

Dialysate Composition: Accuracy of the Prescription

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Joe Johnston
Sr. Vice Pres. Biomedical Services
Fresenius Medical Care

The Starting Point

The role of the biomedical technician is to:

- a) protect patients, through proper practice in the repair and maintenance of the technology,
- b) bring transparency to the technology, so medical professionals can deliver the best care

For many in the industry, technical is a “black box”.

The Voice of the Customer

The “VOC” is an important element in product design.

Question : If the manufacturers are going to ask you for what you want in new products and technology for dialysis, what do you say?

- a) Faster
- b) Cheaper
- c) Easier
- d) Better



What does “better” mean?

Comparison of Prescribed and Measured Dialysate Sodium: A Quality Improvement Project

*Ambreen Gul, MD,¹ Dana C. Miskulin, MD,² Susan S. Paine, MPH,¹
Sriram S. Narsipur, MD,³ Leonard A. Arbeit, MD,⁴
Antonia M. Harford, MD,⁵ Daniel E. Weiner, MD,² Ronald Schrader, PhD,¹
Bruce L. Horowitz, MD,⁵ and Philip G. Zager, MD^{1,5}*

Background: There is controversy regarding the optimal dialysate sodium concentration for hemodialysis patients. Dialysate sodium concentrations of 134 to 138 mEq/L may decrease interdialytic weight gain and improve hypertension control, whereas a higher dialysate sodium concentration may offer protection to patients with low serum sodium concentrations and hypotension. We conducted a quality improvement project to explore the hypothesis that prescribed and delivered dialysate sodium concentrations may differ significantly.

Study Design: Cross-sectional quality improvement project.

Setting & Participants: 333 hemodialysis treatments in 4 facilities operated by Dialysis Clinic, Inc.

Quality Improvement Plan: Measure dialysate sodium to assess the relationships of prescribed and measured dialysate sodium concentrations.

Outcomes: Magnitude of differences between prescribed and measured dialysate sodium concentrations.

Measurements: Dialysate sodium measured pre- and late dialysis.

Results: The least square mean of the difference between prescribed minus measured dialysate sodium concentration was -2.48 (95% CI, -2.87 to -2.10) mEq/L. Clinics with a greater number of different dialysate sodium prescriptions (clinic 1, $n = 8$; clinic 2, $n = 7$) and that mixed dialysate concentrates on site had greater differences between prescribed and measured dialysate sodium concentrations. Overall, 57% of measured dialysate sodium concentrations were within ± 2 mEq/L of the prescribed dialysate sodium concentration. Differences were greater at higher prescribed dialysate sodium concentrations.

Limitations: We only studied 4 facilities and dialysate delivery machines from 2 manufacturers. Because clinics using premixed dialysate used the same type of machine, we were unable to independently assess the impact of these factors. Pressures in dialysate delivery loops were not measured.

Conclusions: There were significant differences between prescribed and measured dialysate sodium concentrations. This may have beneficial or deleterious effects on clinical outcomes, as well as confound results from studies assessing the relationships of dialysate sodium concentrations to outcomes. Additional studies are needed to identify factors that contribute to differences between prescribed and measured dialysate sodium concentrations. Quality assurance and performance improvement (QAPI) programs should include measurements of dialysate sodium.

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Selected highlights of the paper:

- Small study (4 clinics)
- The range of difference (prescribed vs. measured) was -13 to + 6 mEq/L of Na⁺
- On average, the sodium measured was 2-4 mEq/L higher than the nominal (prescribed)
- Dialysate loop delivery pressures were not measured.
- Differences were smaller in units using one, predominantly prescribed dialysate Na⁺
- Multiple factors affecting delivered Na⁺ are listed

Isn't the AAMI standard for dialysate sodium $\pm 2.5\%$ from nominal value?

Dialysis Fluid Composition

Standards & Regulations

- RD62 - ANSI/AAMI/ISO 13959:2009 Water for hemodialysis and related therapies
- RD61 – ANSI/AAMI/ISO 13958:2009 Concentrates for hemodialysis and related therapies
- ANSI/AAMI/ISO 11663:2009 Quality of dialysis fluid for hemodialysis and related therapies
- RD5 - ANSI/AAMI/IEC 60601-2-16:2012 - Particular requirements for basic safety and essential performance of hemodialysis, hemodiafiltration and hemofiltration equipment
- RD52 - ANSI/AAMI/ISO 23500:2011 Guidance for the preparation and quality management of fluids for hemodialysis and related

Dialysis Fluid Composition

ANSI/AAMI/ISO 13958:2009 Concentrates for hemodialysis

4.1.2.1 Liquid solute concentrations

All electrolytes identified on the label shall be present within $\pm 5\%$ or ± 0.1 mEq/l (expressed as dialysis fluid concentrations), whichever is greater, of the stated concentration, with the exception of sodium, which shall be present within $\pm 2.5\%$ of the labeled concentration.....

4.1.2.2 Solute concentrations from powder

When concentrate is packaged in dry form or a combination of dry and liquid and is mixed according to the manufacturer's instruction for use, the final concentrate shall meet the requirements of 4.1.2.1.

5.4 Systems for mixing concentrate at a dialysis facility

* The manufacturer must only meet their stated specifications *

Dialysis Fluid Composition

ANSI/AAMI/IEC 60601-2-16:2012 - Particular requirements for basic safety and essential performance of hemodialysis, hemodiafiltration and hemofiltration equipment

Subclause 201.12.4.4.101 Composition of the DIALYSIS FLUID

The requirement for a PROTECTIVE SYSTEM is also applicable to human errors (e.g. mistaking of DIALYSIS FLUID CONCENTRATES) and also refers to Clause 15 (Construction of ME EQUIPMENT) and Clause 16 (ME SYSTEMS). In acetate treatment, it is considered to be appropriate if **the PROTECTIVE SYSTEM is designed** such that it prevents a deviation beyond the following limits:

– conductivity of final DIALYSIS FLUID 12 mS/cm – 16 mS/cm

– **sodium in DIALYSIS FLUID ± 5 % from set point**

Additionally in bicarbonate treatment:

– **bicarbonate in DIALYSIS FLUID ± 25 % from set point**

If other components can be added individually, additionally:

– other electrolytes in DIALYSIS FLUID ± 20 % from set point

Dialysis Fluid Composition

ANSI/AAMI/ISO 23500:2011 - Guidance for the preparation and quality management of fluids for hemodialysis and related therapies

7.5.1 Monitoring of mixing systems

Systems for preparing either bicarbonate or acid concentrate from powder or other highly concentrated media at a dialysis facility should be monitored according to the mixing system manufacturer's instructions to ensure appropriate dissolution. If a facility designs its own system, procedures should be developed and demonstrated to ensure proper mixing of the concentrate, including establishment of acceptable limits for tests of proper concentration. In this case, verification can be accomplished by testing a sample from each batch prepared over a 3 day period. Acid and bicarbonate concentrates may be tested by measuring conductivity, density with a density meter or specific gravity with a hydrometer according to the manufacturer's instructions.

Although not required, some manufacturers of concentrate powder or other highly concentrated media may provide allowable ranges for either the conductivity, density or the specific gravity of concentrates prepared from their powder....

When it was really a “bath” (the batch of dialysate), the existing standard worked (only volume of water and volume of concentrate varied)

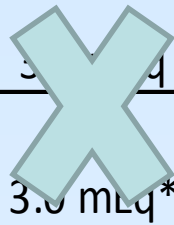
Now, other sources of error have been added:

- Machine proportioning (pump calibration, intake resistance and backpressure, servo-sensor calibration, servo-control lag time)
- Bicarb dialysate (now 2 parts to the concentrate, each has sodium)
- On-site mixing of one or both concentrates from powder
- Central delivery of concentrates (esp. pressures)

The goal is NOT a final dialysate conductivity, but correct chemical composition **[GIGO]**

Dialysis Fluid Composition

Nominal 137 Na (100 from acid & 37 from bicarb)

	Water	Acid (liquid/dry)	Bicarbonate (liquid/dry)	Concentrate Mixers	Distribution Systems	Dialysis Machines	What we believed
AAMI/ISO		2.5% (2.5mEq/L)	2.5% (0.9mEq/L)	N/A	N/A	5.0% (6.9mEq/L)	2.5% (3.4mEq/L)
Mfg		3.0 mEq*	2.5% (2.5mEq/L)	2.5% (0.9mEq/L)	?	?	

* RO alarms significantly lower

Ask your Nephrologist, what is an allowable deviation from prescription for delivered Na?

- 1 mEq/L
- 3 mEq/L
- 5 mEq/L
- 7 mEq/L

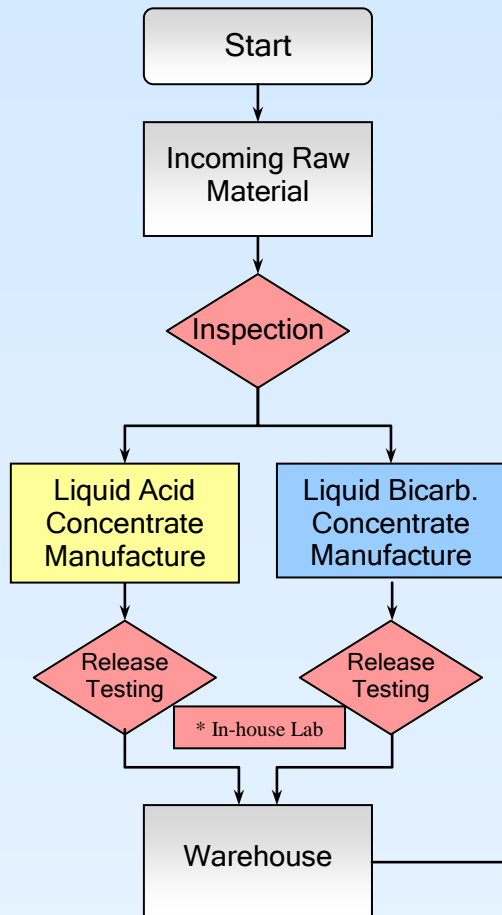
AAMI TIR 72 RDN469:2013 (draft) “Hemodialysis Fluid Chemical Composition”

... The objective is to provide dialysis practitioners additional background information related to the dialysis processes described in ANSI/AAMI 23500, *Guidance for the preparation and quality management of fluids for hemodialysis and related therapies*, that affect the chemical composition of dialysis fluid. ...

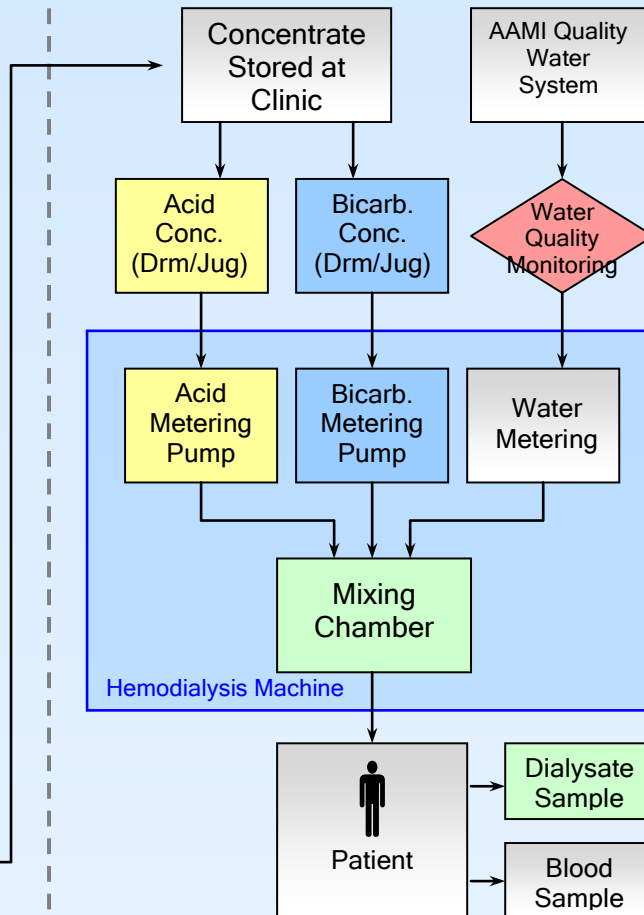
Dialysis Fluid - Process Flow

Liquid Hemodialysis Concentrates System Diagram

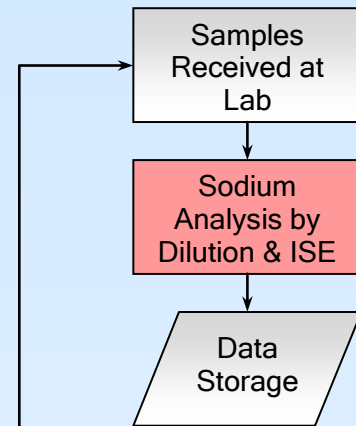
Manufacturing (Concentrates)



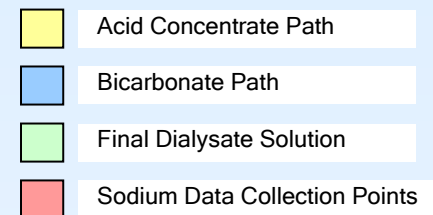
Clinic (Including Hemodialysis Machine)



Laboratories (XYZ Labs)



Color Key

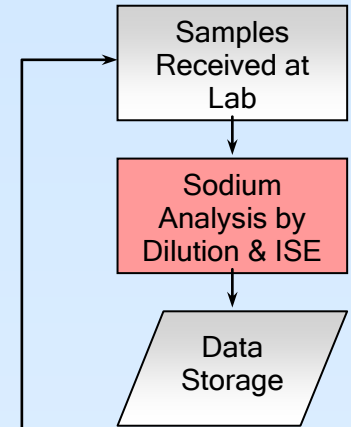
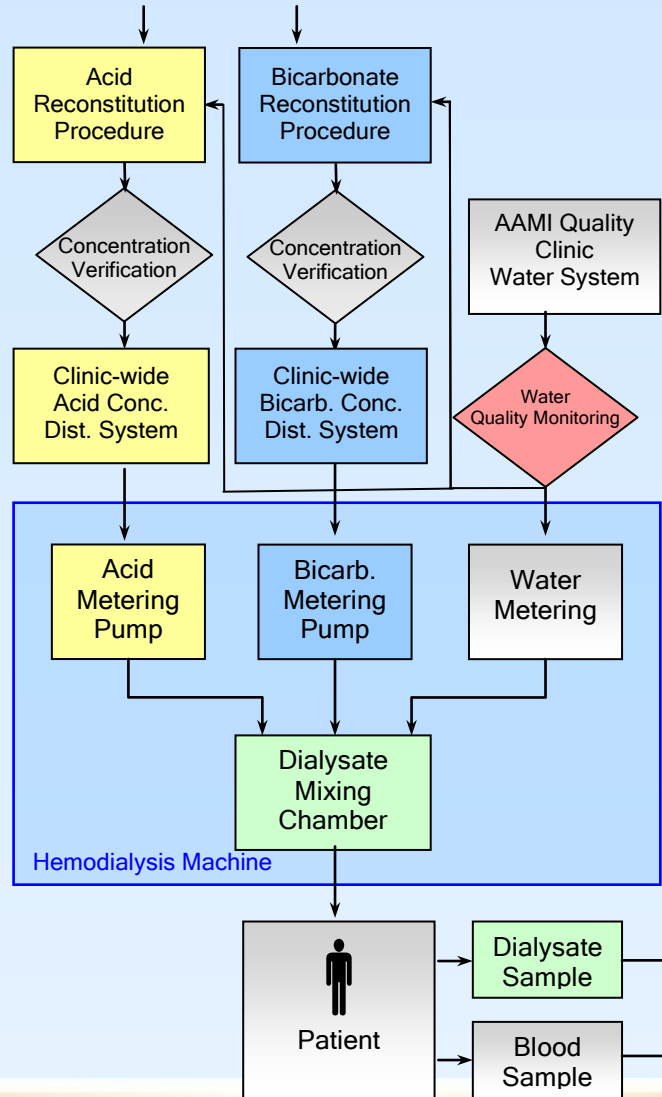
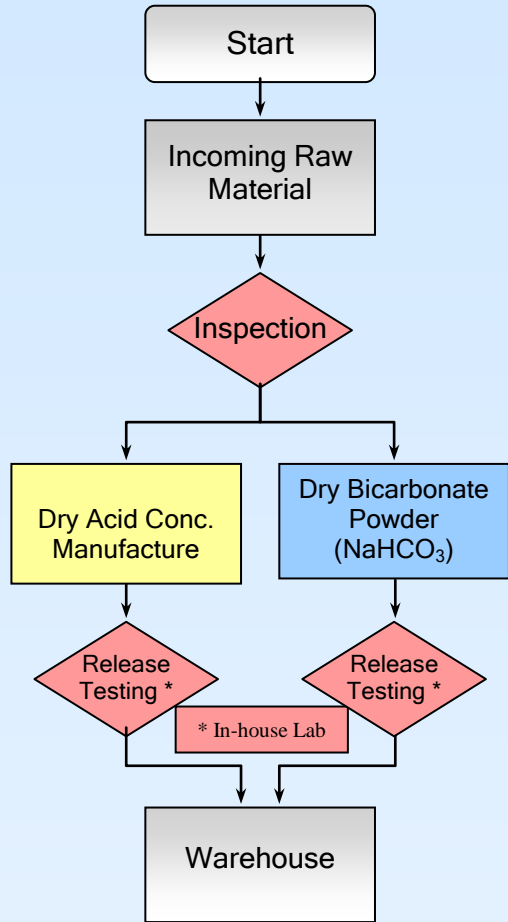


Solid (Dry Powder) Hemodialysis Concentrates System Diagram

Manufacturing (Concentrates)

Clinic (Including Hemodialysis Machine)

Laboratories (XYZ Labs)



Color Key

- Acid Concentrate Path
- Bicarbonate Path
- Final Dialysate Solution
- Sodium Data Collection Points

Sources of Error

Step through the process flow chart – where are the sources of error !

- Correct formulas
- RO water
- Powdered concentrate mixing
- Concentrate delivery pressure
 - Distribution loop feed pressure
 - Level/height of concentrate jug
- Machine
 - Calibration of pumps and sensors
 - Random pumping errors

Right Formulation ?

- Too many formulas available in the clinic ?
 - Storage conditions well controlled? No mix ups !
- Good control on jug labeling, cleaning ?
- Connected to the right wall outlet?
- Wall box plumbing
 - Is 2 K coming from the 3 K outlet?
 - How do you know? Do you check at install/repair

The Water ?

- RO water –

Electrolytes normally included in dialysis fluid

Ca⁺² 0.05 mmol/L

Mg⁺² 0.15 mmol/L

K⁻ 0.2 mmol/L

Na⁻ 3.0 mmol/L

- Do you monitor / trend the sodium ?

- Materials used in water systems

- Everyone knows about aluminum pump heads. How about plastic colorant in tubing, micro-static plastics (imbedded silver salts), gaskets, o-rings and lubricants?

- Does your policy call for only OEM parts?

Powder to liquid?

Powdered concentrate

– Dissolution

- Gallons vs. liters , 10 Tx vs 12 Tx bags
- Water volume check – how is the tank calibrated?
- Powder fully dissolved?
- How is dilution during delivery prevented?
- Following IFU's for times, temperature, testing?
- **What would your clinic do if a “little” powder is spilled? Would you dump the batch and start over? Would conductivity catch an error in powder addition?**

– Mixing and storage

- Control procedure for the cases?
- Is 2 K being pumped to the 3 K tank?
- Do you use manifolds?

Dialysis Fluid Composition

Answer

Dialysis machine manufacturers are required by ANSI/AAMI/IEC standards to prevent deviations of bicarbonate concentration in delivered dialysate from exceeding:

- a) **25%**
- b) 5.0%
- c) 2.5%

Delivery ?

Concentrate central delivery

- Distribution loop feed pressure
- Level/height of concentrate jug

Fresenius machines: -1.3 to + 2 psi

The Machine ?

Machine Proportioning:

- Calibration of pumps and sensors
 - Are there limits on the entered value for pump calibration and sensor settings?
- Intake resistance and backpressure
- Random pumping errors

Machine Sensors:

- Calibration technique and method
- Servo-sensor calibration
- Servo-control lag time

Machine Alarms and Alarm Resets:

* Know the effect and consequence of each alarm *

The Lab ?

Lab – testing errors can be 1-2%.

Don't chase “ghosts”.

Dialysis Fluid Composition

Things to Remember

- Current Standards / Regulations do not define parameters for every source of error in the preparation of dialysis fluid
- Users should understand the limitations of equipment, processes, and tests involved in the preparation and quality monitoring of dialysis fluid
- User may wish to consider evaluating variation even within current limits of protective systems to determine if composition of dialysis fluid meets expectations.