THE 29TH INTERNATIONAL CONFERENCE ON
ADVANCES IN CRITICAL CARE NEPHROLOGY
AKI & CRRT 2024
MARCH 12-15, 2024 MANCHESTER GRAND HYATT SAN DIEGO, CALIFO

Standard Workshops
Group 2
2:00 – 3:30 PM

Precision Solute Control and Dynamic Dosing wi CRRT

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IIBISMED, Universidad Mayor de San Simon
Cochabamba, Bolivia

Case

- A 56 year old man with Chagas disease arrives to ER complaining of muscle weakness, disnea, and oliguria.
  - Weight 52 Kg
  - BP 90/54 mmHg
  - SaO2 86% with pulmonary congestion
  - K 7.8, HCO3 17, BUN 126, sCr 5.4 (baseline 1.4), Hto 30%, INR 4.5
  - UO (less than 2 cups past 24 hours)
  - Medications: Losartan 50 mg day, Carvedilol 3,125 mg c/12 hours, spironolactone 50 mg day, warfarin 5 mg alt. 2.5 mg.

KRT prescription?

KDIGO Clinical Practical Guideline for Acute Kidney Injury

Chapter 5.8: Dose of renal replacement therapy in AKI

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*)

Kidney Int suppl 2:89-115; 2012

KDIGO Clinical Practical Guideline for Acute Kidney Injury

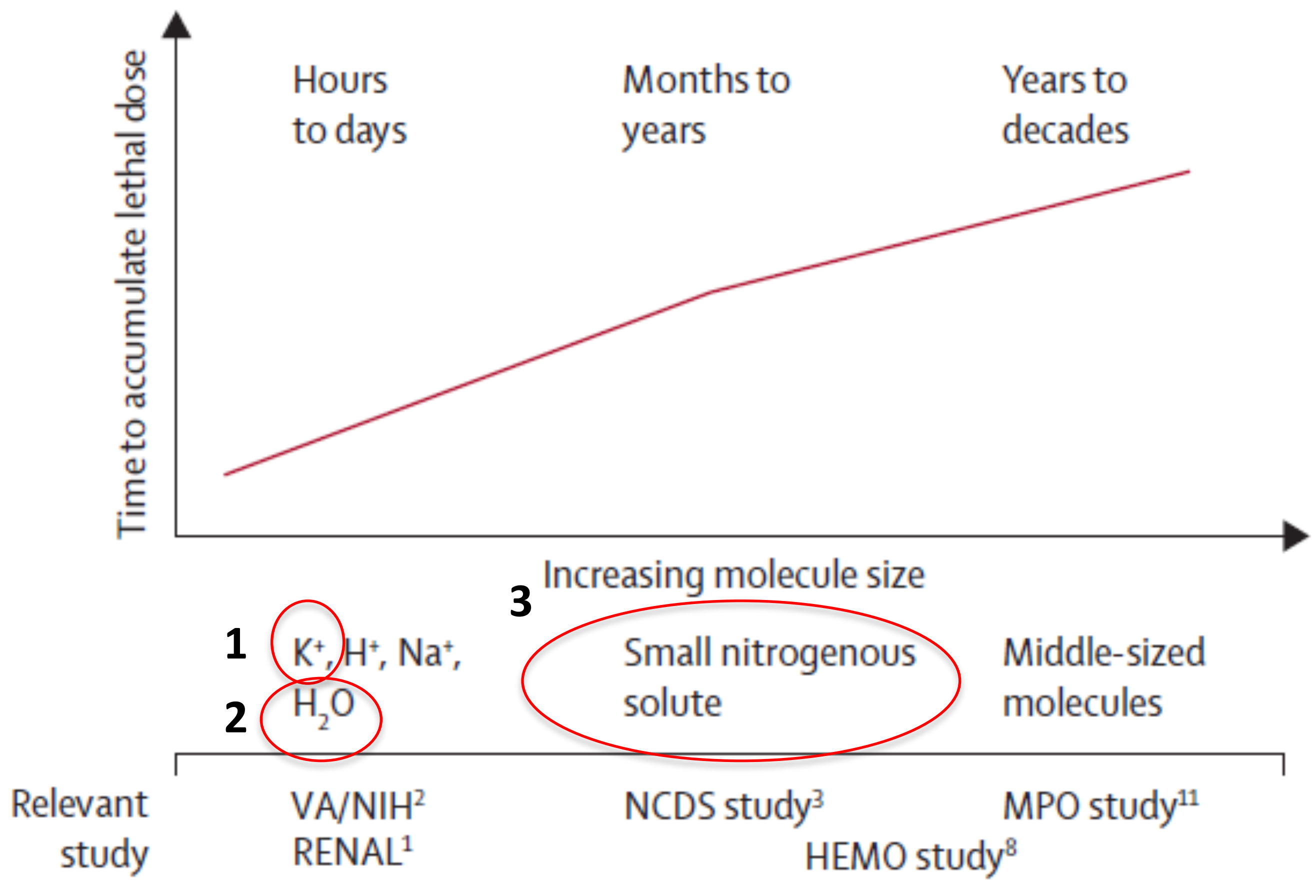
Chapter 5.8: Dose of renal replacement therapy in AKI

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*)

Kidney Int suppl 2:89-115; 2012

Dialysis dose in acute kidney injury and chronic dialysis

*Andrew Davenport, Ken Farrington
Centre for Nephrology, University College London Medical School, Royal Free Campus, London NW3 2PF, UK (AD); and Renal Unit, Lister Hospital, Stevenage, Hertfordshire, UK (KF)



Davenport and Farrington Lancet; 2010

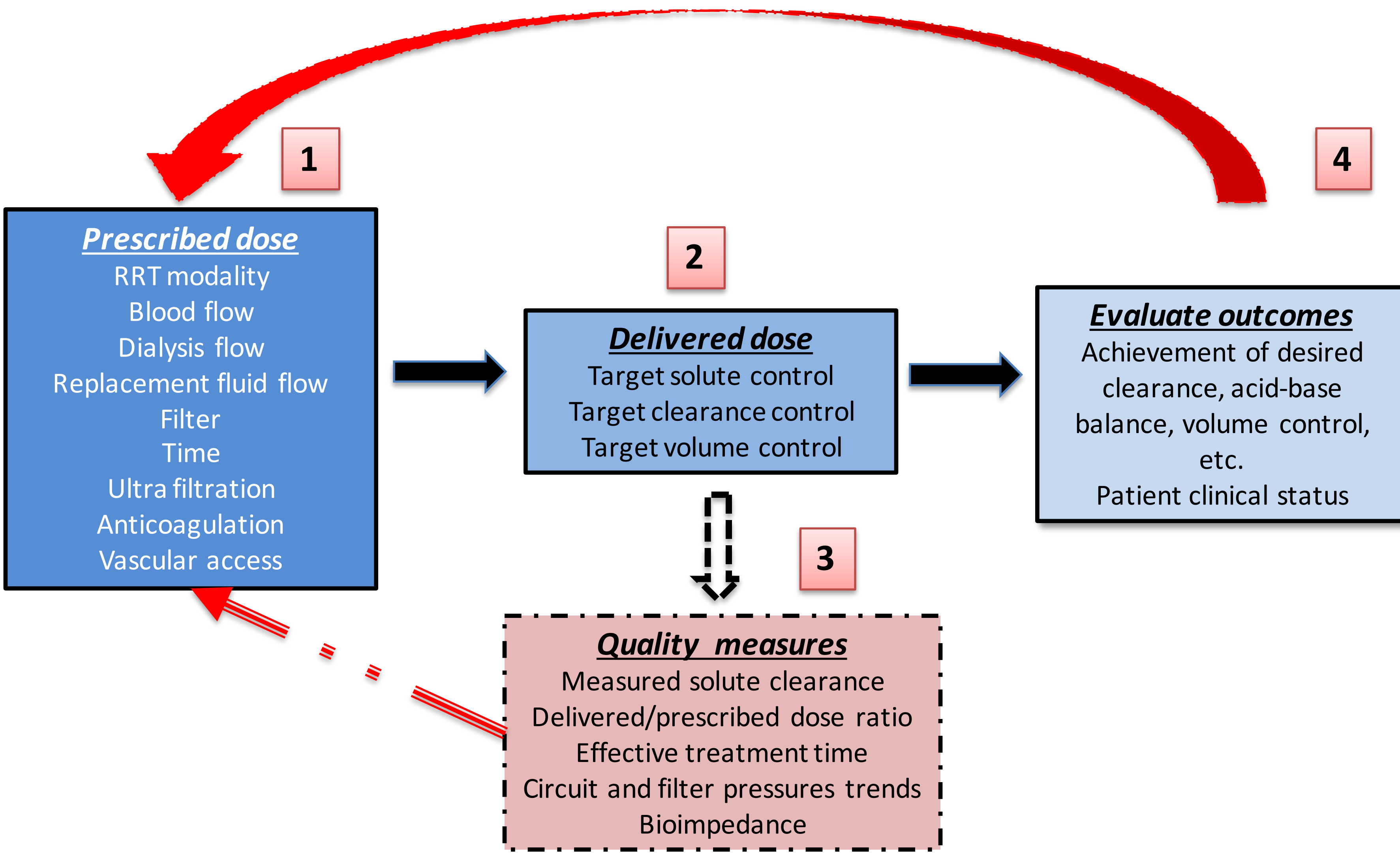
Blood Purification

ADQI Consensus

Blood Purif 2016;42:238–247
DOI: 10.1159/000448507

Published online: August 26, 2016

Precision Continuous Renal Replacement Therapy and Solute Control



1. Potassium control IHD

Session length: 3 hours

Dialyzer: Acute

Dialysis solution with K 0 mmol/L

Temperature 35° C

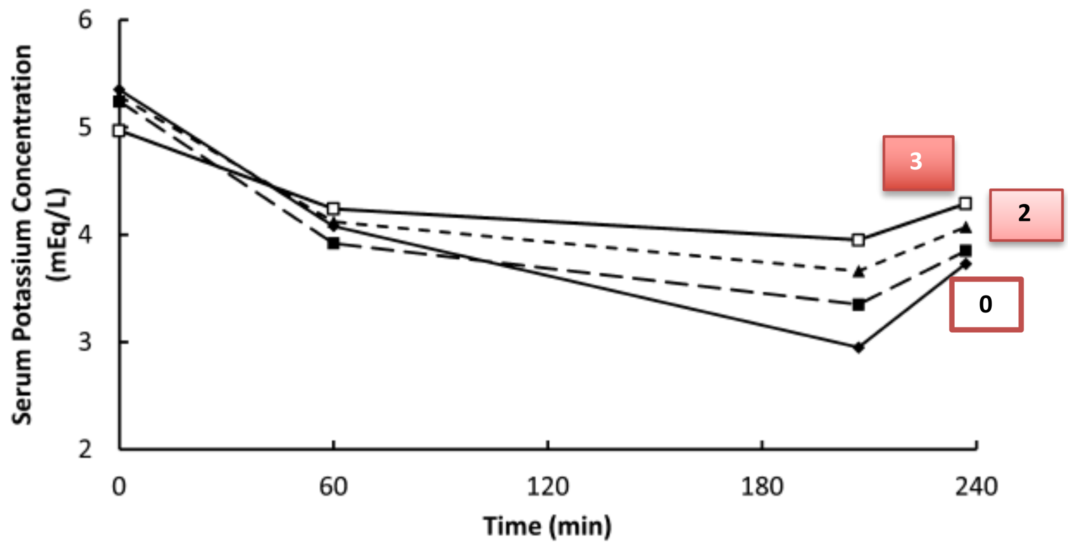
Qb 300 mL/min

Qd 500 mL/min

UF: 0

Potassium kinetics during hemodialysis

Baris U. AGAR,[1] Bruce F. CULLETON,[1] Richard FLUCK,[2] John K. LEYPOLDT[1]
[1]Medical Products (Renal), Baxter Healthcare Corporation, Deerfield, Illinois, USA; [2]Department of Renal Medicine, Royal Derby Hospital, Derby, UK



Hemodialysis International doi.org/10.1111/hdi.12195

Haemodialysis in the critically ill

Chapter: Haemodialysis in the critically ill

Author(s): Rolando Claure-Del Granado and Ravindra L. Mehta

DOI: 10.1093/med/9780199600830.003.0215

Oxford Textbook of Critical Care (2 ed.)

Table 215.2 Advantages and disadvantages of intermittent haemodialysis, sustained low-efficiency dialysis, extended daily dialysis, and continuous renal replacement therapies

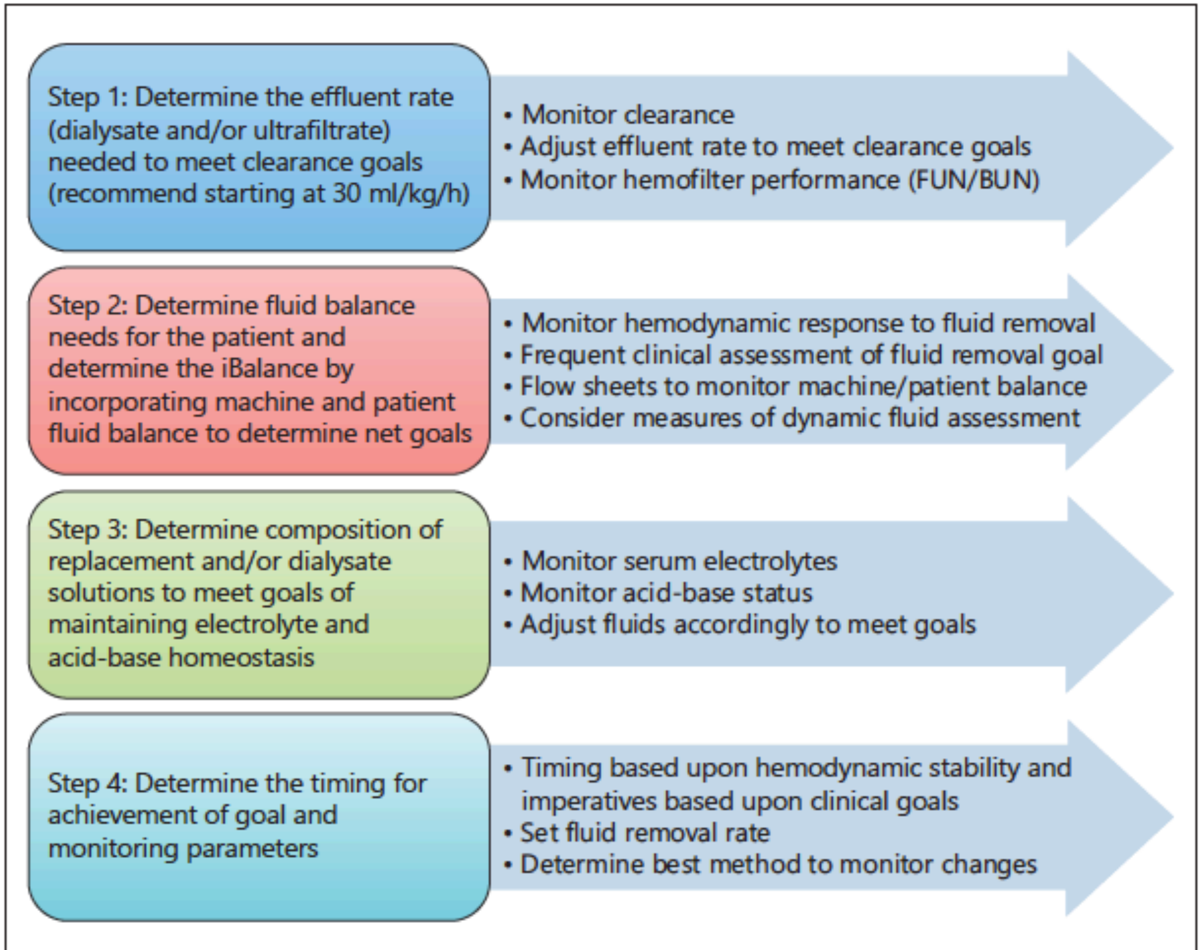
	IHD	SLED/EDD	CRRT
Haemodynamic stability	++	+++	++++
Treatment duration	++	+++	++++
Patient mobility	++++	++	+
Fluid control	+	++	++++
Low osmolality variations	+	++	++++
No anticoagulation	++++	++	+
Small solute clearance	++++	+++	+++
Removal of medium molecular weight solutes	+	++	+++
Need of water production	+	+	-
1 machine several patients per day	++++	++	-
Continuous and adaptable therapy	+	++	++++
Cost	++	+++	++++
Nurse training	++++	++	+
Nurse workload	++	++	+

2. Fluid control
KDIGO Clinical Practical Guideline for Acute Kidney Injury
Fluid control

- Separate dimension of dose
- Prescription strategies
  - Ultrafiltration technique
  - Renal replacement technique
- Inadequate achievement of ultrafiltration targets
  - Machine/circuit related
  - Reductions in UF in response to hypotensive episodes

Kidney Int suppl 2:89-115; 2012

Precision Fluid Management in Continuous Renal Replacement Therapy



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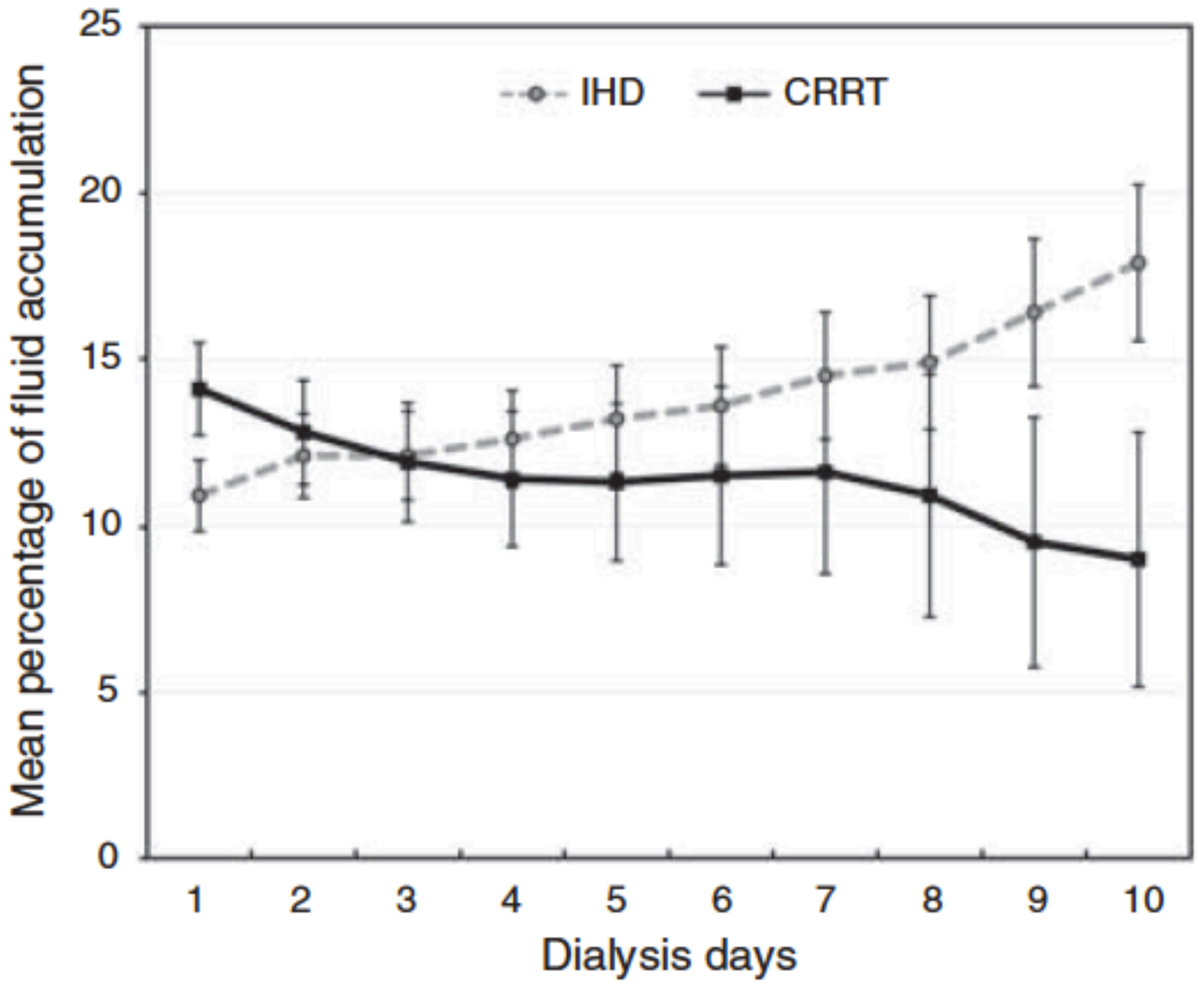
1 machine several patients per day	++++	++	-
Continuous and adaptable therapy	+	++	++++
Cost	++	+++	++++
Nurse training	++++	++	+
Nurse workload	++	++	+

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



Bouchard et al. Kidney Int; 2009

Precision Fluid Management in Continuous Renal Replacement Therapy

ADQI Consensus

Table 6. Two different methods for fluid balance in CRRT

Variable	Ultrafiltration technique	Replacement fluid technique
Fluid balance	Achieved by varying UF rate	Achieved by adjusting amount of replacement fluids
Differences	Output is varied to accommodate changes in intake and output to reach a fluid removal goal	Output is fixed to achieve solute clearance goal and replacement fluid rates are changed to allow flexibility in reaching net fluid balance goals
Advantages	Familiar strategy from intermittent HD Can allow for fluid balance calculations over an extended period with calculation of a rate per unit time	Allows for constant solute clearance Dissociates clearance parameters from fluid balance
Disadvantages	Solute clearance may fluctuate Requires frequent interactions with CRRT machine to adjust UF rates to meet patient needs	Requires hourly calculations of the amount of replacement fluid to be given with risk for fluid imbalance if rate not calculated correctly with clear appreciation of all of the inputs and outputs for the patient

Blood Purif 2016;42:266–278

3. Solute control (small solutes)
Prescription of CRRT dose

- Prescription of CRRT dose is based on the desired clearance for an individual patient.
  - Specific goal of therapy
  - At a particular time of evaluation
- Dose of CRRT relates to clearance measured as the removal rate ***of urea*** from plasma into UF
  - Sieving coefficient approximately 1
  - Main driver of clearance in CRRT is total effluent fluid rate

Prescribed CRRT dose

- Consensual recommended effluent dose of 25-30 ml/kg/h on average

Seminars in Dialysis. 2021;00:1–8.

Blood Purification

ADQI Consensus

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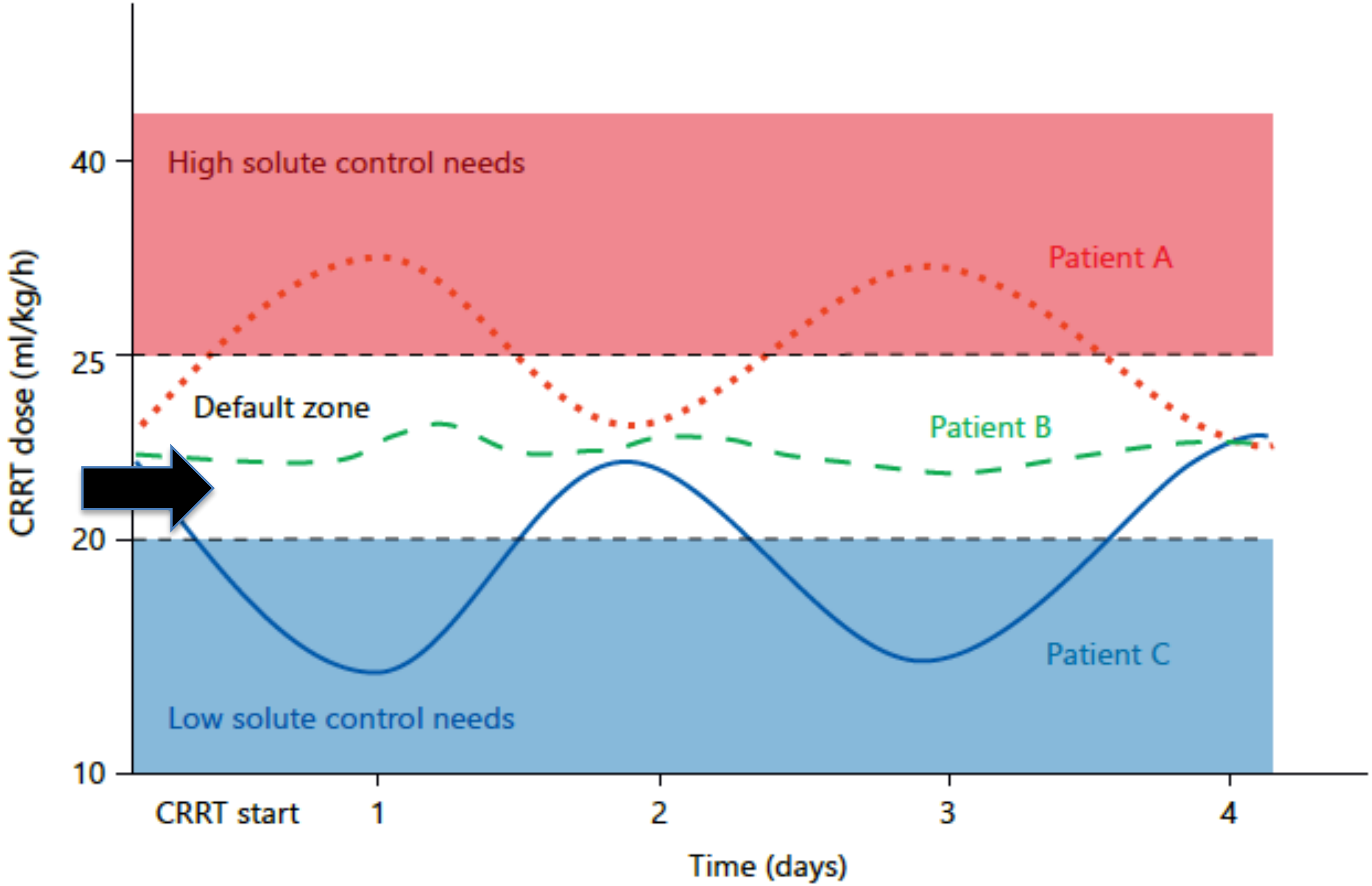
Precision Continuous Renal Replacement Therapy and Solute Control



Post-dilutional CVVH

- K = [effluent flow rate] Q_e*(C_e/C_b)
- Post-dilutional CVVH:
  - Q_b 200 ml/min.; Hto 30%
  - Q_{ef} 1.500 l/h
  - Net UF rate 83.3 ml/h
  - *No anticoagulation*
  - *K 2*

Prescribed dose

- K_{urea} = 1500 mL/h * 126/126
  = 1500 mL/h
  = **25 ml/min.**
  (28.8 mL/kg/hr)

Efficiency = K (clearance)

Precision Continuous Renal Replacement Therapy and Solute Control

Table 2. Summary of proposed quality measures for CRRT dose

Metric	Definition	Calculation	Benchmark target
Dose (clearance)	This QM focuses on solute clearance to determine delivered dose using blood and effluent solute concentration. This QM provides an instantaneous estimate of filter efficacy (i.e., sieving coefficient). This QM can be serially measured to evaluate solute clearance and filter performance. The default solute is urea; however, this QM could be applied to additional solutes	QM = effluent (urea)/blood (urea)	≥0.80
Dose (ratio of delivered/prescribed)	This QM focuses on the effluent volume delivered relative to prescribed dose. This measure would be calculated as the ratio of average effective delivered dose (time-averaged (24 h)) divided by prescribed dose	QM = average effective delivered dose/prescribed dose	≥0.80
Effective treatment time	This QM focuses on the total average time a patient receives treatment in a given 24 h period. This measure is based on time and would incorporate treatment interruptions that were planned and unanticipated. Initial benchmark target should be ≥20 h/day. Additional QMs related to contributors and response to unplanned interruptions are necessary (e.g., catheter function, circuit/filter clotting, anticoagulation)	QM = 24 – downtime (hours)	≥20

Blood Purif 2016;42:238–247

Post-dilutional CVVH
>20 hours (filter clotted)

- K = [effluent flow rate] Q_e*(C_e/C_b)
- Post-dilutional CVVH:
  - Q_b 200 ml/min.; Hto 30%
  - Q_{ef} 1.500 l/h
  - BUN 85 mg/dl
  - FUN 60 mg/dl
- K_{urea} = 1500 mL/h * 60/85 (0.7)

  = 1050 mL/h

  = **17.5 ml/min.**

  (20 mL/kg/hr)

FUN/BUN < 0.8

P/D dose ratio < 0.8 (0.67)

≥ 20 hours

Seminars in Dialysis

RENAL REPLACEMENT THERAPY IN ACUTE KIDNEY INJURY: WHEN, HOW AND HOW MUCH?

Assessing and Delivering Dialysis Dose in Acute Kidney Injury

K 4.3
pH 7.42 HCO_3 18

TABLE 2. Proposed parameters for delivered dose assessment

Parameter	Measurement	Tools
Solute		
Very small waste products	K^+, Na^+, Phosphate H^-	Blood levels of K, Na, PO_4 Phosphate clearance pH, HCO_3 AG, SIDeff, SIDapp, SIG, Delta gap, Delta ratio.
Small waste products	Urea	Clearance (ml/minutes) EKR (ml/minutes) Std*Kt/V*
Middle-sized molecules	Serum $ß_2$ Microglobulin	$ß_2$ Microglobulin clearance
Fluid	Weight (kg) Inputs–Outputs BIA BNP	Weight changes Fluid accumulation Fluid overload BIVA BNP profile

Claure-Del Granado R and Mehta RL. Sem Dialysis; 2011

U.M.S.S.

RESEARCH Open Access

Fluid overload at start of continuous renal replacement therapy is associated with poorer clinical condition and outcome: a prospective observational study on the combined use of bioimpedance vector analysis and serum N-terminal pro-B-type natriuretic peptide measurement

CRITICAL CARE

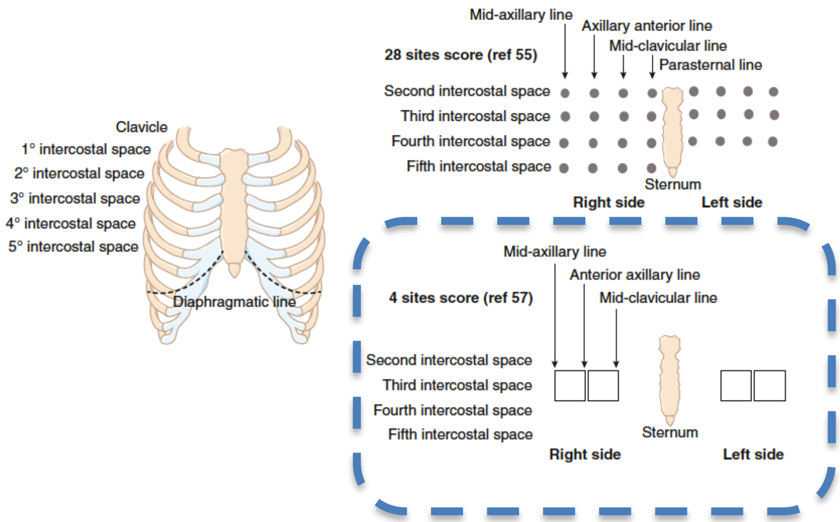
Table 3 Changes of fluid status and cumulative fluid balance over 3 days and outcomes (n = 70)

Fluid status before CRRT		Fluid status 3 days later				Total death, n (%)
		Type 1	Type 2	Type 3	Type 4	
Type 1	Cumulative fluid balance, mL	1,664 ± 1,971	3,832 ± 4,291	2,626 ± 3,732	870	
	Death, n (%)	1/10 (10%)	1/3 (33.3%)	2/3 (66.6%)	0/1 (0%)	4/17 (23.5%)
Type 2	Cumulative fluid balance, mL	1,566	2,365 ± 2,140	3,935 ± 2,130	5,974 ± 3,144	
	Death, n (%)	0/1 (0%)	1/4 (25%)	0/2 (0%)	2/4 (50%)	3/11 (27.3%)
Type 3	Cumulative fluid balance, mL	571	-	1,601 ± 1,147	3,242 ± 3,296	
	Death, n (%)	0/1 (0%)	0	1/3 (33.3%)	2/5 (40%)	3/9 (33.3%)
Type 4	Cumulative fluid balance, mL	−1,380 ± 3,308	−1,159 ± 3,394	2,461 ± 2,844	2,613 ± 3,962	
	Death, n (%)	3/4 (75%)	1/5 (20%)	1/4 (25%)	14/20 (70%)	19/33 (57.6%)
Total death, n (%)		4/16 (25%)	3/12 (25%)	4/12 (33.3%)	18/30 (60%)	29/70 (41.4%)

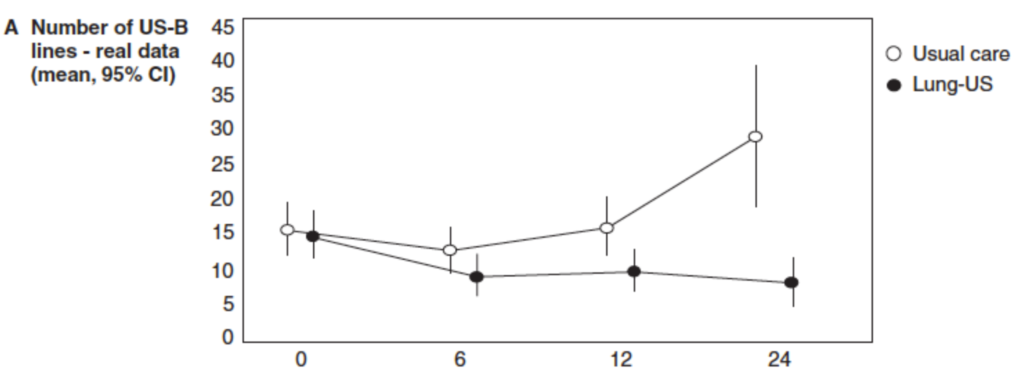
Fluid status: type 1, no overhydration and B-type natriuretic peptide (BNP) normal; type 2, no overhydration but BNP abnormal; type 3, overhydration but BNP normal; type 4, overhydration and BNP abnormal. CRRT, continuous renal replacement therapy.

Detecting and Treating Lung Congestion with Kidney Failure

Carmine Zoccali,[1] Francesca Mallamaci,[2,3] and Eugenio Picano[4]



LUST RCT multicentre
UF – dry weight
183 POCUS vs. 180 control
Follow-up 1.49 years
Improvement in pulmonary congestion in the POCUS group

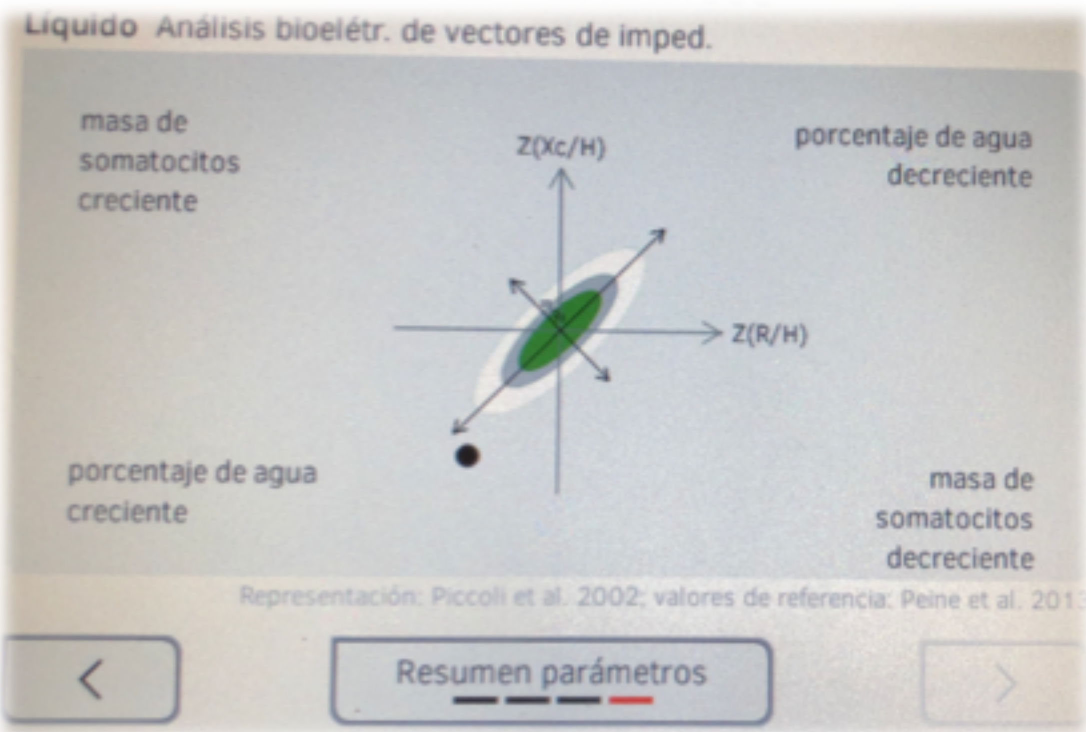


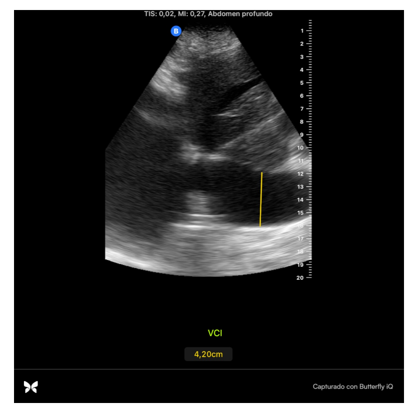
CJASN 17: ●●●–●●●, May, 2022

BiVa & POCUS


seca
medical Body Composition Analyzer


TIS: 0.01, MI: 0.51, Lung
Captured with Butterfly iQ

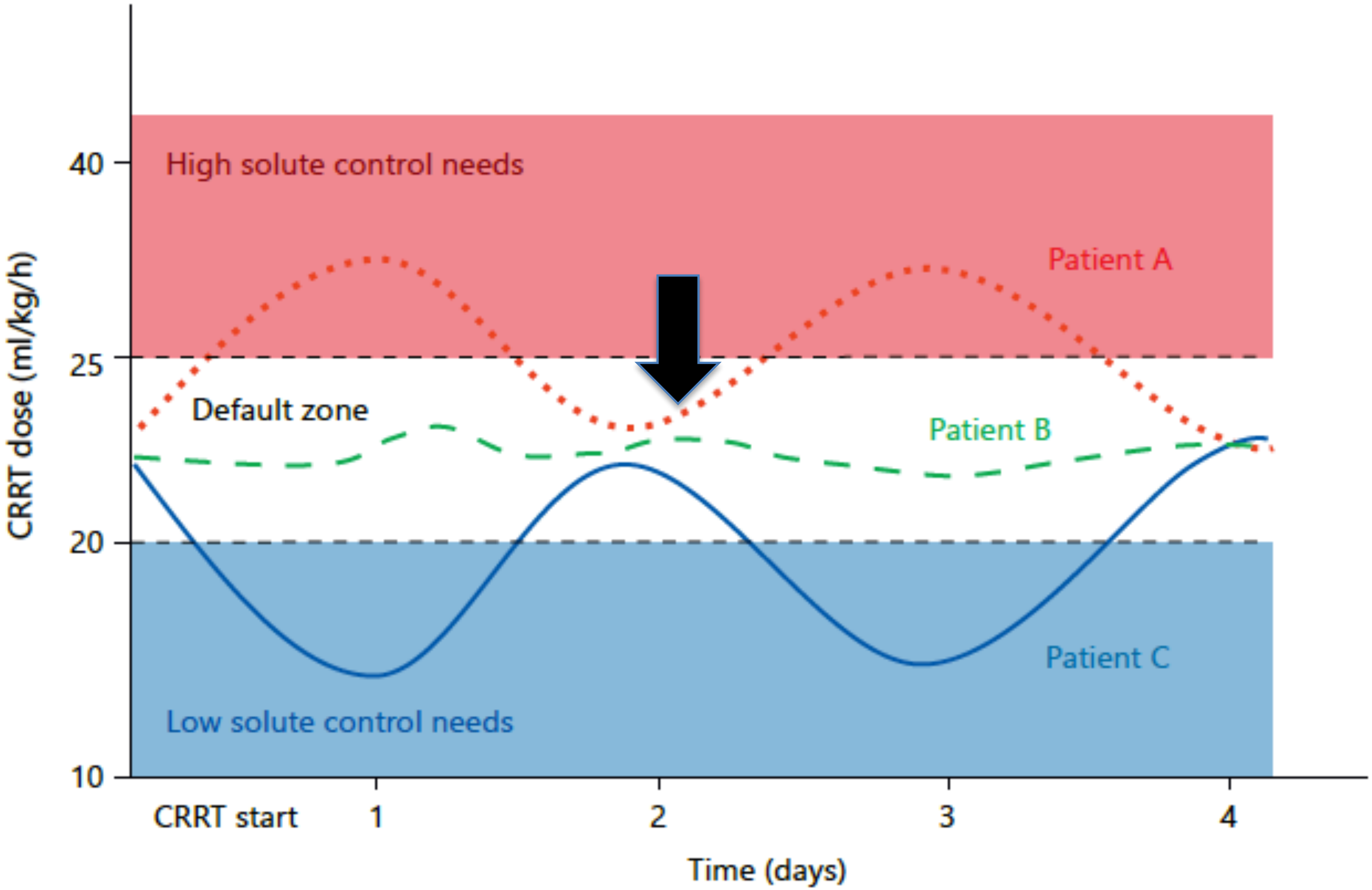

Líquido Análisis bioelétr. de vectores de imped.
masa de somatocitos creciente
Z(Xc/H)
porcentaje de agua decreciente
Z(R/H)
porcentaje de agua creciente
masa de somatocitos decreciente
Representación: Piccoli et al. 2002; valores de referencia: Peine et al. 2013
Resumen parámetros


TIS: 0,02, MI: 0,27, Abdomen profundo
VCI
4,20cm
Capturado con Butterfly iQ

Post-dilutional CVVH

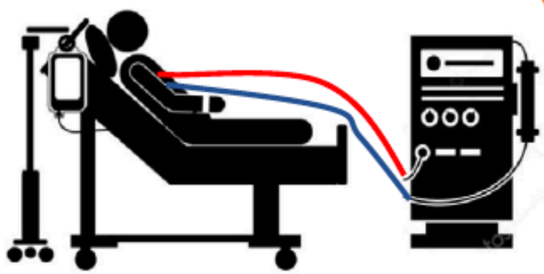
- K = [effluent flow rate] Q_e*(C_e/C_b)
- Post-dilutional CVVH:
  - Q_b 200 ml/min.; Hto 30%
  - Q_{eff} 1.500 l/h
  - BUN 85 mg/dl
  - FUN 60 mg/dl
- K_{urea} = 1500 mL/h * 60/85
  = 1050 mL/h
  = **17.5 ml/min.**
  (20 mL/kg/hr)
- Filtration fraction:
  - Q_{eff}/Q_p
  - Q_p = Q_b ml/hr *(1-Hto)
- Filter clotting ***FF=25%***
- FF = 1500 / (12000 * (1-0.30)) = 0.18 (18%)
- Prevent clotting:
  - ***Increase Q_b***
  - ***Use pre-dilution***
  - ***Anticoagulation***
  - ***Change UF strategy***

Precision Continuous Renal Replacement Therapy and Solute Control



Blood Purif 2016;42:238–247

Reasons why delivered dose may be less than prescribed dose



Causes of loss of CRRT filter efficiency

- Loss of filter surface area due to clotting or air
- Loss of permeability due to clogging, clotting, adsorption (solute fouling on the membrane surface)
- Concentration polarization

Prescribed CRRT dose

- Consensual recommended effluent dose of 25-30 ml/kg/h on average

Treatment Interruptions

- <u>**Intended**</u>
- Procedures
- Mobilization
- Recirculation
- <u>**Unintended**</u>
- Catheter problems
- Filter change
- Bag changes

Delivered CRRT dose

- Consensual recommendation ≥80% of prescribed CRRT dose

Anticoagulation
UFH protocol at Hospital Obrero No 2 – CNS
No citrate available

- No heparin after mayor surgery, epidural procedures (24 – 48 h.)
- Prime circuit with 5000 UI ***(1st bolus)***
- ***Second bolus*** *like shown on table*
- UFH infusion 10,000 UI en 1000 ml = 10 UI/ml
- Label as just for CRRT use
- Add the volume of heparin to the final amount of UF
- Pre-filter administration
- Lab control at 6 h, then each 12 h.

UFH	*INR*	*TTPa*	*Platelets*
70 UI*kg 10 UI Kg/h	**<1.5**	**<40 s**	**>150**
35 UI*Kg 5 UI Kg/h	**>1.5 - < 2.5**	**> 40 s**	**<150 - >60**
No bolus	**>2.5**	**>60 s**	**<60**

Pre-dilution CVVH

- Q_b 200 mL/min.; Hto 30%
- $Q_{r\ pre}$ 2000 mL/hr
- **<u>Started on anticoagulation</u>**
- Q_{UF} 500 mL/h (fixed/replacement fluid technique)
- Net UF 3000

- Pre-dilution CVVH
- FF:
  2000 / [(12000(1-0.3)) + 2000]
  0.19 → (19%)

Dilution factor:
$Q_b/(Q_b+Q_r)$

- **Pre-dilution CVVH**
  $K = Q_{eff} * (C_e/C_b)* [Q_b/(Q_b + Q_r)]$

$K = 2000$ mL/h * 0.95 * (12000/(12000 + 2000))
= 1620 ml/h

Prescribed = 2000 ml/h = 38 mL/kg/hr
Delivered = 27 mL/min → 31 mL/kg/hr

FUN/BUN > 0.8
P/D dose ratio > 0.8 (0.82)
≥ 48 hours

Precision Fluid Management in Continuous Renal Replacement Therapy

ADQI Consensus

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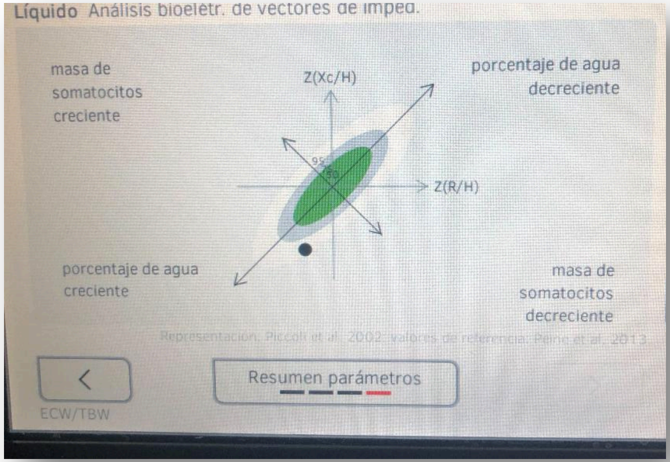
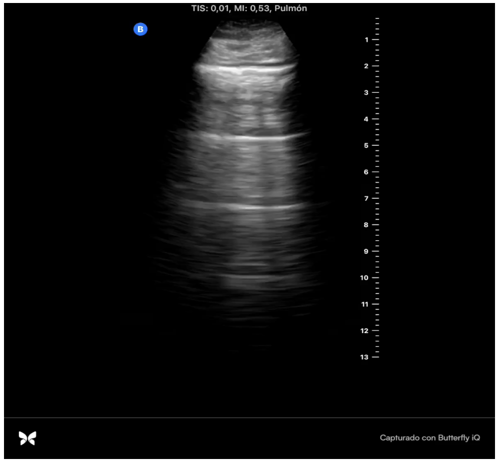
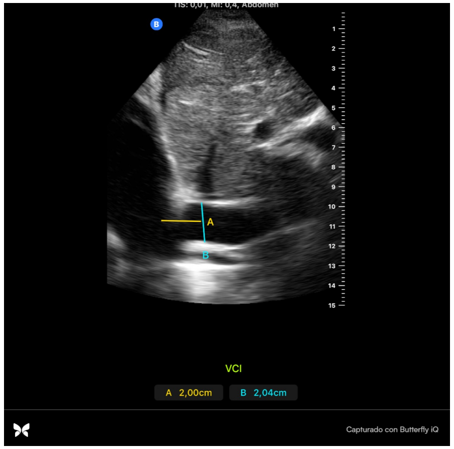
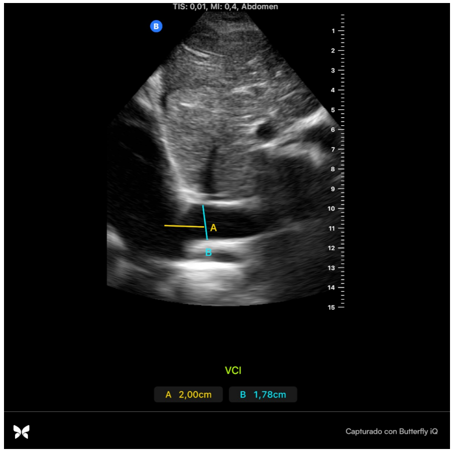
Blood Purif 2016;42:266–278

BiVa & POCUS


Líquido Análisis bioeletr. de vectores de imped.
masa de somatocitos creciente
Z(Xc/H)
porcentaje de agua decreciente
Z(R/H)
porcentaje de agua creciente
masa de somatocitos decreciente
Resumen parámetros
ECW/TBW


TIS: 0,01, MI: 0,53, Pulmón
Capturado con Butterfly iQ


VCI
A 2,00cm
B 2,04cm
Capturado con Butterfly iQ


TIS: 0,01, MI: 0,4, Abdomen
VCI
A 2,00cm
B 1,78cm
Capturado con Butterfly iQ

Dosing in RRT for AKI: Practical considerations

- Use CRRT and IHD as complementary therapies in AKI patients.
- An effluent flow of at least 20-25 mL/Kg per hour could be sufficient, so long as there is careful attention to ensuring that the target dose of therapy is actually delivered.
- In order to ensure delivery of the target dose, an initial prescription of 25-30 mL/kg per hour could be recommended.
- But…dose prescription should be dynamic.
- Fluid management is also a dynamic process with 3 goals: maintenance of the circuit, of electrolyte and acid-base homeostasis, and fluid balance regulation.
- Replacement fluid technique allows for constant solute clearance.