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Solutions & Fluid Balance

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Disclosures

- Consultation for adjudication for Bioporto.

Objectives

- Review the concept of precision fluid management in CRRT
- Understand terminology and characteristics of the solutions available for performing CRRT
- Understand the timing, quantity, and practical issues of fluid removal on CRRT

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ADQI Consensus

Blood Purification

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Precision Fluid Management in Continuous Renal Replacement Therapy

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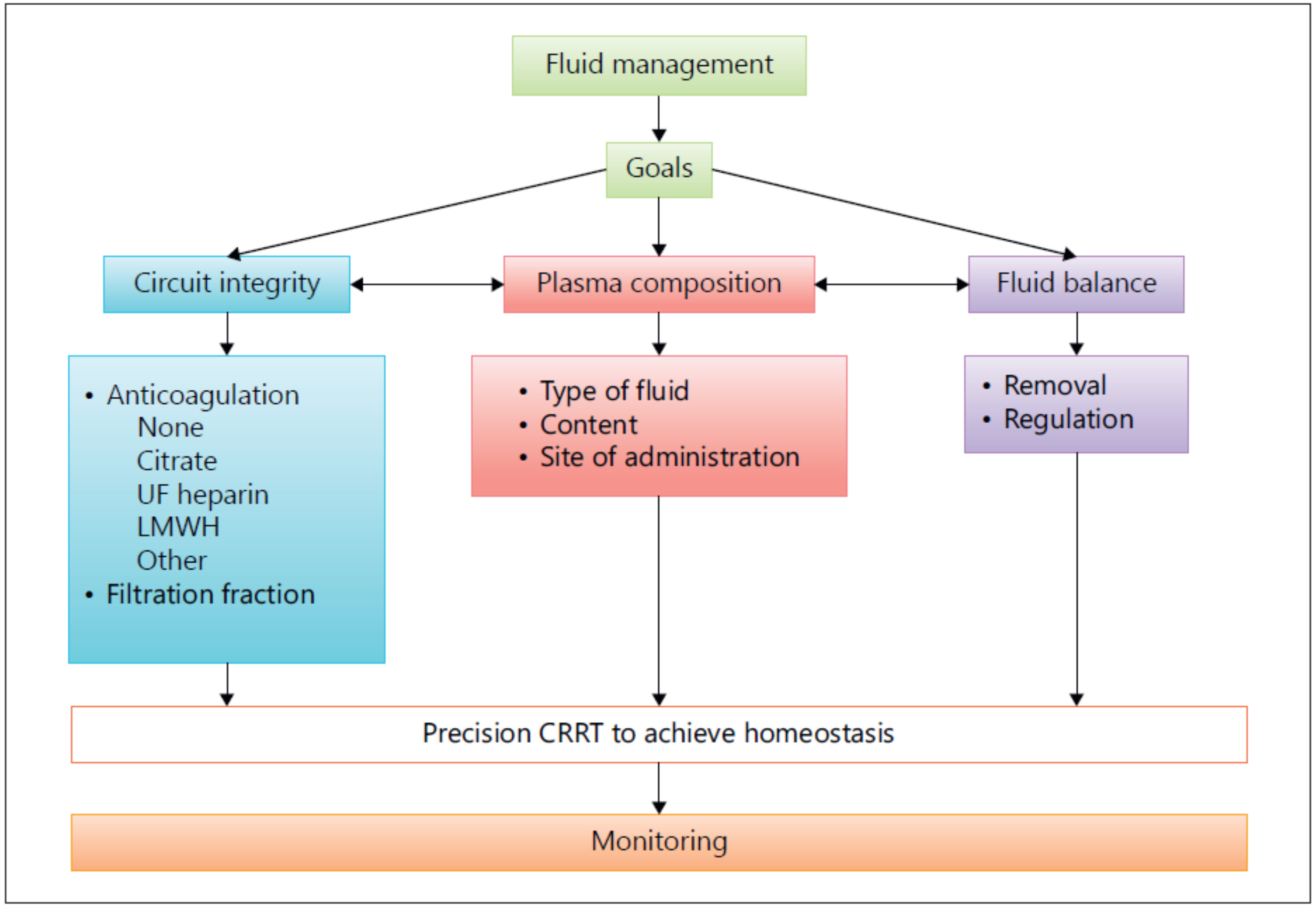
on behalf of the Acute Disease Quality Initiative (ADQI) Consensus Group

- Fluid Management During CRRT: 3 goals
  - Maintain patency of the circuit
  - Maintain plasma and acid-base homeostasis
  - Regulate fluid balance

Conceptual Framework: Fluid Management during CRRT



Terminology: Dialysis & Replacement Solutions

- United States: FDA standards and approvals for dialysis and replacement solutions differ

- United States FDA: Considers anything placed into vascular space a drug
  - Replacement Solutions: Considered a drug

Fluid Composition

- Buffer
- Electrolyte Composition
- Glucose

Buffers

- Acetate (abandoned): Associated with hemodynamic instability
  - Excessive nitric oxide production
  - Excessive cytokine synthesis

- Lactate
  - Converted to bicarb on equimolar amounts
  - Hyperlactatemia (intolerance highest in liver failure & circulatory arrest)
    - Worsened acidosis
    - Impair cellular function and catabolism
  - May lead to clinical misinterpretation

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Buffers

- Bicarbonate
  - Major extracellular buffer
  - Higher risk of bacterial contamination
  - Solution unstable in presence of
    - Calcium and Magnesium
- Clinical Trials evaluating lactate vs. bicarbonate
  - Bicarbonate buffers associated with less
    - Hyperlactatemia
    - Better correction of acidosis
    - Better hemodynamics and hemodynamic tolerance

KDIGO

5.7.1: We suggest using bicarbonate, rather than lactate, as a buffer in dialysate and replacement fluid for RRT in patients with AKI. (*2C*)

5.7.2: We recommend using bicarbonate, rather than lactate, as a buffer in dialysate and replacement fluid for RRT in patients with AKI and circulatory shock. (*1B*)

5.7.3: We suggest using bicarbonate, rather than lactate, as a buffer in dialysate and replacement fluid for RRT in patients with AKI and liver failure and/or lactic acidemia. (*2B*)

Fluid Composition: Electrolyte & Glucose

- Sodium
  - 130 -140 mEq/L
  - Consider 130 depending on anticoagulation strategy
- Potassium
  - 0-4 mEq/L
  - Generally use 4
- Bicarbonate
  - 22-35 mEq/L
  - Adjust based on anticoagulation strategy
- Phosphate
- Glucose
- Magnesium
- Calcium
  - Calcium free for RCA

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N_xStage ® : Pureflow Bicarbonate Solution

Product Code	Bicarbonate (mEq/L)	Potassium (mEq/L)	Sodium (mEq/L)	Calcium (mEq/L)	Magnesium (mEq/L)	Chloride (mEq/L)	Glucose (mg/dL)
RFP-400	35	2	140	3	1	111	100
RFP-401	35	4	140	3	1	113	100
RFP-402	35	0	140	3	1	109	100
RFP-403	35	2	140	0	1.5	108.5	100
RFP-404	35	4	140	2.5	1.5	113	100
RFP-406*	35	3	140	3	1.5	112.5	100
RFP-453	25	2	130	0	1.5	108.5	100
RFP-454	25	4	130	0	1.5	110.5	100
RFP-456	25	4	140	0	1.5	120.5	100

Prismasate ® Diasylate (Baxter)

		Calcium Formulas		Calcium-Free Formulas			
	Plasma[4]	PrismaSATE BGK 4/2.5	PrismaSATE BK 0/3.5	PrismaSATE BGK 2/0	PrismaSATE BGK 4/0/1.2	PrismaSATE B22GK 4/0	PrismaSATE BK 2/0
Potassium K^+ (mEq/L)	3.5-5.0	4	0	2	4	4	2
Calcium Ca^{2+} (mEq/L)	2.3-2.6†	2.5	3.5	0	0	0	0
Magnesium Mg^{2+} (mEq/L)	1.4-2.0	1.5	1.0	1.0	1.2	1.5	1.0
Sodium Na^+ (mEq/L)	135-145	140	140	140	140	140	140
Chloride Cl^- (mEq/L)	100-108	113	109.5	108	110.2	120.5	108
Bicarbonate HCO_3^- (mEq/L)	22-26	32	32	32	32	22	32
Lactate (mEq/L)	0.5-2.2	3	3	3	3	3	3
Dextrose (mg/dL)	70-110	110	0	110	110	110	0
Osmolarity (mOsm/L)	280-296	300	287	292	296	296	286

DUOSOL® (Braun)

	Bicarbonate 35 Dialysate 0K/3Ca	Bicarbonate 35 Dialysate 2K/3Ca	Bicarbonate 25 Dialysate 2K/0Ca	Bicarbonate 32 Dialysate 2K/0Ca	Bicarbonate 35 Dialysate 4K/3Ca	Bicarbonate 25 Dialysate 4K/0Ca
Na	140	140	136	136	140	136
K	0	2	2	2	4	4
Ca	3	3	0	0	3	0
Mg	1	1	1.5	1.5	1	1.5
Cl	109	111	115	107.5	113	117
Lactate	0	0	0	0	0	0
HCO_3	35	35	25	32	35	25
Glucose g/L	1	1	0	0	1	0

Replacement Solutions

Fluid	Comment
Sodium Bicarbonate 150 meq/L	- Treats metabolic acidosis - Must be compounded - Ameliorates the need for a bicarb drip separate from CRRT device
0.9% Normal Saline	- Isotonic - Induce Acidosis - Treat alkalosis
Other Options:	- Lactated Ringer or Balance Electrolyte solution - 0.45 NS + 75 meq/L Sodium Bicarbonate

Prismasol®

	BGK 0/2.5	BGK 4/2.5	BGK 4/3.5	BGK 2/3.5	BGK 2/0	B22GK 4/0	BK 0/0/1.2	BGK 4/0/1.2
Ca	2.5	2.5	3.5	3.5	0	0	0	0
Bicarb	32	32	32	32	32	22	32	32
K	0	4	4	2	2	4	0	4
Mg	1.5	1.5	1	1	1	1.5	1.2	1.2
Na	140	140	140	140	140	140	140	140
Cl	109	113	113.5	111.5	108	120.5	106.2	110.2
Lactate	3	3	3	3	3	3	3	3
Dextrose	100	100	100	100	100	100	100	100

Phosphate containing Solutions

Continuous veno-venous hemofiltration using a phosphate-containing replacement fluid in the setting of regional citrate anticoagulation

Santo Morabito[1], Valentina Pistolesi[1], Luigi Tritapepe[2], Elio Vitaliano[3], Laura Zeppilli[1], Francesca Polistena[1], Enrico Fiaccadori[4], Alessandro Pierucci[1]

Original Paper

Blood Purification

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Preventing Continuous Renal Replacement Therapy-Induced Hypophosphatemia: An Extended Clinical Experience with a Phosphate-Containing Solution in the Setting of Regional Citrate Anticoagulation

Valentina Pistolesi[a] Laura Zeppilli[a] Francesca Polistena[a] Maria Itala Sacco[a]
Alessandro Pierucci[a] Luigi Tritapepe[b] Giuseppe Regolisti[c] Enrico Fiaccadori[c]
Santo Morabito[a]

So many choices. What to do?

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As my mother says, “Keep it Simple Silly!”

- My Previous Institution Michigan Pediatrics (2 Base Solutions)
  - Prismasol BK 0/0/1.2 (Bicarb 32, 0 Calcium, 0 K)
  - Prismasol BGK 0/2.5 (Bicarb 32, 2.5 Calcium, 0 K)
  - Add Potassium (almost always 4) and Phos (.75 or 1.5 mmol)
  - Normal saline
  - 150 meq/L NaBicarb

- Michigan Adults
  - Duosol (Na 136, bicarb 25, 2K, no calcium or glucose)
  - Add Potassium (to 3 or 4) and Phos (0.68 or 1.68 mmol)
  - Add bicarb as needed

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My current institution (NxStage)

- When utilizing citrate anticoagulation
  - NxStage RFP 403(Bicarb 35, K 2, Ca 0, Mag 1.5)
    - Add PO4 (1.2 mmol KPO4)

- Heparin anticoagulation or if on ECMO (calcium containing NxStage)
  - RFP 400 (Bicarb 35, K 2, Ca 3, Mag 1)
    - Add PO4, K, and Mag

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Other institutions

- UAB (Dr. Tolwani): 4 solutions
  - Due to high volume and safety concerns. They do not add electrolytes to bags
  - CVVHDF institution
  - K 4/bicarb 25/Ca 0 (used with citrate)
  - K 4/bicarb 35/Ca 3
  - K 0/bicarb 35/Ca 3.
  - Dilute citrate solution with 0K that serves as a replacement solution and anticoagulant.

- Reality: **There is no right answer. Know what you do and do it well.**

Fluid Balance

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Fluid Balance

- When?

- How much?

- How?

When do we start to remove fluid?

British Journal of Anaesthesia Page 1 of 8
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BJA

Four phases of intravenous fluid therapy: a conceptual model

E. A. Hoste[1,2], K. Maitland[3,4], C. S. Brudney[5], R. Mehta[6], J.-L. Vincent[7], D. Yates[8], J. A. Kellum[9], M. G. Mythen[10] and A. D. Shaw[11] for the ADQI XII Investigators Group

- Rescue
  - Life saving
  - Correct shock
  - Minutes

- Optimization
  - Organ Rescue
  - Optimize tissue perfusion
  - Hours

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British Journal of Anaesthesia Page 1 of 8
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BJA

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- Stabilization
  - Organ support
  - Goal zero or negative fluid balance
  - Days

- De-escalation
  - Organ recovery
  - Mobilize fluid
  - Days to weeks

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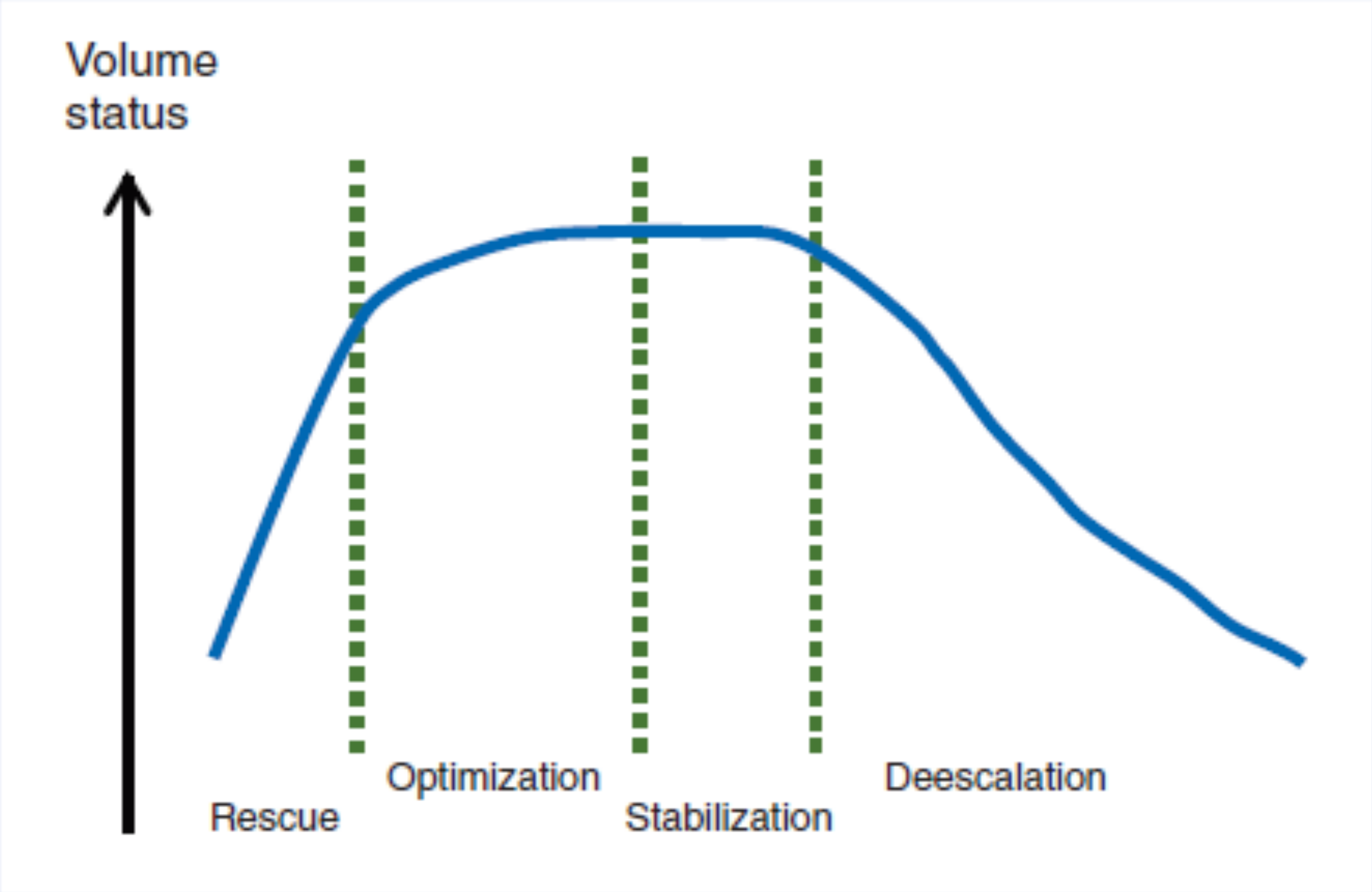

Fig 2 Patients' volume status at different stages of resuscitation. Reproduced with permission from ADQI (www.ADQI.org).

When?

- CRRT may be initiated during any phase
- Classically fluid removal occurs during the de-escalation phase
- Is this absolute? **Of course not. We are clinicians not robots.**
  - Certain clinical scenarios may warrant earlier intervention.
    - Florid pulmonary edema going toward ECMO
    - Critically ill on ECMO

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How much? Machine concerns

- Governed by Filtration Fraction
  - FF = $\frac{\text{Ultrafiltration flow rate}}{\text{Plasma flow rate}}$
- Increase filtration fraction with
  - Increase UF rate
  - Increase Hct
  - Decreased blood flow
- **FF >20-25% associated with increased clotting**

How much? Machine concerns

- Current machines calculate FF
  - Calculate UF/blood flow
  - Do not take into account plasma volume
  - Underestimate FF

How much? Patient concerns

- Plasma refilling rate Is a critical concept
  - From interstitial compartment
  - If UF exceed refilling rate = hypotension. **No Bueno!!!**
- CRRT fluid removal prescription must take into account:
  - A collaborative fluid balance goal set by team
  - Hemodynamic status
  - Rate of fluid removal
- Role of tools to assess volume status: IVC volume, pulse/ stroke variability, bedside echo?
- Currently driven by trial and error

How much and how fast?

- Fluid removal strategies on CRRT have not been systematically studied
  - Can't recommend one over another

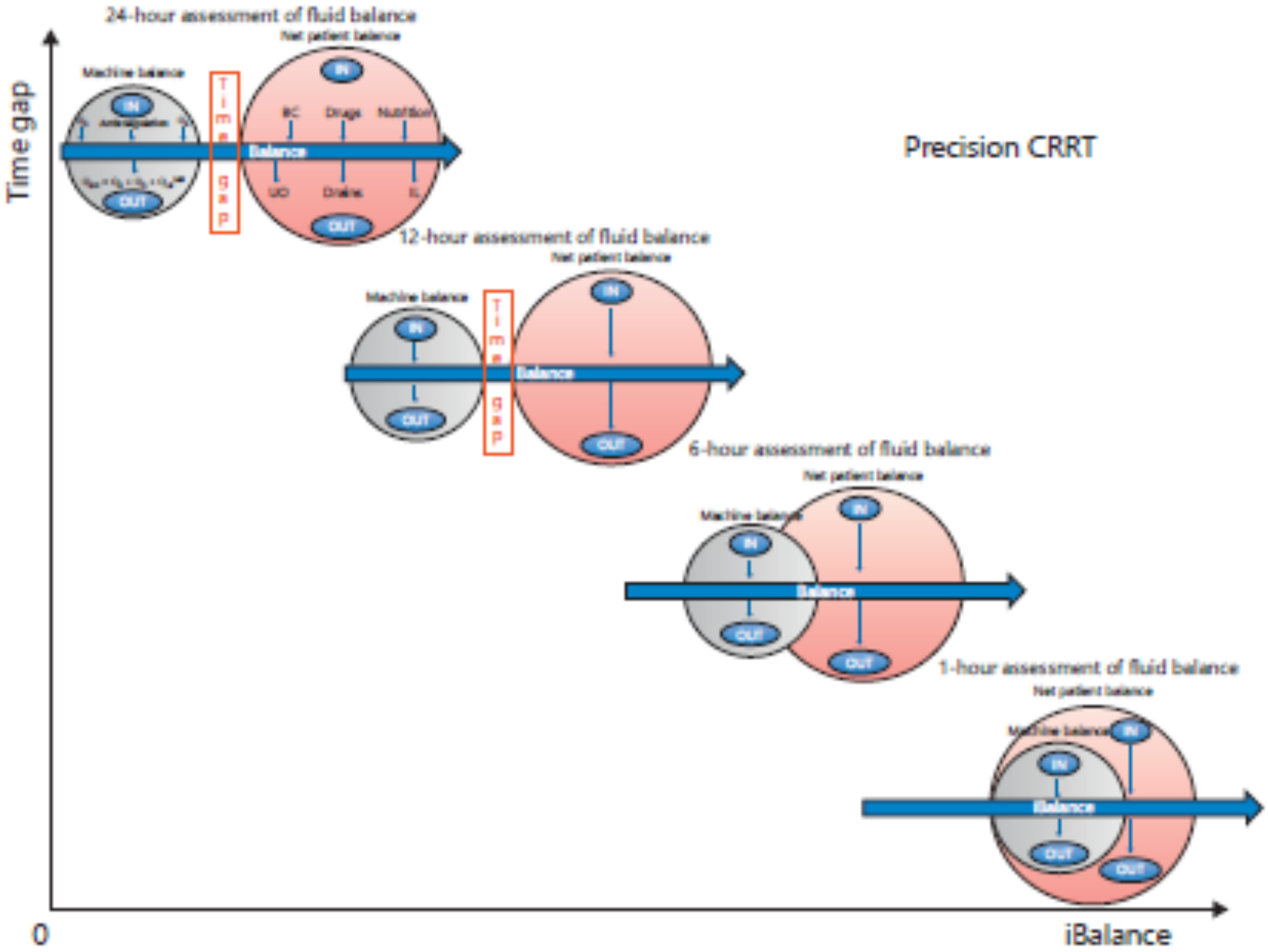
- Pediatric "limit" of fluid removal
  - Classically 2 mL/kg/hr

- Adults "limit" fluid removal
  - Classically 200 – 250 mL/hr
  - 4 to 6 liters per day

How? Terminology

- Machine fluid balance
  - Depends on UF, replacement fluid rates, anticoagulation
- Patient fluid balance
  - ∑ (patient inputs and outputs)
    - Inputs: blood products, IVF, TPN, medications
    - Outputs: Urine, drains, stool
- Integrated Balance = Machine + Patient fluid balance
  - Accuracy improves with more frequent assessments

Precision CRRT



Murugan et al, *Blood Puri*, 2016

How? Delicate balance

- Many competing Interests
  - Nursing burden
  - Nursing education
  - Standardized protocols
  - Physician communication
  - Who orders fluid removal
  - Hourly assessment versus goal for a day?

- Precision CRRT achieved with hourly assessments.

- What strategy does the literature support????

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What do we do?

- Michigan Adult & Pediatrics & MUSC Pediatrics
  - Max fluid removal
    - Pediatrics 2 mL/kg/hr and Adults 200 -250 mL/hr
  - Utilize hourly NET fluid balance rate
    - Nurses take into account the I/O's from previous hour and program into machine each hour on the hour
    - Ex: Anuric patient.
      - Goal: -50/hr
      - Patient input total 200mL last hour
      - Nurse will program in 250ml fluid removal for the next hour.
    - Careful: Fluid boluses, blood products, etc.
      - May lead to high filtration fraction

The most critical point is Collaboration

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Thank You & Questions

Neonatal KIDNEY Collaborative

The Prospective Pediatric Acute Kidney Injury Research Group

Kidney Interventions During Membrane Oxygenation