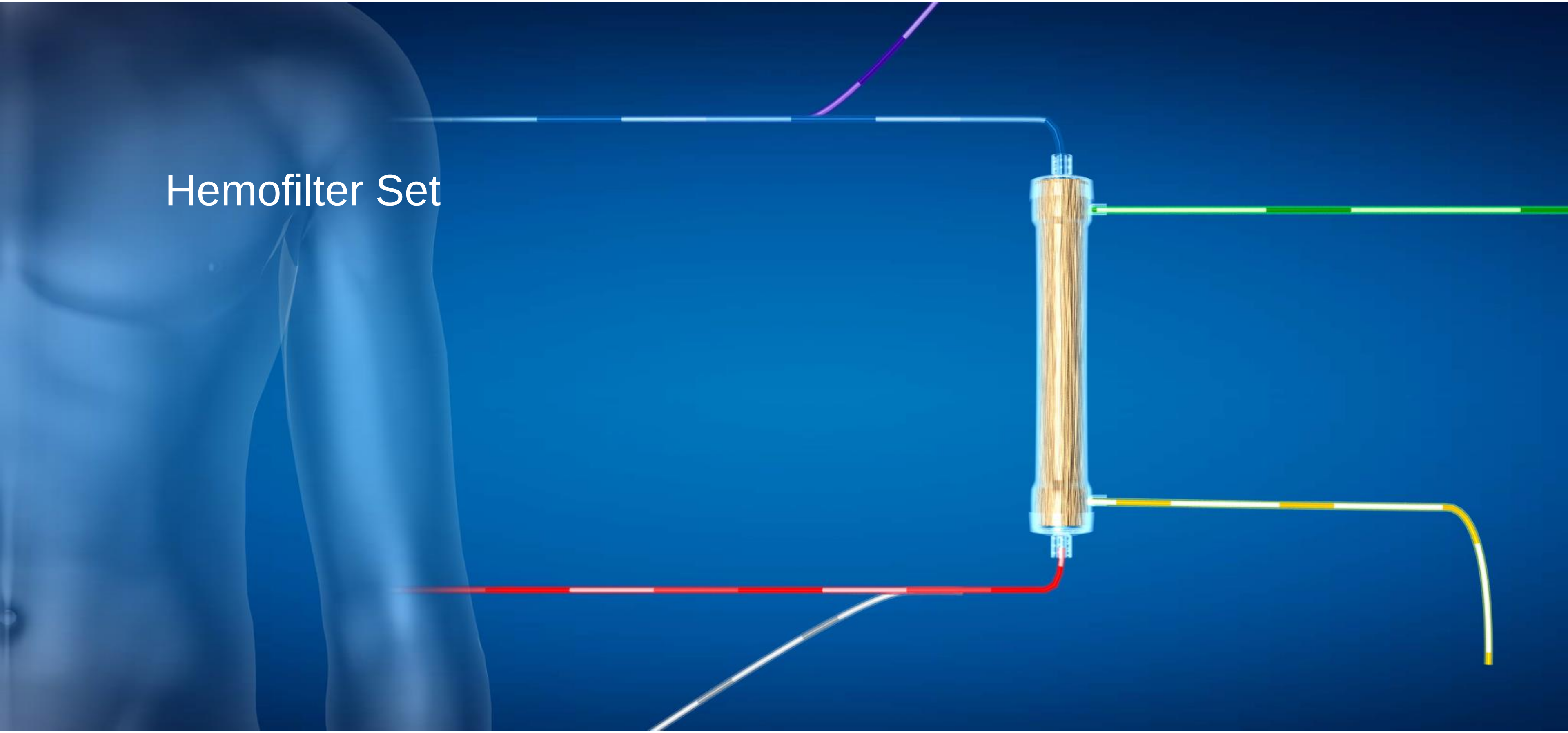
Blood flow rate, choice of filter and vascular access site / size

should all compliment each other

Reference #12

PACE: Applying what we know

Patient, Access, **Circuit,** Equipment



Anticoagulation strategies

- Therapeutic on coumadin/warfarin
- Coagulopathy from various reasons – sepsis, liver failure
- Systemic anticoagulant – Heparin
- If HIT+ then consider regional or none
- Regional anticoagulant - Citrate

Why?

Aim of anticoagulation during CRRT is to prevent clotting of the circuit in order to:

- preserve filter performance
- increase circuit survival
- minimize loss of blood due to increased circuit changes

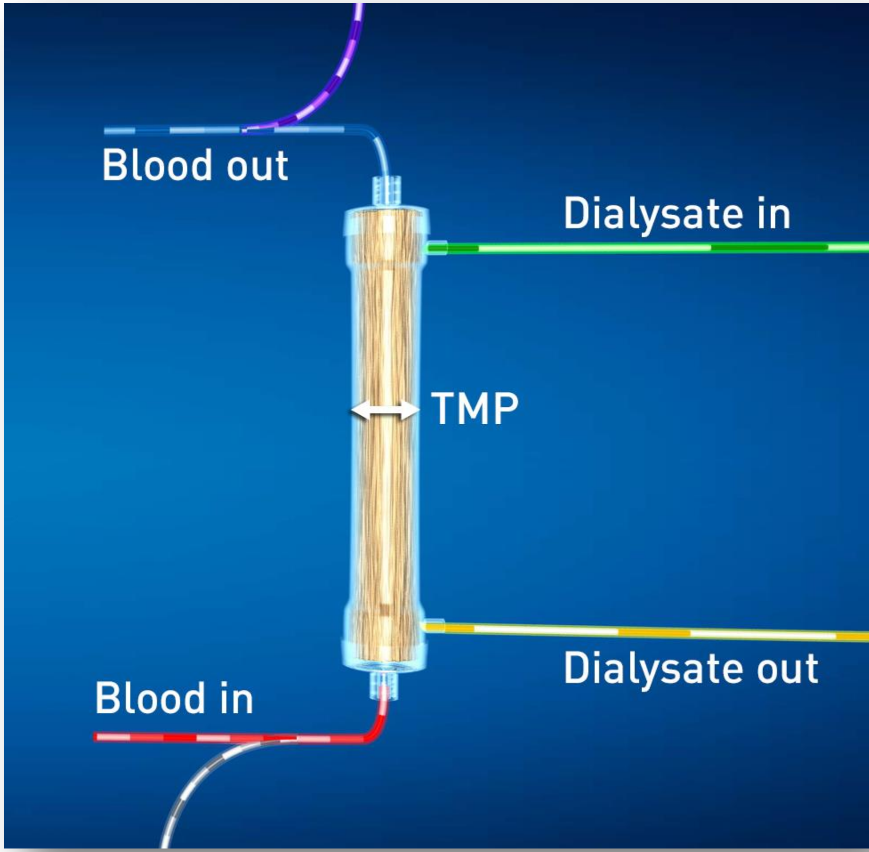
Impact of filter clotting:

- CRRT is only continuous if anticoagulation is adequate
- decrease in clearance
- increase in filter changes
- wasted nursing time
- increase in cost
- Patient blood loss – may be MDR reportable!

Filter viability

Trans-membrane Pressure (TMP)

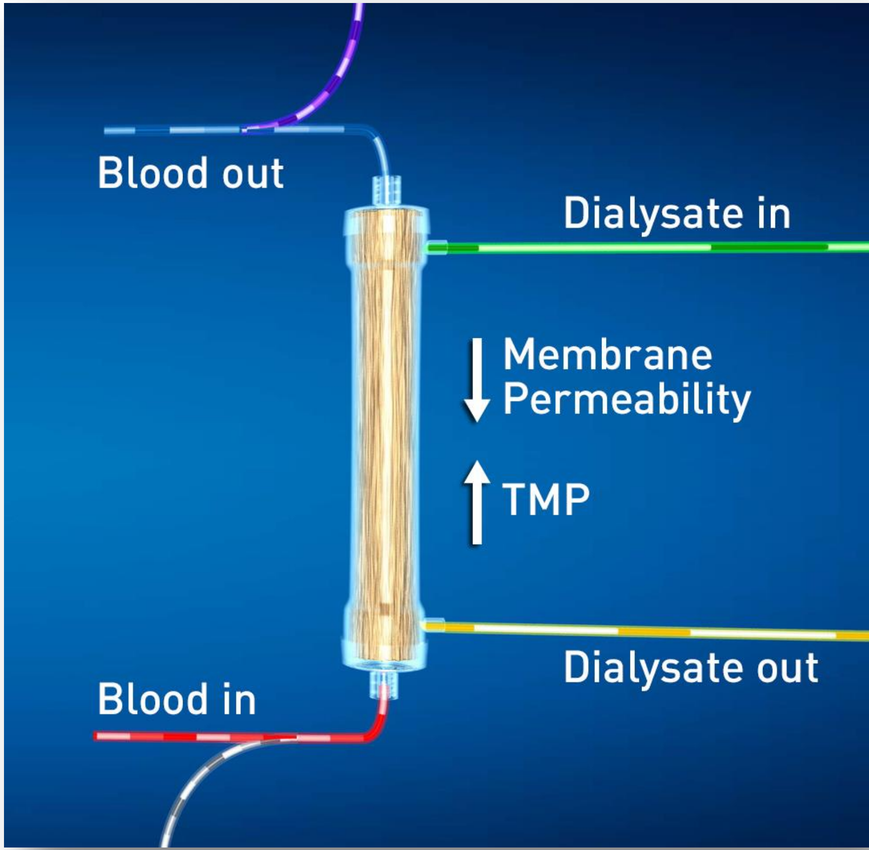
- Pressure exerted on filter membrane during operation
- Reflects pressure difference between fluid and blood compartments of filter
- Calculated by Prismaflex software



Trans-Membrane Pressure (TMP)

Calculated and automatically recorded:

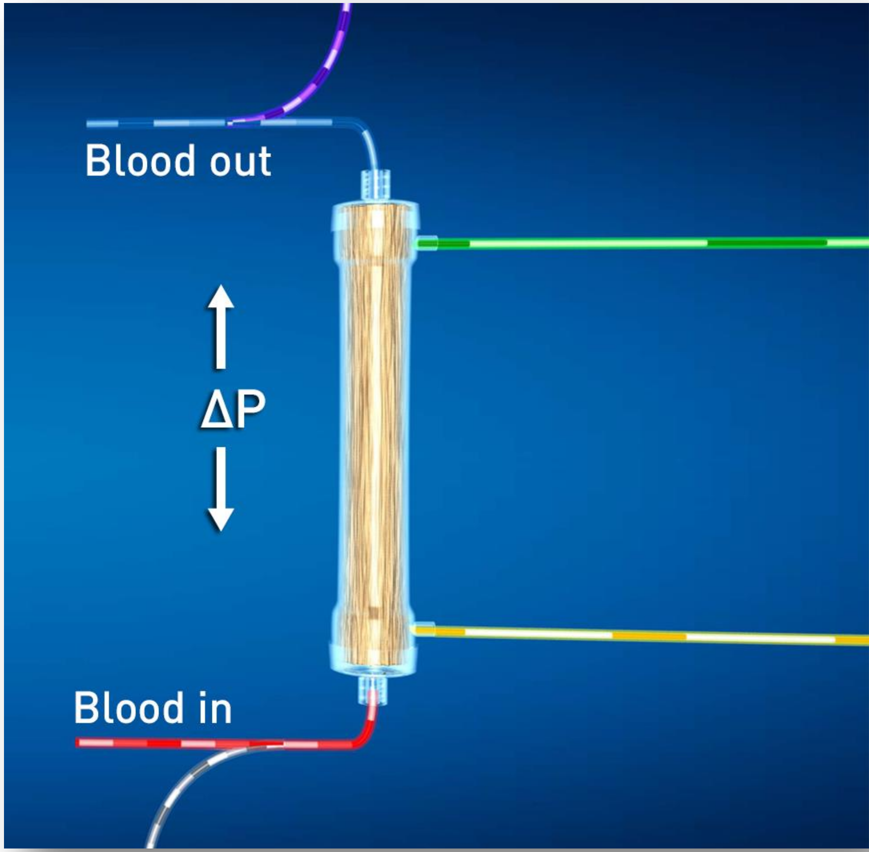
- Entering Run mode - blood flow is stabilized
- Blood flow rate is changed
- Patient fluid removal rate is changed
- Replacement solution rate is changed



Filter viability

Filter Pressure Drop (ΔP Filter)

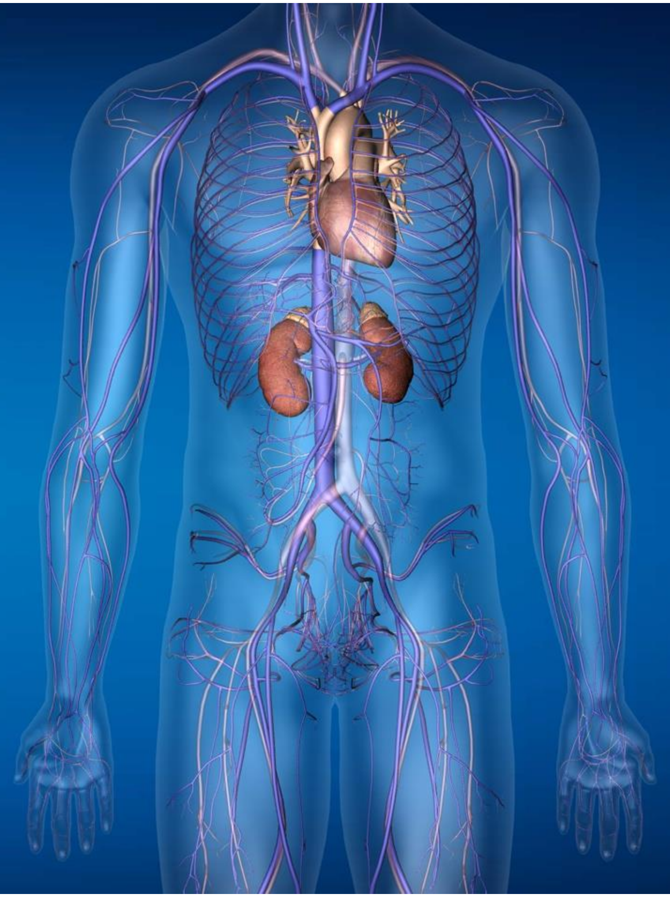
- Change of pressure from blood entering filter and leaving filter
- Determines pressure conditions inside hollow fibers
- Calculated and automatically recorded:
  - Entering Run mode
  - Blood flow rate is changed
- Calculated by Prismaflex software



PACE: Applying what we know

Patient, Access, Circuit, **Equipment**

CRRT machine delivers prescribed therapies and solutions



Modality

Choose modality based on patient needs and desired outcomes

Questions

Thank you!

References

1) Bellomo R., Ronco C., Mehta R, Nomenclature for Continuous Renal Replacement Therapies, AJKD, Vol 28, No. 5, Suppl 3, Nov 1996
2) Beginning and Ending Supportive Therapy for the Kidney. (2005, August 17). Acute renal failure in critically ill patients: a multinational, multicenter study. JAMA, 7, 813-818.
3) Cerda, J. & Ronco , C. (2010). Choosing a RRT in AKI. In J. A. Kellum, R. Bellomo, & C. Ronco (Eds.), Continuous Renal Replacement Therapy (pp. 79 - 92). New York, USA: Oxford University Press
4) DOse REsponse Multicentre International Collaborative Initiative. (2009, April 15). Delivered dose of renal replacement therapy and mortality in critically ill patients with acute kidney injury. Critical Care, 1-14. http://dx.doi.org/doi:10.1186/cc7784
5) Karvellas, C. J., Farhat, M. R., Sajjad, I., Mogenson, S. S., Lueng, A. A., Wald, R., & Bagshaw, S. M. (2011, Feb 25). A comparison of early versus late initiation of renal replacement therapy in critically ill patients with acute kidney injury: a systematic review and meta-analysis. Critical Care, 15.
6) Prismaflex Tutorial Version 5.1 DVD
7) Prismaflex Operators manual. Version 5.10 of the Prismaflex software contains the "libdmtx" library ("the Library"), Copyright © 2008, 2009 Mike Laughton, Copyright © 2011 Gambro Lundia AB, released under the GNU Lesser General Public License Version 2.1 ("the License"). A copy of the License is attached to the manual. The user may obtain code in accordance with section 6(c) of the License by contacting Gambro Lundia AB, Legal and Intellectual Property Department.
8) Prismasate Specifications sheet
9) Prismasol Specifications sheet
10) Program to Improve Care in Acute Renal Disease. (2009, May 13). Fluid accumulation, survival and recovery of kidney function in critically ill patients with acute kidney injury. Kidney International, 76, 422-427.
11) Ricci, Z., Baldwin, I., & Ronco, C. (2010). Alarms and Troubleshooting. In J. A. Kellum, R. Bellomo, & C. Ronco (Eds.), Continuous Renal Replacement Therapy (pp. 121-128). New York, USA: Oxford University Press
12) Ricci, Z., Baldwin, I., & Ronco, C. (2010). Nonanticoagulation stratagies. In J. A. Kellum, R. Bellomo, & C. Ronco (Eds.), Continuous Renal Replacement Therapy (pp. 129-140). New York, USA: Oxford University Press
13) Schlondorff, D., Ross, M., & Al-Awqati, Q. (Eds.). (2012). KDIGO Clinical Practice Guideline for Acute Kidney Injury [Special issue]. Kidney International, 2(1).
14) Sepsis Occurrence in Acutely Ill Patients. (2008, June 4). A positive fluid balance is associated with a worse outcome in patients with acute renal failure. Critical Care, 12(3), 1-7.
15) The RENAL Replacement Therapy Study Investigators. (2009, Octonber 22). Intensity of Continuous Renal-Replacement Therapy in Critically Ill Patients. The New England Journal of Medicine, 361, 1627 – 1238.
16) 16) Uchino S, Kellum JA, Bellomo R, et al. Acute Renal Failure in Critically Ill Patients: A Multinational, Multicenter Study. JAMA. 2005;294(7):813-818. doi:10.1001/jama.294.7.813.
17) Zarbrock, A., & Singbartl, K. (2010). Vascular access for continuous renal replacement therapy. In J. A. Kellum, R. Bellomo, & C. Ronco (Eds.), Continuous Renal Replacement Therapy (pp. 93-99). New York, USA: Oxford University Press.
18) http://www.fistulafirst.org/LinkClick.aspx?fileticket=GN8QYytKHFo%3d&tabid=39
19) http://www.fistulafirst.org/Home.aspx
20) http://www.accessdata.fda.gov/cdrh_docs/pdf5/K052719.pdf
21) http://www.accessdata.fda.gov/cdrh_docs/pdf5/K051727.pdf
22) http://labtestsonline.org/understanding/analytes/urinalysis/tab/test

GAMBRO®