University Hospitals Bristol and Weston NHS Foundation Trust

Adult Intensive Care
General ICU (Ward A600) & Cardiac ICU (Ward A604)

Reference Guide for Continuous Renal Replacement Therapy

Using Citrate on the Fresenius MultiFiltrate Pro®

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CONTENTS

Chapter 1

Introduction

This document provides a quick reference guide for trained users of the Fresenius MultiFiltrate® CRRT system with citrate anticoagulation.

Target Audience: Critical care nursing and medical staff at University Hospitals Bristol and Weston NHS Foundation Trust.

Scope: This guideline covers the setup, management, and troubleshooting of continuous renal replacement therapy using citrate anticoagulation on the Fresenius MultiFiltrate Pro® system.

Key Points:

- Always follow local policies and procedures
- Ensure appropriate training before operating equipment
- Consult senior clinician for complex cases
- Regular monitoring is essential for patient safety

Chapter 2

Locking the Vascath to Prevent Clotting

If the vascath is not used for more than 1 hour, it should be locked with Citralock.

Procedure:

1. Flush both lumens with 20 mL of 0.9% sodium chloride
2. Fill each lumen with the appropriate volume of **Citralock** for the catheter size
3. Clamp both lumens
4. Label catheter with date and time of locking

> ⚠️ **Important:** Use Citralock (not heparin) for catheter locking to prevent clotting and maintain compatibility with citrate anticoagulation.

Chapter 3

Selecting the Correct Filter Set

Two types of filter are available for use with the Fresenius MultiFiltrate® CRRT system. Both have a surface area of 1.8m².

Filter Type	Pore Size	Clinical Use
AV1000s (Standard)	20 kDa	Suitable for most patients on stable RRT
EMiC2 (Enhanced)	40 kDa	Better clearance of middle molecules **Use for:** Sepsis, rhabdomyolysis, suspected high lipid levels, or unstable patients

> **Clinical Decision:** Start with EMiC2 filter for sick or unstable patients. This should be the default for septic patients.

Filter Lifespan:

- Target filter life: 72-96 hours
- Change filter if evidence of clotting or blockage
- Monitor transmembrane pressure (TMP) trends

Chapter 4

Selecting the CRRT Mode

Mode	Description	Clinical Use
CVV-HD	Continuous Veno-Venous **HaemoDialysis**	Pure diffusive clearance Suitable for most patients
CVV-HDF	Continuous Veno-Venous **HaemoDiaFiltration**	Combined diffusive and convective clearance Enhanced middle molecule clearance

> **Standard Practice:** CVV-HD is appropriate for most patients. CVV-HDF may be considered in specific circumstances (consult senior clinician).

Chapter 5

Preparing the Machine & Technique Overview

Pre-Priming Checks:

1. Verify patient identity and prescription
2. Check filter type is appropriate
3. Ensure all solutions are available and correct
4. Verify vascular access is patent
5. Document pre-treatment observations

Machine Priming:

1. Follow manufacturer's instructions for priming sequence
2. Prime with 0.9% sodium chloride
3. Ensure all air is removed from circuit
4. Connect dialysate and replacement fluid bags
5. Complete pressure tests as per protocol

> ⚠️ **Safety Check:** Always verify circuit integrity before connecting to patient. Double-check all connections are secure.

Starting Treatment:

- Connect arterial line (red) to vascath arterial lumen
- Connect venous line (blue) to vascath venous lumen
- Start blood flow gradually (start at 50-100 mL/min)
- Increase to target blood flow over 15-30 minutes
- Monitor patient closely during initiation

Chapter 6

CRRT Dialysate Solutions

Available Solutions:

Solution	Na+ (mmol/L)	K+ (mmol/L)	Clinical Use
Ci-Ca K4	133	4	Standard - most patients
Ci-Ca K2	133	2	Hyperkalaemia (K+ >5.5 mmol/L)
MultiBic 2K	140	2	Alternative - higher bicarbonate
MultiBic 4K	140	4	Alternative - higher bicarbonate

Selection Guide:

- Use K4 solutions for normokalaemia
- Use K2 solutions for hyperkalaemia
- Consider MultiBic for metabolic acidosis

Sodium Modifications:

For patients with hyponatraemia or hypernatraemia, dialysate sodium can be adjusted by adding or removing fluid. See Chapter 11 for detailed guidance.

Chapter 7

Selecting Starting Dialysis and Blood Flow Rates

Standard Flow Rates:

Parameter	Standard Protocol	Enhanced Protocol
Blood Flow	100-150 mL/min	150-200 mL/min
Dialysate Flow	1500-2000 mL/h	2000-2500 mL/h
Target Clearance	25 mL/kg/h	35 mL/kg/h

Clearance Calculation: Target clearance (mL/kg/h) = Dialysate Flow (mL/h) ÷ Body Weight (kg)

Flow Rate Limits:

- **Blood Flow:** Minimum 80 mL/min, Maximum 200 mL/min (for citrate anticoagulation)
- **Dialysate Flow:** Maximum 4000 mL/h (system limit)
- For citrate anticoagulation: recommended maximum 2000 mL/h to reduce citrate load
- Maintain blood flow:dialysate flow ratio of approximately 1:20

⚠️ **Important:** Higher blood flows (>200 mL/min) increase citrate delivery and accumulation risk. Only use after senior review.

Indications for Enhanced Protocol:

- Severe metabolic acidosis (pH <7.2)
- Severe hyperkalaemia (K+ ≥6.5 mmol/L)
- Inadequate clearance on standard protocol
- High urea/creatinine requiring enhanced clearance

Chapter 8

Management of Serum Calcium

Target Range:

Systemic ionised calcium (iCa^{2+}): **1.12-1.20 mmol/L**

Calcium Infusion:

Calcium chloride 10% is infused via a central line to replace calcium that is chelated by citrate.

Systemic iCa^{2+} (mmol/L)	Action
< 1.00	**Give 10 mL 10% $CaCl_2$ IV bolus** Recheck in 30 mins Increase $CaCl_2$ infusion rate by 0.2 mmol/L/h
1.00-1.12	Increase $CaCl_2$ infusion rate by 0.1 mmol/L/h Recheck in 1 hour
1.12-1.20	**TARGET RANGE** - Continue current rate
1.20-1.30	Decrease $CaCl_2$ infusion rate by 0.1 mmol/L/h Recheck in 1-2 hours
> 1.30	**Stop $CaCl_2$ infusion** Recheck in 30 mins Consider reducing citrate dose

Monitoring Frequency:

- First hour: Every 30 minutes
- Hours 2-4: Hourly
- After 4 hours (if stable): 2-4 hourly
- After any adjustment: Increase frequency temporarily

Post-Filter iCa^{2+}:

Target: **0.25-0.35 mmol/L**

- If >0.35 mmol/L: Increase citrate dose
- If <0.25 mmol/L: Decrease citrate dose (risk of filter clotting higher but acceptable if filter lasting >48h)

Chapter 9

Management of Citrate Anticoagulation

Citrate Dose Selection:

Blood Flow (mL/min)	Citrate Dose (mmol/L)
100-125	3.0
126-150	3.5
151-175	4.0
176-200	4.5

Adjusting Citrate:

Increase citrate if:

- Post-filter iCa^{2+} >0.35 mmol/L
- Filter clotting frequently (<48 hours filter life)
- Visible clotting in circuit

Decrease citrate if:

- Systemic iCa^{2+} difficult to maintain in range despite $CaCl_2$ infusion
- Signs of citrate accumulation (see Chapter 14)

⚠️ **Citrate Accumulation Risk Factors:**

- Liver failure (reduced citrate metabolism)
- Shock state with hypoperfusion
- Very high blood flow rates (>200 mL/min)
- Metabolic acidosis (pH <7.2)

Chapter 10

Acid-Base Balance

Target pH Range:

7.35-7.45 (acceptable 7.32-7.48)

Metabolic Acidosis Management:

pH	Severity	Management
< 7.05	Very Severe	**Emergency:** 100 mL 8.4% $NaHCO_3$ IV bolus Switch to Enhanced Protocol Senior review
7.05-7.15	Severe	Switch to Enhanced Protocol Consider MultiBic dialysate Senior review
7.15-7.25	Moderate	Increase dialysate flow by 20% Consider Enhanced Protocol
7.25-7.35	Mild	Increase blood flow by 10-20% Monitor closely

Metabolic Alkalosis Management:

pH	Likely Cause	Management
> 7.55	Filter membrane blockage (pores blocked - citrate getting through, clearance not)	**Change filter immediately** May need higher dialysate flow temporarily
7.48-7.55	Excessive citrate or poor clearance	Check post-filter iCa^{2+} Reduce citrate if possible Increase dialysate flow Check filter function

> **Key Point:** Rising Na^+, iCa^{2+}, HCO_3^-, and Cl^- together suggest filter membrane blockage. This requires urgent filter change. See Chapter 16 for details.

Chapter 11

Management of Electrolyte Abnormalities

Potassium Management:

Serum K+ (mmol/L)	Action
> 5.5	Use K2 dialysate (Ci-Ca K2 or MultiBic 2K) Ensure adequate clearance
3.5-5.5	Use K4 dialysate (Ci-Ca K4 or MultiBic 4K)
< 3.5	Use K4 dialysate Consider additional KCl supplementation via IV

Sodium Management:

Principle: Modify dialysate sodium to reduce the concentration gradient between patient serum and dialysate.

Hyponatraemia (Patient Na+ <135 mmol/L):

- **Method:** Add sterile water to dialysate to reduce dialysate sodium concentration
- This reduces the gradient and slows sodium loss from patient
- Target correction rate: Maximum 8-10 mmol/L per 24 hours
- See tables below for exact volumes

Hypernatraemia (Patient Na+ >145 mmol/L):

- **Method:** Add hypertonic saline to dialysate to increase dialysate sodium concentration
- This reduces the gradient and slows sodium removal from patient
- Target correction rate: Maximum 8-10 mmol/L per 24 hours
- Use 30% NaCl for most practical volumes (see tables below)

> ⚠️ **Warning:** Rapid sodium correction can cause osmotic demyelination syndrome (hyponatraemia) or cerebral oedema (hypernatraemia). Always correct gradually and monitor closely.

Senior Approval Required: All sodium modifications require:

- Consultant intensivist approval
- Band 6+ nurse second check
- Clear documentation in notes
- Increased monitoring frequency

Reducing Sodium Concentration (Hyponatraemia)

Method: Remove calculated volume from 5L bag, then add equal volume of sterile water

For Ci-Ca Dialysate (Starting Na: 133 mmol/L)

Target Na+ (mmol/L)	Volume to Remove (mL)	Sterile Water to Add (mL)
130	113	113
125	301	301
120	489	489
115	677	677
110	865	865
105	1053	1053
100	1241	1241

For MultiBic Dialysate (Starting Na: 140 mmol/L)

Target Na+ (mmol/L)	Volume to Remove (mL)	Sterile Water to Add (mL)
130	357	357
125	536	536
120	714	714
115	893	893
110	1071	1071
105	1250	1250
100	1429	1429

Increasing Sodium Concentration (Hypernatraemia)

Method: Remove calculated volume from 5L bag, then add equal volume of hypertonic NaCl

For Ci-Ca Dialysate (Starting Na: 133 mmol/L)

Target Na+ (mmol/L)	Volume to Remove/Add (mL)		
	1.4% NaCl	5% NaCl	30% NaCl
145	563	83	**12**
150	797	118	**17**
155	1032	152	**22**
160	1266	187	**27**
165	1501	222	**32**

For MultiBic Dialysate (Starting Na: 140 mmol/L)

Target Na+ (mmol/L)	Volume to Remove/Add (mL)		
	1.4% NaCl	5% NaCl	30% NaCl
145	251	35	**5**
150	502	70	**10**
155	753	105	**15**
160	1004	140	**20**
165	1255	175	**25**

Color Guide:

- 🟢 **Green:** Practical volume (<1000 mL)
- 🟠 **Orange:** Large volume (1000-4500 mL)
- 🔴 **Red:** Impractical (>4500 mL) - Choose different NaCl concentration

Procedure for Modifying Dialysate:

1. Calculate required volume from tables above
2. Obtain consultant approval and Band 6+ second check
3. Using aseptic technique, remove calculated volume from 5L dialysate bag
4. Add equal volume of sterile water (hyponatraemia) or hypertonic NaCl (hypernatraemia)
5. Mix thoroughly by inverting bag several times
6. Label bag clearly: "MODIFIED - Target Na: [X] mmol/L - Date - Initials"
7. Document in patient notes
8. Monitor serum sodium 4-6 hourly

Phosphate Management:

- RRT removes phosphate - monitor regularly
- Target: 0.8-1.5 mmol/L
- If <0.5 mmol/L: IV phosphate replacement required
- Adjust enteral/parenteral nutrition phosphate content

Magnesium:

- Dialysate contains magnesium (Ci-Ca: 0.5 mmol/L, MultiBic: 0.75 mmol/L)
- Target: 0.7-1.0 mmol/L
- Supplement if <0.5 mmol/L

Chapter 12

Fluid Removal

Setting Fluid Removal Rate:

Calculate target fluid removal:

1. Estimate fluid input over next 24 hours (IV fluids, nutrition, drugs)
2. Estimate fluid output (urine, drains, insensible losses)
3. Determine desired net balance (usually negative to achieve target weight)
4. Set ultrafiltration rate to achieve desired balance

Typical Settings:

Clinical Scenario	Typical UF Rate
Fluid overload, good BP	100-200 mL/h
Maintenance, euvolaemic	50-100 mL/h
Cardiovascular instability	0-50 mL/h

Monitoring:

- Monitor blood pressure and cardiovascular status
- Assess fluid balance every 4-6 hours
- Adjust UF rate based on clinical status
- Consider vasopressor requirements

⚠️ **Haemodynamic Instability:** If blood pressure drops or vasopressor requirements increase:

- Reduce or stop ultrafiltration
- Consider fluid bolus
- Reassess volume status
- Senior review

Chapter 13

Citrate Accumulation: Detection

Clinical Signs of Citrate Accumulation:

Citrate accumulation occurs when citrate metabolism is impaired (usually due to liver dysfunction or hypoperfusion).

Biochemical Markers:

Parameter	Normal	Citrate Accumulation
Total Ca / iCa ratio	< 2.25	> 2.5
Metabolic acidosis	pH > 7.35	Worsening acidosis despite RRT
Anion gap	8-16 mmol/L	Increasing (citrate is unmeasured anion)
iCa^{2+} difficult to maintain	Stable with $CaCl_2$	Falling despite high $CaCl_2$ doses

Key Diagnostic Ratio: Total Calcium ÷ Ionised Calcium

- < 2.25: No accumulation
- 2.25-2.5: Possible accumulation - increase monitoring
- > 2.5: Significant accumulation - action required

Risk Factors:

- **Liver failure** - most important (reduced citrate metabolism)
- Shock state with tissue hypoperfusion
- High citrate doses (blood flow >200 mL/min)
- High lactate (competes for same metabolic pathway)

Clinical Features:

- Worsening metabolic acidosis
- Hypotension
- Cardiac arrhythmias

- Myocardial depression
- Paraesthesias, tetany (from hypocalcaemia)

Chapter 14

Citrate Accumulation: Management

Immediate Actions:

1. **Reduce or stop citrate:**
    - Reduce blood flow rate by 20-30%
    - Reduce citrate dose
    - Consider alternative anticoagulation (heparin, epoprostenol)
2. **Increase calcium replacement:**
    - Increase $CaCl_2$ infusion rate
    - Monitor iCa^{2+} every 30 minutes
    - Target systemic iCa^{2+} 1.12-1.20 mmol/L minimum
3. **Senior review:**
    - Inform intensivist immediately
    - Consider switching to heparin anticoagulation
    - Assess liver function and perfusion

Switching to Alternative Anticoagulation:

Heparin anticoagulation:

- Can use higher blood flow rates (up to 400 mL/min)
- Target anti-Xa 0.3-0.5 U/mL
- Check anti-Xa 4-6 hourly
- Bleeding risk - contraindicated if active bleeding

Epoprostenol (prostacyclin):

- Can be used if heparin contraindicated
- May cause hypotension
- Specialist use - discuss with senior

No anticoagulation:

- Can be used in coagulopathic patients

- Shorter filter life expected
- Monitor closely for clotting

> ⚠️ **Do Not Resume Citrate:** Until liver function improves and citrate metabolism restored. Continue alternative anticoagulation method.

Prevention:

- Screen for risk factors before starting citrate
- Consider alternative anticoagulation in severe liver failure
- Monitor Total Ca/iCa ratio in high-risk patients
- Use lowest effective citrate dose
- Avoid blood flow rates >200 mL/min unless essential

Chapter 15

Troubleshooting: Access, Clotting & Filter Issues

Circuit Pressures - Normal Ranges:

Pressure	Normal Range	Concerning Values
Access Pressure	-50 to -150 mmHg	< -200 mmHg (poor access)
Return Pressure	+50 to +200 mmHg	> +250 mmHg (obstruction)
TMP (Transmembrane Pressure)	0 to 200 mmHg	> 250 mmHg (filter clogging)

Common Problems & Solutions:

1. High Negative Access Pressure (< -200 mmHg)

Causes:

- Hypovolaemia / poor vascular filling
- Catheter malposition
- Catheter tip against vessel wall
- Blood flow rate too high for catheter

Actions:

1. Check patient volume status - consider fluid bolus
2. Check haematocrit - if >40%, consider fluid administration
3. Reduce blood flow rate by 20%
4. Ask patient to change position
5. Consider switching access/return lumens
6. If persistent, consider catheter repositioning

2. High Return Pressure (> +250 mmHg)

Causes:

- Catheter kinking
- Return line obstruction

- Clot in return lumen
- Patient position restricting catheter

Actions:

1. Check return line for kinking
2. Check catheter position and patient positioning
3. Reduce blood flow rate
4. Consider flushing catheter (if safe to do so)
5. May need catheter manipulation or replacement

3. High TMP (> 250 mmHg)

Causes:

- Filter clogging/clotting
- High haematocrit
- Inadequate anticoagulation
- High ultrafiltration rate

Actions:

TMP Value	Action
250-300 mmHg	**Warning zone** - Check anticoagulation (post-filter iCa^{2+} or anti-Xa) - Check haematocrit - Monitor TMP closely - Prepare for filter change
> 300 mmHg	**URGENT filter change required** - Imminent filter failure - Change filter set immediately

4. Frequent Filter Clotting (< 48 hours filter life)

Check:

- **Anticoagulation:** Post-filter iCa^{2+} should be 0.25-0.35 mmol/L (for citrate) or anti-Xa 0.3-0.5 U/mL (for heparin)
- **Haematocrit:** If >40%, consider fluid administration
- **Fluid balance:** Very negative balance increases haemoconcentration
- **Access pressures:** Poor access (high negative pressure) increases clotting risk

- **Blood flow:** Ensure minimum 80 mL/min to maintain circuit flow

Actions:

1. Increase anticoagulation dose (citrate or heparin)
2. Optimize volume status
3. Reduce ultrafiltration rate if very negative balance
4. Switch to EMiC2 filter if using AV1000s
5. Consider switching anticoagulation method if issues persist

5. Visible Clotting in Circuit

⚠️ **Do not attempt to flush clots through filter**

- Risk of clot embolism to patient
- Filter change required
- Review anticoagulation strategy

Haematocrit & Fluid Balance Monitoring:

Parameter	Target	Action if Abnormal
Haematocrit	30-40%	If >40%: Risk of clotting increased Consider IV fluid bolus
Fluid Balance Today	-0.5 to -2 L	If <-2 L: Haemoconcentration risk Reduce UF rate, consider fluid administration

Preventive Measures:

- Maintain adequate anticoagulation
- Optimize volume status and haematocrit
- Ensure minimum blood flow 80 mL/min
- Regular monitoring of circuit pressures
- Early recognition and intervention for rising TMP

Chapter 16

Filter Membrane Pore Blockage

Understanding Filter Membrane Blockage:

Filter membrane pore blockage is a specific type of filter dysfunction where the membrane pores become blocked (usually by protein/inflammatory material), but the membrane itself remains intact.

Mechanism of Filter Membrane Blockage

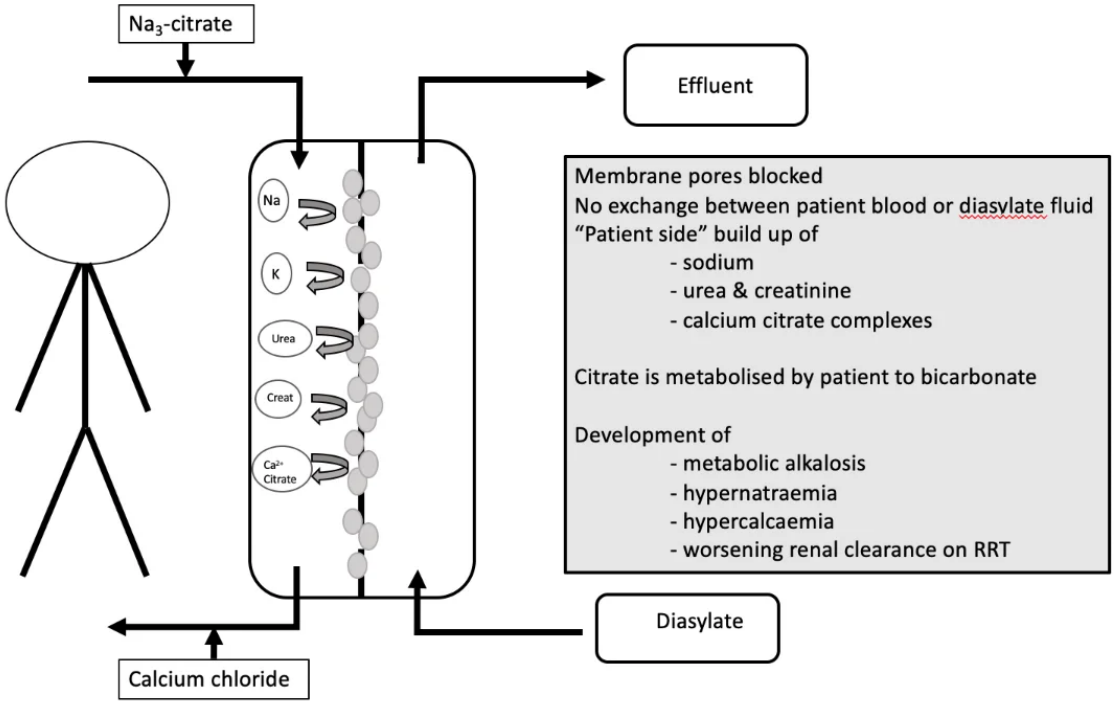

Diagram showing how membrane pore blockage prevents clearance of urea, creatinine and K+ while allowing citrate and calcium to pass through, leading to accumulation on the patient side.

⚠️ **Critical Understanding:**

Why electrolytes rise with filter blockage:

- **Sodium (Na^+) rises:** Patient receives trisodium citrate pre-filter (anticoagulation) - the sodium component accumulates when clearance fails
- **Chloride (Cl^-) rises:** Patient receives calcium chloride ($CaCl_2$) infusion post-filter to replace chelated calcium - the chloride component accumulates
- **Calcium (iCa^{2+}) rises:** Calcium chloride infusion continues post-filter while clearance is impaired
- **Bicarbonate (HCO_3^-) rises:** Citrate is metabolized by the patient to bicarbonate, causing metabolic alkalosis
- **Urea & creatinine rise:** No clearance occurring due to blocked pores despite patient receiving citrate load

Key Concept:

With blocked filter pores:

- Patient continues to receive trisodium citrate (pre-filter anticoagulation)
- Patient continues to receive calcium chloride (post-filter replacement)
- BUT no clearance of urea, creatinine, or potassium occurs
- Result: Rising Na^+ (from citrate), Cl^- (from $CaCl_2$), iCa^{2+} (from $CaCl_2$), and HCO_3^- (from citrate metabolism)
- Meanwhile: Worsening uraemia despite "adequate" RRT settings

Clinical Recognition:

Classic biochemical pattern (any TWO of the following):

- Sodium rising by ≥3 mmol/L (from trisodium citrate)
- Chloride rising by ≥3 mmol/L (from calcium chloride infusion)
- Systemic iCa^{2+} rising by ≥0.05 mmol/L (from calcium chloride infusion)
- Bicarbonate rising by ≥3 mmol/L (from citrate metabolism)

OR absolute values:

- Sodium >145 mmol/L AND pH >7.48
- Chloride >110 mmol/L with rising trend

Additional signs:

- Worsening uraemia despite "adequate" RRT settings
- Rising TMP (often >200 mmHg)
- Post-filter iCa^{2+} may be normal or low (citrate still being delivered)

Parameter	Normal RRT	Filter Blockage	Source of Rise
Sodium (Na^+)	Stable or controlled	Rising	**Trisodium citrate** (pre-filter)
Chloride (Cl^-)	Stable	Rising	**Calcium chloride** (post-filter)
iCa^{2+}	Stable in target range	Rising	**Calcium chloride** (post-filter)
HCO_3^- / pH	Stable or improving acidosis	Rising / alkalosis	**Citrate metabolism** to bicarbonate
Urea / Creatinine	Falling or stable	Rising	No clearance (pores blocked)
Post-filter iCa^{2+}	0.25-0.35 mmol/L	May be normal	Citrate still being delivered

Management:

🚨 **URGENT ACTION REQUIRED**

CHANGE FILTER SET IMMEDIATELY

Do not delay - patient is receiving citrate load (Na^+ source) and calcium chloride (Cl^- and Ca^{2+} source) without clearance

Post-Filter Change Management:

1. **May need temporarily higher dialysate flow** (2500-3000 mL/h for first 4-6 hours) to clear accumulated sodium, chloride, calcium, and bicarbonate
2. Monitor biochemistry closely:
    - Na^+, Cl^-, iCa^{2+}, HCO_3^-, pH hourly for first 4 hours
    - Expect gradual normalization over 4-8 hours
3. Consider causes of blockage:
    - Severe inflammatory state (sepsis, ARDS)
    - High protein load
    - Consider EMiC2 filter (40 kDa) for replacement if using AV1000s

Prevention Strategies:

- Use EMiC2 filter (larger pores) in severe inflammatory states
- Monitor trend of Na^+, Cl^-, iCa^{2+}, HCO_3^- together
- Early recognition allows elective filter change before severe derangement
- Consider filter change if TMP rising steadily even if <250 mmHg
- Remember: Rising Na^+ + Cl^- + Ca^{2+} + HCO_3^- = Filter blockage pattern