ASN Dialysis Advisory Group

ASN DIALYSIS CURRICULUM

Dialysis Circuit Review

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Disclosures

- **None**

Dialysate Circuit Outline

The main components of the dialysate circuit include:

- Deaeration
- Dialysate proportioning and conductivity
- Dialysate formulation
- Monitors, alarms, and conductivity
- Ultrafiltration: Volumetric and flow-sensor control
- Dialysate disinfection and rinsing
- Emergencies

Introduction

- The process of hemodialysis pumps the patients' blood against dialysate that may be generated by the dialysis machine or at a central location
- Dialysis machines are essentially composed of pumps, monitors, and alarms that allow safe proportioning of dialysate
- Knowledge of the components of a dialysate circuit are important for patient safety and care
- It is important for each nephrologist to become familiar with his/her dialysis machine for patient safety
- The blood circuit will not be reviewed here

Dialysis Machine Dialysate Circuitry

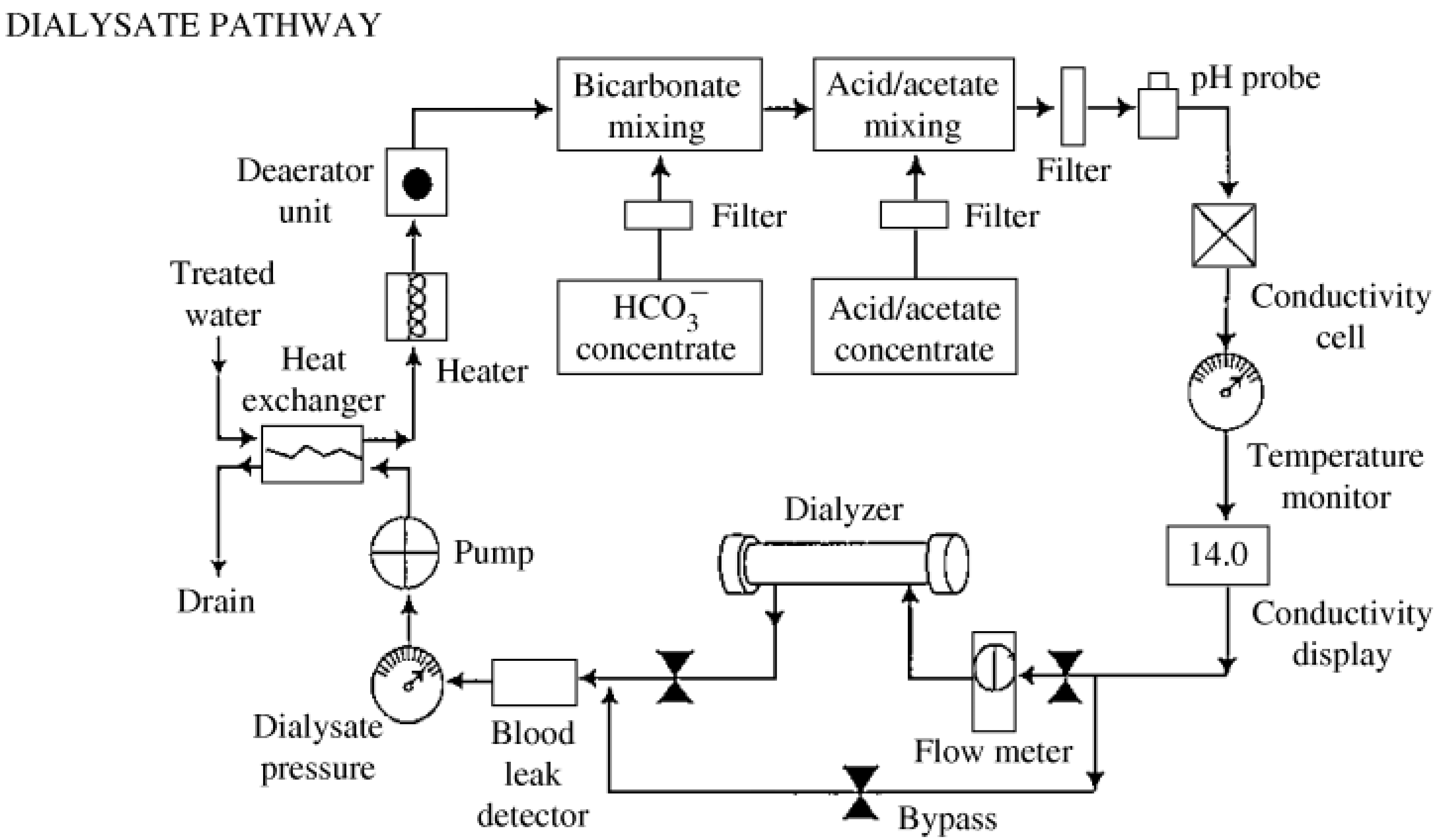
- **Once pure product water has been generated, bicarbonate and acid solutions are mixed with water to form dialysate solution**
- **Mixing or proportioning may be done by the individual machine or centrally in a dialysis unit**
- **Several components of proportioning ensure safe dialysate that is monitored by a series of alarms, pumps, and monitors**
- **Fluid ultrafiltration occurs by volumetric or flow sensor controllers**
- **Disinfection prevents bacterial overgrowth**

Dialysate Circuit Key Components

- **The key components of the dialysate circuit include:**
  - Heating
  - Deaeration
  - Proportioning
  - Monitoring
  - Ultrafiltration
  - Disinfection

Dialysate Circuit Key Components

The Dialysis Circuit



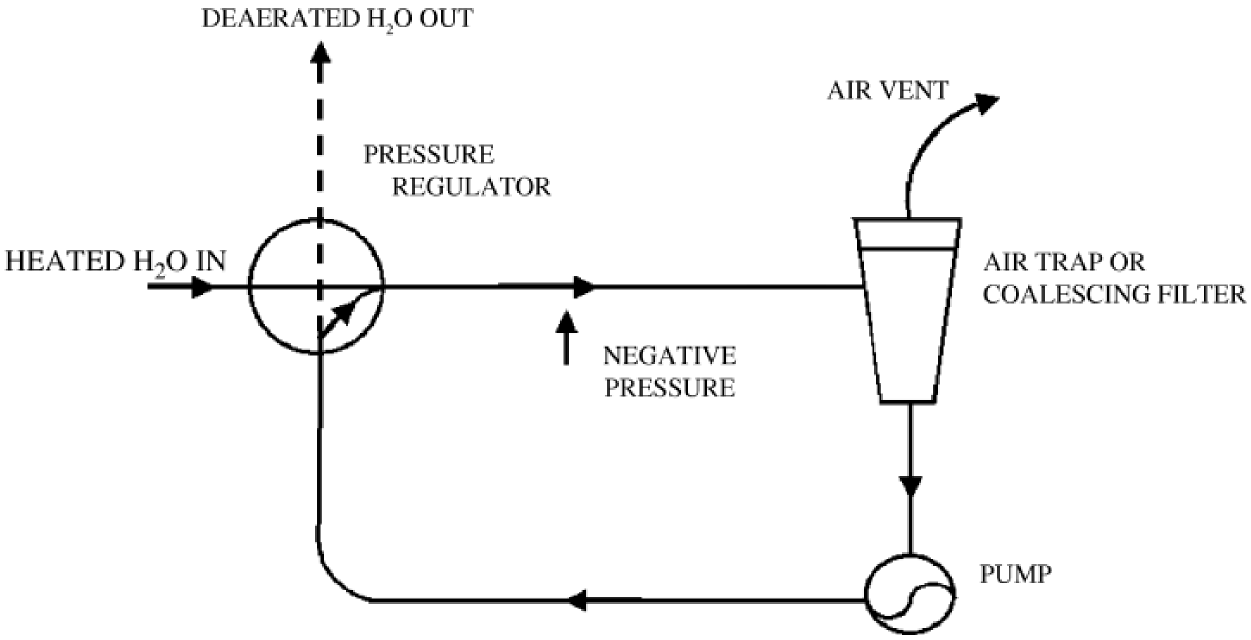
Degassing Dialysate Water

- **Treated water inflows into the dialysis machine and passes through a heat exchanger prior to entering the heater**
- **Heating the treated water assists in degassing the cold water**
- **Water is heated to body temperature (33□–39□C) by stainless steel heating elements**
- **Temperature is monitored downstream by a special temperature monitoring device**

Deaeration

- **Water heated to physiologic temperatures is subjected to negative pressure to remove any air**
- **Air in the water can interfere with dialysate flow and cause “air trapping”**
- **Negative pressure is maintained by a closed loop composed of a pump, constricting valve, air trap, and vent**
- **Heating treated water to 85C followed by cooling prior to proportioning can also de-gas purified water**

Deaeration


DEAERATED H2O OUT
AIR VENT
PRESSURE
REGULATOR
HEATED H2O IN
AIR TRAP OR
COALESCING FILTER
NEGATIVE
PRESSURE
PUMP

Dialysate Proportioning

- **Proportioning assures proper mixing of heated and treated water to produce the appropriate dialysate solution**
- **Proportioning pumps mix premade fresh dialysate acid (A) and bicarbonate (B) solution**
- **Acid solutions contain acid/chloride salts including sodium, potassium, calcium, magnesium, and acetate**
- **Bicarbonate solutions are made fresh, since pre-prepared bicarbonate can release CO_2 and encourage bacterial growth**

Dialysate Proportioning

- **Dialysate solutions are passed through a small filter prior to and after formation**
- **Potential problems include:**
  - Incorrect bicarbonate or acid concentrate
  - Inadequate dialysate mixing
  - Clogged filters
  - Device alarms disarmed by the operator
  - Precipitation of calcium or bicarbonate salts

Dialysate Formulation

Electrolyte	Concentration
Sodium	134–145 meq/L
Potassium	0–4 meq/L
Calcium	0.0–3.5 meq/L (2.25 standard)
Magnesium	0.5–1.0 meq/L
Chloride	100–124 meq/L
Bicarbonate	32–40 meq/L
Glucose	0–250 mg/dL

Dialysate Modeling

- **Sodium**
  - Sodium modeling can be used to maintain hemodynamic stability during ultrafiltration. However, some controversy exists regarding its use due to the increased incidence of patient thirst, which may lead to more intradialytic weight gain and fluid retention
  - Sodium modeling programs are available on dialysis machines and allow alteration of sodium concentration over time

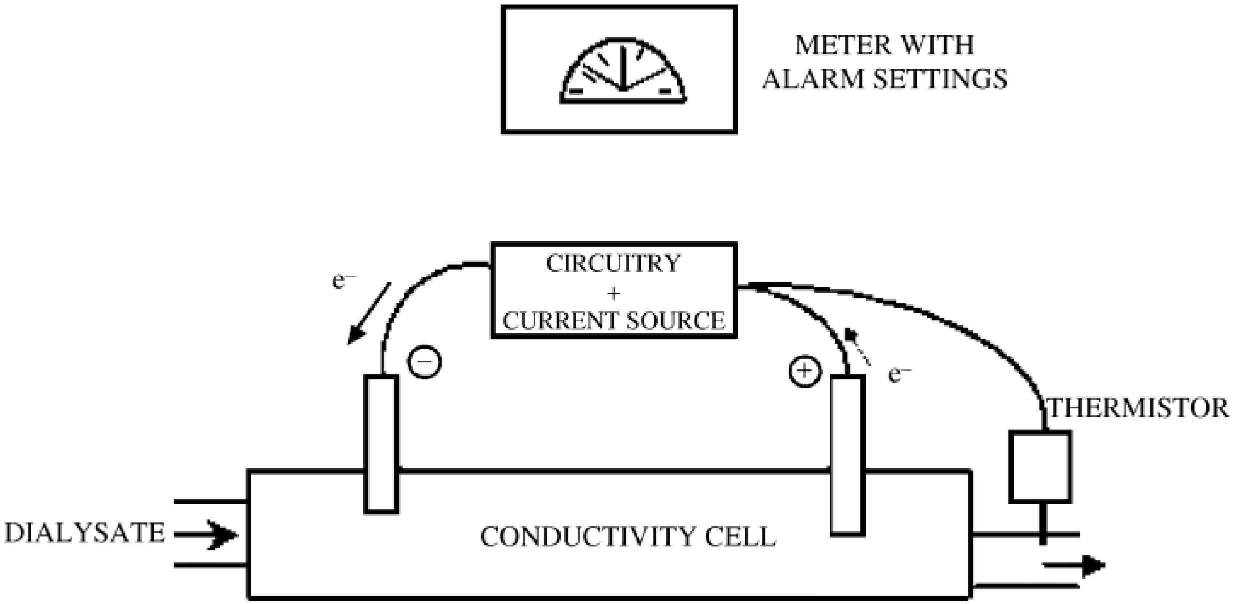
Dialysate Monitoring

- **pH**
  - The recommended pH range is 6.8–7.6. Not all machines have a monitor, but dialysate pH should be monitored each session
- **Temperature**
  - A heat sensor monitors dialysate temperature near the dialyzer and provides a short feedback loop for changes. Temperature should be between 35°–42°C
    - Low temperatures can cause shivering
    - High temperatures can cause protein denaturing or hemolysis

Dialysate Monitoring

- **Conductivity**
  - Conductivity is the amount of electrical current conducted through a dialysate and reflects electrolyte concentration
  - A constant voltage is applied across two electrodes 1 cm apart in the dialysate flow. If the concentration of electrolytes changes, the voltage will change
  - Conductivity should be between 12–16mS/cm (millisiemens per centimeter). The greater the number of ions, the greater the conductivity of the dialysate
  - Conductivity can be affected by temperature, or concentration of acid to base
  - Alarms will stop dialysate flow if conductivity is out of limits

Conductivity



Alarms—Conductivity

- **Conductivity alarms can occur in the following:**
  - An empty concentrate jug
  - Change in electrolyte concentration of dialysate
  - Abnormal water inlet pressure
  - Water leaks or puddles beneath the mixing chamber
  - Concentration line connector unplugged
- **The conductivity settings should never be adjusted while the patient is on the dialysis machine**

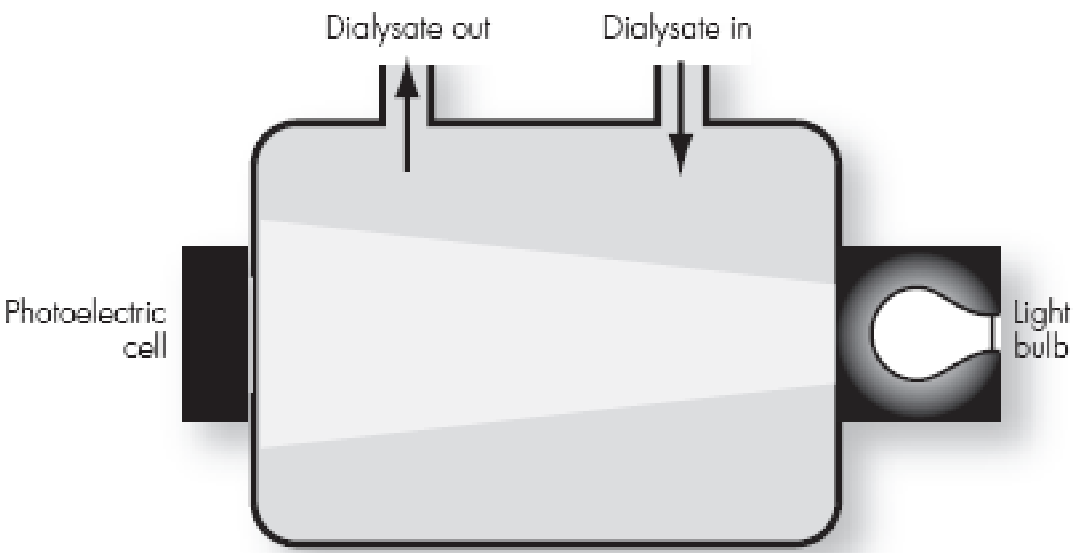
Alarms—Temperature and Pressure Monitors

- **Temperature Monitor**
  - A malfunctioning heating element can cause abnormal dialysate temperatures
    - Cool temperatures (<35°C) will result in shivering
    - Warm temperature (>42°C) can cause protein denaturing or hemolysis (>45°C)
- **Pressure Monitor**
  - The pressure range is –400 to +350 mmHg with an accuracy of ± 10%
    - Alarm limits are set at ± 10% of the pressure setting
    - Pressure in the dialysate compartment should not exceed that in the blood compartment or there is an increased risk of blood contamination by unsterile dialysate secondary to dialyzer membrane rupture and back filtration
    - Ultrafiltration (UF) is controlled by transmembrane pressure (TMP)
    - TMP = PBO – PDO

Blood Leak Monitor

- **Blood should not cross the blood/dialysate membrane**
- **Leakage of blood into the dialysate circuit is detected by the blood leak monitor, which is usually located downstream from dialyzer**
- **Infrared or photoelectric cells detect decreases in light from source**
- **Red blood cells scatter light and trigger alarm, which deactivates the blood pump**

Blood Leak Monitor



If the light beam is interrupted by blood,
an alarm will sound, and the blood pump will stop.

Volumetric-based Ultrafiltration

- **Ultrafiltration is the process of removing fluid from the patient in a controlled fashion, during which volume is accurately measured**
- **Most dialysis machines use volumetric-based control, which uses a balancing chamber(s) composed of 2 compartments separated by a flexible membrane**
- **One side of the membrane allows fresh dialysate in, while the other allows spent or used dialysate out**

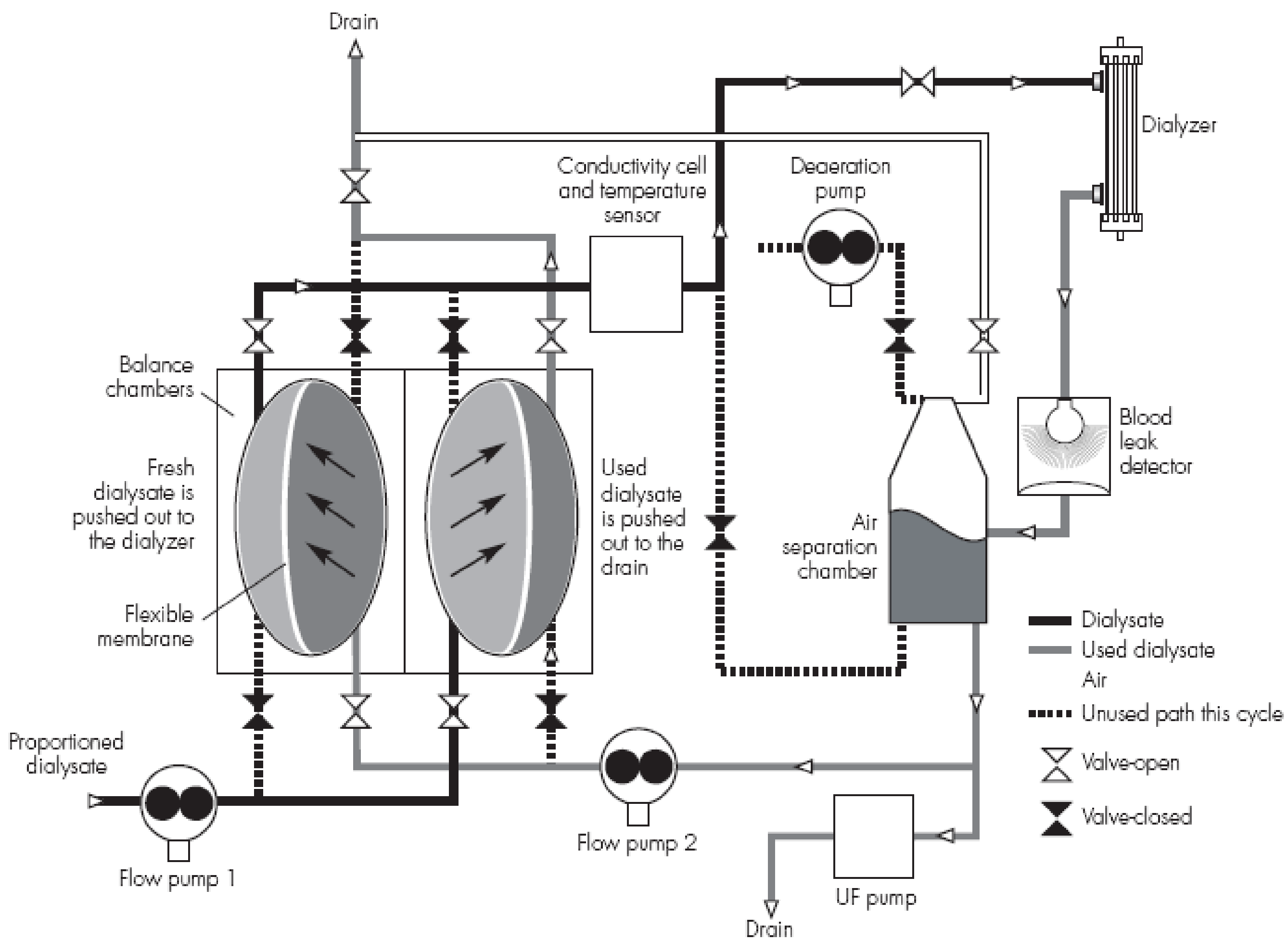
Volumetric-based Ultrafiltration

- **Valves are connected on the inlet and outlet and allows fluid to enter one side of the chamber, which pushes an equal amount of fluid out of the other side of the chamber**
- **One chamber fills with used dialysate and pushes fresh dialysate to the dialyzer, while the other chamber is filling with fresh dialysate and pushes used dialysate to the drain**
  - One pump moves proportioned dialysis to the balance chambers; a second pump pulls dialysate from the dialyzer and pushes it to the balance chambers

Ultrafiltration Pump

- **The UF pump or the fluid removal pump removes fluid from the closed loop, which results in fluid removal from the dialyzer membrane**
- **Most UF pumps are piston type and placed in the used dialysate flow path by negative pressure**
- **When the UF pump is off, there is no pressure gradient between the blood and dialysate and no fluid is removed from the patient**

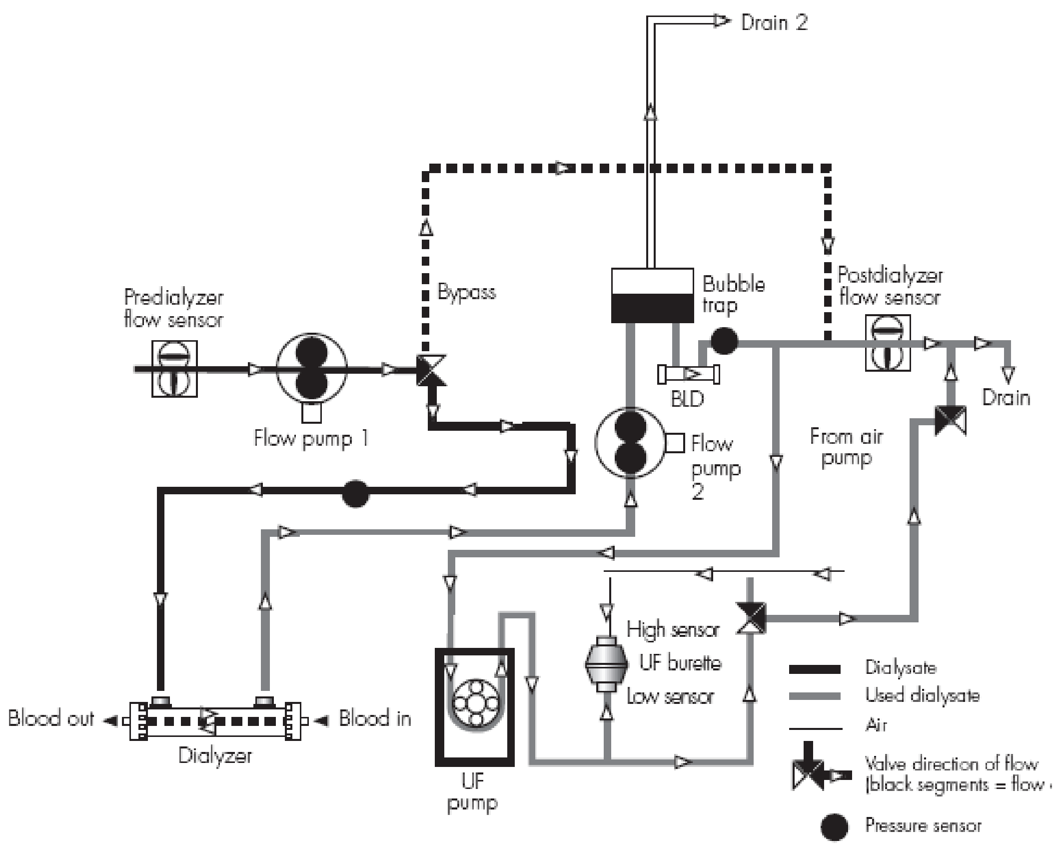
Volumetric UF Control



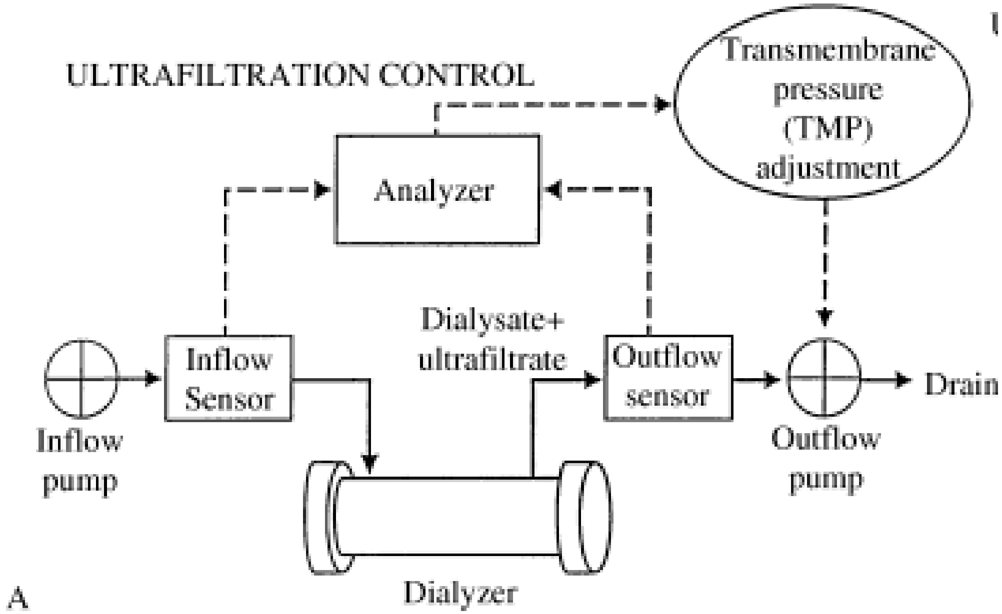
Ultrafiltration: Flow Control

- **Flow-control UF has flow sensors on the inlet and outlet side of the dialyzer that allow control of dialysate flow**
- **A post-dialyzer UF pump removes fluid at an UF rate calculated by the dialysis machine**

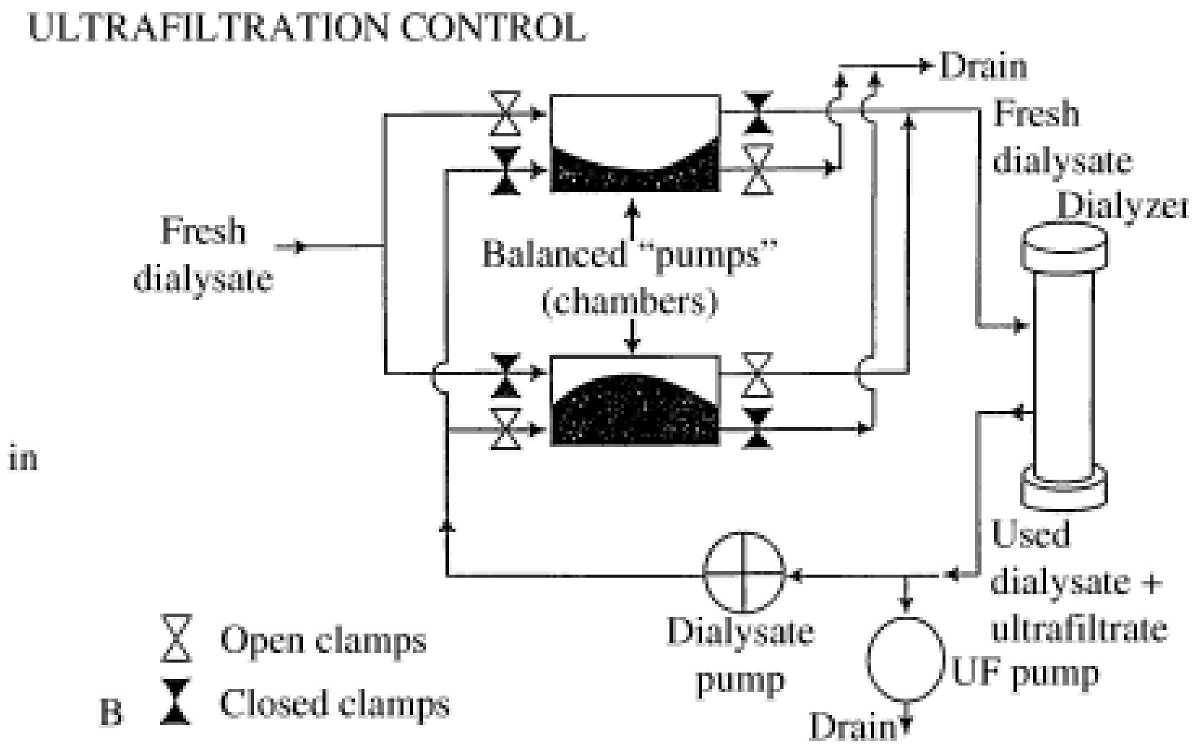
Ultrafiltration: Flow Control



Flow Sensor UF Controller



Volumetric UF Controller



Dialysate Disinfection and Rinsing

- **Dialysis machines should be disinfected according to the manufacturer's recommendations, usually daily**
- **The dialysate circuit should be exposed to disinfectant**
- **Reused bicarbonate/acid containers should be disinfected between use**
- **Disinfectants and rinse solutions include:**
  - Formaldehyde
  - Hypochlorite (bleach)
  - Peracetic acid
- **Machines should be rinsed between chemicals and before a dialysis session**
- **Dead space is needed between dialysate effluent line and drain**
- **Some dialysis machines incorporate a bacterial and endotoxin-retentive ultrafilter that prevents bacterial contamination. This is termed "ultrapure dialysate"**

Emergencies—Clinical

- **Dialysis machine proportioning problems can result in severe serum electrolyte abnormalities. Some of these emergencies include:**
  - High or low serum sodium, potassium, calcium or magnesium
  - High or low plasma osmolarity due to hyper- or hypo-osmolar dialysate
- **Clinical emergencies can occur if significant levels of contaminants are in the dialysate**
  - Copper or cupraphane may be released from heating element or dialyzer and can cause severe hemolysis
  - Chloramines and nitrates can cause severe hemolysis
  - Fluoride can cause severe pruritis, nausea, and ventricular tachycardia or fatal ventricular fibrillation
  - Aluminum can cause bone disease, anemia, and fatal progressive neurologic deterioration commonly known as dialysis encephalopathy syndrome
  - Lead, copper, zinc, and aluminum can leach from metal pipes and cause anemia

Emergencies—Power

- **Power Failure**
  - In the event of loss of power, the system is no longer safe for dialysis patients. Blood should be returned manually to patients and patients taken off the machine if power is not restored in 15–30 minutes

Conclusions

- **Dialysis circuitry requires monitoring to assure patient safety**
- **Water safety and knowledge of dialysate circuitry is the purview of all nephrologists caring for dialysis patients**
- **Every nephrologist should "know their machine" in order to safely troubleshoot problems**