Decoding the Dialysis Machine

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OBJECTIVES

• Review functions of dialysis machine
• Review the blood circuit and features
• Review the dialysate circuit and features
• Discuss the types of dialyzer membranes
• Discuss safety features of the dialysis machine

Disclosures

• I have no disclosures

Complicated Dialysis Machine

Different types of dialysis machines

Functions of the Dialysis Machine

• Hold the “artificial kidney”
• Cleanse the blood
• Eliminate excess salts and wastes
• Remove excess fluid
• Correct electrolyte imbalances
• Correct acid/base imbalances
• Provide for safe dialysis treatment with monitoring systems and alarms
Three Components of the Dialysis Machine

Blood Circuit

Dialysate Circuit

Dialyzer

The Blood Circuit

• Begins at vascular access of patient
• Blood is pumped through arterial bloodlines
• Blood enters dialyzer
• Blood leaves dialyzer
• Blood is pumped through venous bloodlines
• Blood is returned to patient’s vascular access

Arterial Bloodlines

• Carry blood from patient to the dialyzer (inflow)
• Color-coded red
• Saline infusion port
• Heparin infusion port
• Drip chambers
• Pressure monitors
• Blood pump segment

Blood Pump

• Spring-loaded roller pump
• Must completely occlude the tubing to ensure accurate stroke volume
• Works like milking a straw along its length
• Blood Flow Rate (BFR) = rotation of pump in rpm x diameter of tubing (blood pump segment volume)

Pre-Pump Arterial Pressure Monitor

• Measures pressure in bloodlines prior to blood pump via pressure transducer
• Pressure is always negative
• Factors which influence pressure
  • Resistance at access/needle
  • Blood viscosity (higher hgb = more neg)
  • Size of needle
  • Speed of pump
• Alarms will stop pump if preset limits are exceeded
Post-Pump Arterial Pressure Monitor
- Measures pressure in bloodlines after blood pump via pressure transducer
- Pressure is always positive
- Factors which influence pressure
  - Blood flow rate
  - Blood viscosity
  - Downstream resistance
- Alarms will stop pump if preset pressure limits are exceeded

Venous Bloodlines
- Carry blood from dialyzer to the patient (outflow)
- Color-coded blue
- Drip chamber allows for removal of accumulated air from line
- Venous pressure monitor
- Air detector
- Blood sensor
- Medication port

Venous Pressure Monitor
- Always positive pressure
- Pressure affected by
  - Blood flow rate
  - Blood viscosity
  - Clotting in chamber
  - Resistance in the needle/access
- Clamps bloodline and turns off the pump if preset limits are exceeded
- Important to note: at low blood speeds, needle dislodgement may not change outflow pressure much as most of the resistance is located in the NEEDLE.

Dialysate Circuit
- Delivers dialysis solution consisting of purified water and concentrate to dialyzer
- Removes wastes and fluids from dialyzer
- UF controller to monitor fluid removal from patient
- Monitors dialysis temperature
- Ensures safe concentration of dialysate delivery to patient
- Detects barrier leaks of blood/dialysate compartments
- Disinfects machine

Water Purification System
- Dialysis patient is exposed to 120 to 200 liters of water per treatment
- All small molecular weight substances present in water can pass across dialyzer into the bloodstream
- Association for the Advancement of Medical Instrumentation (AAMI) develops standards for water purity
- Ultrapure dialysate filters used on machine to trap endotoxins and bacteria

Harmful Water Contaminants
<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Physical Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Bone disease, anemia, dialysis encephalopathy syndrome</td>
</tr>
<tr>
<td>Chloramine</td>
<td>Hemolytic anemia</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Severe pruritus, nausea, ventricular fibrillation</td>
</tr>
<tr>
<td>Copper, Zinc, Lead</td>
<td>Hemolytic anemia</td>
</tr>
<tr>
<td>Bacteria and Endotoxin</td>
<td>Pyrogenic reactions and infections</td>
</tr>
</tbody>
</table>
Concentrate Delivery System

- Machines mix concentrated electrolyte solutions or powders with purified water to make a final dialysate solution that is delivered to the dialyzer
- Central vs. individual proportioning
- Heating and degassing the solution - as water is heated, the dissolved gases expand and bubble out

Dialysate Formulations

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>135-145 mEq/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>0-4 mEq/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.0-3.5 mEq/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.5-1.0 mEq/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>100-124 mEq/L</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>32-40 mEq/L</td>
</tr>
<tr>
<td>Glucose</td>
<td>0-200 mg/dL</td>
</tr>
</tbody>
</table>

Monitors and Alarms

- Conductivity
  - Detect excessively dilute or concentrated dialysate
  - Too high: hypernatremia and crenation
  - Too low: hyponatremia and hemolysis
- Temperature
  - Too cool: risk of hypothermia in unconscious patient (conscious patient will complain and shiver)
  - Too hot: blood protein denaturation and hemolysis

Monitors and Alarms

- Bypass Valve: diverts unacceptable dialysate around dialyzer directly to drain
- Blood Leak Detector
  - Located in dialysate outflow line
  - Change in flow of light traveling through sensor
  - Activates an alarm to alert of membrane breach
- Transmembrane Pressure Monitor (TMP): to detect internal pressure problems within the dialyzer

Transmembrane Pressure-TMP

- Pressure created from countercurrent flow of dialysate against blood flow
- Measures the difference in pressure between the two sides of the semipermeable membrane
- Higher pressure can cause more ultrafiltration in systems without UF pump

Ultrafiltration (UF) Controller

- Removing excess fluid from the patient in a controlled fashion
- Volumetric: uses balancing chambers which measure exact dialysate volume in and out
- UF Pump controls the UF rate by increasing or decreasing the speed of pump and pressure on dialyzer
- Separate line from outflow goes through the UF pump
Advanced Features
• Adjustable bicarbonate
• Variable sodium
• Programmable UF profiles
• Online Kt/v monitoring
• Blood temperature adjustment
• Access flow monitoring
• Blood volume monitoring
• Single needle devices

Delivery System Disinfection
• According to manufacturer’s recommendations - heat vs. chemical
• Reused acid and bicarbonate jugs should be disinfected between each use
• Disinfectant and rinse solutions include:
  - Bleach
  - Formaldehyde
  - Peracetic acid
• Verification of complete removal of disinfectant is required prior to patient use

Dialyzer
• The blood circuit and the dialysate circuit meet in the dialyzer
• Movement of molecules and fluid between dialysate and blood across a semipermeable membrane
• Blood is moved through hollow fibers
• Dialysate solution bathes the hollow fibers in a separate compartment

Dialyzer Membranes
• Cellulose: made from processed cotton - rarely used due to biocompatibility issues
• Substituted cellulose: cellulose acetate, cellulose diacetate, cellulose triacetate
• Cellulosynthetic: Cellusyn, Hemaspan
• Synthetic: polysulfone, polyacrylonitrile most biocompatible

Visual Tools
Dialysis screens display important information regarding the patient treatment and the dialysis prescription settings.
Visual Tools

- Vital signs
- Dialysis time remaining
- Ultrafiltration
  - Goal
  - Rate
  - Volume removed
  - Time remaining
- Blood flow rate
- Dialysate flow rate
- Pressures: arterial, venous, TMP
- Conductivity
- Temperature
- Profile information
  - KECN
  - Kt/V
  - Access flow

Wrap-Up

- The dialysis machine can be broken down into 3 main pathways
- Knowledge of these pathways is critical to nephrology professionals to:
  - Prescribe appropriate dialysis prescriptions
  - Troubleshoot complications
  - Ensure the safety of dialysis patients in their care

References

http://www.asn-online.org/education/distancelearning/curricula/dialysis/HemodialysisMachinesYoung.pdf

Questions?

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Thank you!

Dysfunctional Hemodialysis Catheters

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I have no financial relationship to disclose.

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Objectives

• Describe methods for troubleshooting dysfunctional dialysis catheters.
• Identify current best practices for prevention of dysfunctional catheters.
• Describe catheter management to prevent infection.

Definition of Dysfunction

Dysfunction is defined as failure to attain and maintain an extracorporeal blood flow ≥300 mL/min at a pre-pump arterial pressure more negative than −250 mmHg. [CPG 7.1]

Dysfunctional Catheters

Signs of Catheter Dysfunction

• Mechanical
• Kinks
• Misplaced sutures or too tight sutures
• Catheter migration
• Drug precipitates
• Patient position
• Catheter integrity
• Holes or cracks

Catheter Tip Location

• Non-cuffed catheters (NCC)
  • Tip at the juncture of the Superior Vena Cava and the Right Atrium
  • Needs confirmed by x-ray
  • Called an acute NCC
• Tunneled, cuffed catheters (TCC)
  • Tip in the right atrium
  • Confirmed by fluoroscopy
Signs of Catheter Dysfunction

- Blood flow rates <300 mL/min
- Arterial pressure more negative than -250 mmHg
- Venous pressure >250 mmHg
- KT/V decreasing below 1.2
- Unable to aspirate blood from lumen
- Frequent pressure alarms
- Need to reverse limbs

Thrombus Formation

- Intraluminal thrombus
  - With the lumen, responds well to tPA
- Fibrin sheath
  - Like having a tube sock over the tip of the catheter and up the sides
- Fibrin tail
  - “ball-valve” effect at the tip
- Mural thrombus
  - Clot formation on the vessel wall and encompasses catheter

Prevention and Treatment

- Repositioning of a malpositioned catheter
  - Have patient cough (Valsalva) or change position
- Check to see if sutures are restricting flow
- Flush using the “chug-chug” method
- Catheter lock exact fill volume
- Monitor for correct heparinization
- Thrombolytic (tPA): Instill/dwell or interdialytic lock
- Catheter exchange with sheath disruption when appropriate

Preventing Hemodialysis Catheter Infections

Infections in Dialysis Patients

- Bloodstream infections (BSIs) are a dangerous complication of dialysis
- 1 in 4 patients who get a BSI caused by S. aureus can face complications such as:
  - Endocarditis (infected heart valve)
  - Osteomyelitis (infected bone)
- BSIs can cause sepsis
- Up to 1 in 5 patients with an infection die within 12 weeks

Prevention and Treatment

- Treatment of an infected HD catheter or port should be based on the type and extent of infection.
- All catheter-related infections should be addressed by initiating parenteral treatment with an antibiotic(s) as a result of the culture.
- Definitive antibiotic therapy should be based on the organism(s) isolated as a result of the sensitivity.
Prevention and Treatment

• Catheter exchange:
  o Catheters should be exchanged as soon as possible and within 72 hours of initiating antibiotic therapy
  o Exchange does not require a negative blood culture prior to the exchange.
  o Follow-up cultures are needed 1 week after cessation of antibiotic therapy (standard practice).

Prevent Infection

Step 2: Get the Catheters Out

- **Fact:** Indwelling catheters are the single most important factor contributing to bacteremia in hemodialysis patients.

- **Actions:**
  - Maximize use of fistulas/grafts
  - Use catheters only when essential
  - Remove catheters when they are no longer essential

Biofilm Adheres to Catheters

**Staphylococcus aureus** in ESRD

• **S. aureus** causes a sizable proportion of severe infections in ESRD patients
  - 29% of catheter-related bacteremias
• **S. aureus** bacteremia leads to costly and lengthy hospitalizations, frequent complications and readmissions

Prevent Infection

Step 3: Optimize Access Care

- **Fact:** Careful infection control prevents dialysis catheter-related infections.

- **Actions:**
  - Follow established guidelines for access care
  - Use proper insertion and catheter-care protocols
  - Remove access device when infected
“Scrub-the-Hub”
- For facilities that use dead-end caps to cover the catheter hub
  - Hubs should be scrubbed with antiseptic after removing the cap and before connecting to bloodlines every time
  - Do the same during disconnection before attaching new caps
  - Soaking or wiping the hub with the cap still attached does not effectively address intraluminal contamination

- For facilities that use closed connector devices
  - Follow process similar to just described when changing connectors
  - In between changes, scrub the access port with antiseptic before accessing
- For all facilities
  - Use a sterile antiseptic pad

Use Antimicrobials Wisely
Step 7: Know When to Say “No” to Vanco
- Fact: Reduction of vancomycin use is one of the most important strategies to limit the emergence, selection, and spread of vancomycin resistant bacteria.
- Actions:
  - Follow CDC guidelines for vancomycin use
  - Consider 1st generation cephalosporins

Preventing Infections
- Implement CDC 12 Step Program to Prevent Antimicrobial Resistance in Dialysis Patients
- Follow recommended infection control practices
- Partner with your patients

In Summary...
- Catheters will always be an access for dialysis treatments
- Know the signs of catheter dysfunction
- Early referral for dysfunction is a priority to prevent thrombosis
- Follow infection prevention control processes at all times

References
References


Questions

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