Hemoperfusion

Renal Intensive Care
Self-learning module
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Hemoperfusion is used to complement existing blood purification technologies, such as hemodialysis and/or continuous renal replacement therapies (CRRT), in the management of drug or chemical toxicities, and hepatic encephalopathy. Hemoperfusion may be used simultaneously with hemodialysis, or CRRT, to take advantage of the clinical benefits of each of these therapies.

The clinical indications stated above are usually treated in intensive care units. Due to the nature of these indications, it is a challenge to deliver this blood purification technique. Some blood purification technologies have been improved to address this. An example is the Prismaflex® system, used for CRRT or TPE; it now allows the use of a hemoperfusion set.

This learning module was created to provide information in the clinical use of hemoperfusion, including principles of treatment, components of therapy, and clinical considerations. Use this under the guidance of a clinical leader, in conjunction with your unit’s policies and procedures.
2 Learning objectives

The learner will be able to:

- Define hemoperfusion
- List the main clinical indications for hemoperfusion
- Explain the principles involved in the therapy
- Identify the common drug toxicities indicated for hemoperfusion
- Describe the characteristics of these drugs
- List the requirements to perform the therapy
- State the clinical considerations for the therapy
- Explain the treatment procedure for the therapy
3 What is hemoperfusion?

Hemoperfusion is the process whereby blood is passed through a sorbent system to remove specific toxic substances in the blood. The sorbent system is made up of a plastic housing, or cartridge, which contains the granules that allow adsorption of molecules.
## 4 History

<table>
<thead>
<tr>
<th>Date</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948</td>
<td>Therapy introduced for adsorption of urea.[¹]</td>
</tr>
<tr>
<td>1964</td>
<td>Yatzidis demonstrated that other substances (creatinine, uric acid, guanidine, indoles, phenolic compounds and organic acids) could be removed more efficiently with uncoated activated charcoal than existing dialysis equipment.[¹]</td>
</tr>
<tr>
<td>1966</td>
<td>Chang demonstrated that micro-encapsulation of charcoal within polymers prevented embolization of charcoal particles and reduced platelet activation.[¹]</td>
</tr>
<tr>
<td>1971</td>
<td>Chang confirmed the removal of substances described by Yatzidis, but also polyamino acids, and medium molecules, with greater creatinine clearances compared to conventional hemodialysis.[¹]</td>
</tr>
</tbody>
</table>
5 The sorbent system

5.1 Description
The sorbent device system is made up of granules, such as activated carbons (charcoals), ion-exchange resins, or non-ionic resins, encased in a plastic housing with a blood inlet and outlet. Unlike a hemodialyser, it does not need an inlet and an outlet for dialysate solutions.

5.2 Activated carbons
Activated carbons may come from biological (e.g. coconut shells, peach pits, sawdust, coal, peat or molasses) or non-biological (e.g. petroleum, pitch or organic resins) substances. The physical properties depend on the starting material and the activation process such as controlled oxidation in air, carbon dioxide or steam.

Ideal characteristics for use in hemoperfusion:
- Maximal adsorptive capacity with high surface area and porosity
- Allow wide spectrum adsorption including water and lipid-soluble drugs
- Minimal release of toxic ions
- Highly biocompatible which prevents considerable destruction of blood elements
- Low toxicity and pyrogenecity
- Free from particulate fines, easy to wash, resist erosion
- Easy to sterilize

Adsorptive capacity of the charcoal system depends on the surface area, porosity and thickness of the membrane coating. Devices may contain 70 to 300 g of activated charcoal. Sorbent devices are available with a surface area of 1000 to 3000 m²/g.\(^ {[3]} \)

Pore size is classified according to size of their radius into micropores (<1 nm), mesopores (1-25 nm), and macropores (>25 nm). Complex physical forces (Van der Waals) trap the solutes in the mesopores or micropores.\(^ {[3]} \)

Most commonly used charcoals today are coated with cellulose nitrate, albumin or heparinized copolymers depending on the manufacturers. The polymer membranes range in thickness from 0.05 to 0.5 µm.\(^ {[3]} \)
The coating, depending on the biocompatibility, may limit diffusion of the solutes into the macropores, through the mesopores and into the micropores, where final adsorption occurs.

Charcoal HP irreversibly binds water and lipid soluble molecules with molecular weights ranging from 113 Da to 30 kDa.\[^3\]

Activated charcoal from coconut shells is considered one of the best raw materials for production of activated carbon due to its extra fine pores.

### 5.3 Exchange resins

Ionic and non-ionic resins are also used as adsorptive materials for hemoperfusion. Ion exchange resins exchange one or more ions for another and may remove biologically important ions, such as calcium, potassium and magnesium, from the blood. Uncharged non-ionic resins adsorb solutes with less energy and may allow reversal of adsorbed molecules.\[^3\]

Hemoperfusion with resin is most effective for lipid soluble solutes.
5.4 Quiz

1. Hemoperfusion is the process whereby blood is passed through a hemodialyzer to remove specific toxic substances in the blood.
   a. True
   b. False

2. Hemoperfusion was first used as a treatment for drug intoxications.
   a. True
   b. False

3. The sorbent system contains particles that allow removal of molecules by adsorption.
   a. True
   b. False

4. Hemoperfusion using resin irreversibly binds the solutes.
   a. True
   b. False

5. Micro-encapsulation of charcoal within polymers prevents embolization of charcoal particles and reduced platelet activation.
   a. True
   b. False

6. Name two ideal characteristics of a charcoal filter:
   a. ________________________________
   b. ________________________________

7. Hemoperfusion with resin is most effective for lipid soluble solutes.
   a. True
   b. False
6 Principles of treatment

Adsorption—the molecular adherence to the surface of the sorbent material. This process is particularly effective for protein bound solutes, as the sorbent material competes with the plasma proteins.

Adsorption. Molecules adhere to the surface of the sorbent granules.
7 Solute characteristics

Certain solute characteristics determine the effectiveness of the therapy, such as molecular size, protein binding, and volume of distribution in the body.

7.1 Molecular size

Hemoperfusion targets molecules that tend to be more difficult to remove with conventional hemodialysis or continuous renal replacement therapies (CRRT). These molecules may be of different sizes, ranging from small to large. Small molecules may pass freely through the pores of a high-flux hemofilter. The removal of middle molecules is facilitated with the addition of convective flow in CRRT using hemofiltration or hemodiafiltration. Hemoperfusion allows the removal of small to large molecules in a larger capacity up to the sorbents’ saturation point.

Hemoperfusion has the capacity to remove molecules up to 30,000 Da depending on the characteristics of the sorbent material.

Molecular weight, Daltons

- Albumin (55,000 - 68,000)
- Myoglobin (17,000)
- Beta 2 microglobulin (11,800)
- Inulin (5,200)
- Vitamin B₁₂ (1,355)
- Glucose (180)
- Uric acid (168)
- Creatinine (113)
- Phosphate (80)
- Urea (60)
- Potassium (35)
- Phosphorus (31)
- Sodium (23)
7.2 Protein binding

Protein binding determines the free fraction of the solute or drug available for removal. Only unbound or “free” drug can be removed from the plasma across a conventional hemodialysis membrane.

The two primary plasma-binding proteins are albumin and α1-acid glycoprotein. Both proteins are of large molecular size; therefore, the proteins do not cross even with the use of high permeability membranes.

Molecules that are protein bound may be removed from the blood by adhering to the surface of the hemofilter membrane or HP device, through the process of (CRRT) adsorption. However, the adsorptive capacity of a hemofilter or HP device is limited to its saturation point.

7.3 Volume of distribution

Volume of distribution (Vd) of a certain solute or drug is the theoretical volume into which the drug is distributed in the body.[2] This affects its availability for removal from the blood.

A drug with large Vd may be rapidly removed by hemodialysis or hemoperfusion, but only a small amount of the body’s drug content is removed during one session. A rebound effect occurs in-between therapy. However, the benefit of these therapies is on the immediate removal of the drug and lowering of the blood concentration thus reducing its toxic effects.

CRRT is less impacted by the rebound effect of drugs with large Vd because of its continuous nature allowing redistribution of the drug from the tissues to the blood.

Highly lipid-soluble drugs have high Vd. Hemoperfusion sorbent has a higher saturation point compared to a hemodialysis membrane. It has been found to be more effective in removal of lipid-soluble and protein-bound drugs.
7.4 Quiz

1. The principle of adsorption in hemoperfusion is most effective for particles that are:
   a. Water-soluble
   b. Lipid-soluble
   c. Both a and b

2. Continuous renal replacement therapies (CRRT) target molecules that tend to be more difficult to remove with hemoperfusion.
   a. True
   b. False

3. Hemoperfusion allows the removal of small to large molecules in a larger capacity up to the sorbent’s:
   a. Sieving coefficient
   b. Saturation point
   c. Thickness of the membrane
4. Hemoperfusion can remove molecules with molecular weights of:
   a. Up to 30,000 Da
   b. 40,000 to 50,000 Da
   c. 50,000–100,000 Da

5. These factors affect the availability of drugs in the blood for removal:
   a. Size of the molecules
   b. Protein binding
   c. Volume distribution
   d. All of the above

6. A solute with a high Vd, means more removal compared to those with small Vd
   a. True
   b. False

7. CRRT removes drugs with large Vd better because there is time for redistribution of the drug from the tissues to the blood.
   a. True
   b. False
8 Clinical indications

Hemoperfusion may be used in the treatment of drug or chemical intoxications and hepatic encephalopathy.\(^3\)

8.1 Drug or chemical intoxications

The use of extracorporeal therapies (ECT) for any drug or chemical intoxications is indicated only if there are signs of severe toxicity, slow response to standard therapy, and if it will eliminate the toxins by 30% or more than what the body would remove.

Hemoperfusion does not eliminate the use of the standard methods of treatment such as gastric lavage, establishment of free airway and respiration, controlled electrolyte and water balance, and forced diuresis.

It is important to monitor the levels of vital drugs and substances that may also be eliminated in the process.

Several studies in different drug poisoning recommends early diagnosis and initiation of supportive therapies and intervention can be life saving.

Table 3 indicates that certain drugs are better removed in hemoperfusion compared to hemodialysis.

<table>
<thead>
<tr>
<th>Drug</th>
<th>Hemodialysis</th>
<th>Hemoperfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaminophen</td>
<td>0.4</td>
<td>0.5 to 0.7</td>
</tr>
<tr>
<td>ASA</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Digoxin</td>
<td>0.2</td>
<td>0.3 to 0.6</td>
</tr>
<tr>
<td>Glulethimide</td>
<td>0.16</td>
<td>0.65 to 0.8</td>
</tr>
<tr>
<td>Paraquat</td>
<td>0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>Phenobarbital</td>
<td>0.3 to 0.7</td>
<td>0.5 to 0.85</td>
</tr>
<tr>
<td>Theophylline</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Tricyclics</td>
<td>0.35</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Table 3: Plasma drug extraction ratios with different devices at BFR (Blood Flow Rate) of 200 ml/min.\(^3\)

**Note:** Drug extraction ratio is the portion of the drug removed from the blood.
Common drug and substance toxicities are described in the table below, including possible management and recommended extracorporeal therapy.

<table>
<thead>
<tr>
<th>Drug and other substances</th>
<th>Characteristics</th>
<th>Management/ECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amitriptyline</td>
<td>Used as antidepressant Vd of 10-20 l/kg 75-95 % protein-bound</td>
<td>HP Early initiation of Tx[6]</td>
</tr>
<tr>
<td>Barbiturates (Phenobarbital)</td>
<td>Used as anticonvulsant MW of 232 Da; Vd of 0.5 l/kg 50% protein bound Binds readily to charcoal</td>
<td>Oral administration of charcoal Urine alkalinisation HP, HD or CRRT</td>
</tr>
<tr>
<td>Lithium</td>
<td>Used in bipolar affective disorders MW of 74 Da Vd of 0.6–0.9 L/kg Not protein bound</td>
<td>IHD or CRRT (CVVHD)</td>
</tr>
<tr>
<td>Metformin</td>
<td>Used as oral hypoglycemic MW of 166 Da Vd of 0.6–0.9 l/kg Not protein bound</td>
<td>IHD or CRRT</td>
</tr>
<tr>
<td>Salicylates</td>
<td>Analgesic, anti-inflammatory 50–90 % protein bound Vd of 0.1–0.2 l/kg</td>
<td>HP, HD or CRRT or a combined therapy (first removal of the free fraction, then removal of the protein-bound fraction)</td>
</tr>
<tr>
<td>Theophylline</td>
<td>Bronchodilator &gt;50% protein bound Vd of 0.33 –0.74 l/kg Binds readily to charcoal</td>
<td>HP is ideal treatment CRRT (CVVH) or a combined therapy (first removal of the free fraction, then removal of the protein-bound fraction)</td>
</tr>
<tr>
<td>Valproic acid</td>
<td>Anticonvulsant, mood-stabilizing drug &gt;90% protein bound MW of 144 Da Vd of 0.1–0.5 l/kg</td>
<td>IHD combined with HP or a combined therapy (first removal of the free fraction, then removal of the protein-bound fraction)</td>
</tr>
<tr>
<td>Tricyclics</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>Anticonvulsant 80–85% protein-bound MW of 236 Da</td>
<td>HP or HD</td>
</tr>
<tr>
<td>Diltiazem</td>
<td>Calcium channel blocker 80% protein bound Vd of 5 l/kg MW of 236 Da</td>
<td>Albumin dialysis (MARS)</td>
</tr>
<tr>
<td>Phenytoin</td>
<td>Antiepileptic 90% albumin bound</td>
<td>Albumin dialysis (MARS)</td>
</tr>
<tr>
<td>Mushroom</td>
<td>95% fatality due to Amatoxins Causes hepatorenal failure Limited protein binding MW of 900 Da High affinity to charcoal and polymers</td>
<td>HP or Albumin dialysis (MARS)</td>
</tr>
</tbody>
</table>

Table 4: Drugs and substances possibly removed by HP and other ECT.[9]
8.2 Hepatic encephalopathy

A number of studies suggested significant improvement in consciousness of patients with hepatic encephalopathy with hemoperfusion treatment (Chang et al, 1972; Gazzard et al, 1974; Gelfand et al, 1978; Amano et al, 1978; Odaka et al, 1978). [3]

It is possible to reverse hepatic coma by removing the substances relevant to its development. These substances are listed in table 5. [3]

Controlled clinical trials to suggest timing and frequency of hemoperfusion treatment in hepatic coma are limited. However, a few human studies confirmed that timing of the initiation of therapy is a critical determining factor for outcome. The deepest coma (Stage IV) is associated with irreversible cerebral edema. Treatment done at an earlier stage would most likely result in increased survival and favourable outcome. [3]

A study by Berk suggested that hepatic toxins slowly equilibrate in the body and recommended that detoxification procedures be done every 12 hours. [3]

<table>
<thead>
<tr>
<th>Substances relevant to hepatic failure removed with sorbent HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amino Acids</td>
</tr>
<tr>
<td>- Aromatic &gt; branched chain</td>
</tr>
<tr>
<td>Bile Acids*</td>
</tr>
<tr>
<td>Bilirubin*</td>
</tr>
<tr>
<td>Coagulation factors*</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

* Studied in vivo

Table 5: Substances relevant to hepatic failure removed with sorbent HP. [3]
9 Treatment considerations

9.1 Complications and side effects of treatment
Modern hemoperfusion devices have eliminated some of the complications related to uncoated charcoal particles, such as erosion, release of particulates, and blood reactions to biocompatible materials. These were solved by biocompatible polymer coating, microencapsulation, and commercial washing techniques.

Some of the reported side effects even with modern hemoperfusion devices are:

- Transient leukopenia resulting from complement activation by surface contact\(^3\)
- Margination of leukocytes similar to hemodialysis\(^3\)
- Minor reduction in fibrinogen and fibronectin\(^3\)
  - Adsorption or activation of coagulation factors
- Hypocalcemia, hypophosphotemia\(^2\), hypoglycemia
- Hypothermia

9.2 Contraindications
There are no known contraindications for hemoperfusion. However, due to coagulation disturbances observed on patients on hemoperfusion, patients with profound thrombocytopenia, leukocytopenia or other coagulopathies should be carefully monitored.

9.3 Treatment guidelines or clinical considerations
Treatment guidelines on hemoperfusion are lacking due to limited controlled human trials. Decision to treat should be based on clinical conditions, especially if patient’s condition deteriorates progressively despite intensive supportive therapy.\(^3\)

Some of the factors to be considered when choosing this therapy include:

a. Characteristics of drugs/substances to be removed. HP must be able to remove the solutes or drugs 30% more than endogenous excretion, and maintain a level of improvement.

b. Timing of initiation, length, and frequency of treatment. Early initiation is recommended. Saturation point of the HP device is usually 2-4 hours, depending on surface area. Treatment should be repeated until optimal toxin removal and/or decreased in clinical symptoms is achieved.
c. Monitoring levels of drugs and other vital substances for supplementation. With carbons, adsorption of biologically important small solutes may occur, such as glucose, calcium, amino acids, 25-hydroxycalciferol, and other hormones. Requirements for catecholamine pressors and other drugs may increase due to its removal.

d. Use of other supportive treatment

- Routine infusion of platelets and FFP post treatment may be required due to coagulation disturbances on patients with hepatic encephalopathy, induced by hemoperfusion.

- Use of HD or CRRT in between HP treatments to remove fluid or maintain electrolyte, and acid-base balance, or body temperature.

- Use of warming devices (i.e., warming blankets, blood warmers) to maintain body temperature.

- Providing nutritive supplements as necessary.

e. Expertise of practitioners and existing technology—HP is usually implemented in the intensive care setting. It makes sense to use HP with the existing technology for renal replacement, such as hemodialysis or CRRT system, and expertise.

9.4 Quiz

1. Hemoperfusion may be used in the treatment of:
   a. Drug or chemical intoxications
   b. Hepatic encephalopathy
   c. Uremia
   d. All of the above

2. The use of ECT for any drug or chemical intoxications is indicated only for:
   a. Signs of severe toxicity
   b. Immediate response to standard therapy
   c. The body can remove the specific toxins by 30%
   d. All of the above
3. Standard methods of treatment for toxicities include:
   a. Gastric lavage
   b. Hemoperfusion for toxin removal
   c. Oxygen therapy
   d. Hemodialysis for electrolyte and water balance

4. Hemoperfusion works best for drugs with these characteristics, except:
   a. High protein binding
   b. Middle to large molecular weight
   c. High Vd
   d. Lipid soluble

5. Factors determining the outcome for patients with drug/chemical toxicities and hepatic encephalopathy include:
   a. Initiate therapy for severe symptoms only
   b. Repeat hemoperfusion every 12 hours
   c. Implementation of supportive therapy
   d. Supplementation of vital substances

6. Most common side-effect of hemoperfusion is:
   a. Fluid overload
   b. Coagulopathies
   c. Loss of nutrients
10 Other blood purification techniques

Blood purification techniques that may be applied for the same indications as hemoperfusion are conventional hemodialysis, continuous renal replacement therapy (CRRT) or molecular adsorbent recirculating system (MARS). Characteristics of each of these therapies are as listed:

10.1 Conventional hemodialysis

- Used for highly diffusible substances
- Limited clearance of middle to large and protein-bound molecules, no convective option
- Rapid fluid removal and solute clearance (3-4 hours)
- Acute, frequent hypotensive episodes often observed
- Uremic, electrolytes and pH control achieved only during IHD treatment
- Redistribution of drugs/substances in between treatment (rebound)
- Maintenance of body temperature

10.2 Continuous renal replacement therapy (CRRT)

- Promotes hemodynamic stability, continuous, controlled redistribution of drugs/substances
- Continuous control of uremia, electrolytes, pH and body temperature (optional use of blood warmer)
- Potential for optimization of nutritional support, including administration of parenteral nutrition (PN)
- Convective therapy option allows wider range of clearance but limited for lipid soluble and protein bound molecules

10.3 Molecular adsorbent recirculating system (MARS)

- MARS therapy is based on the selective removal of albumin-bound toxins from the patient’s blood. Detoxification is achieved by dialyzing the patient’s blood against an albumin containing solution across a special membrane. Adsorber columns are used to remove the toxins bound to the albumin circulating on the dialysate side of the special membrane. Albumin is
thus regenerated and can be continuously reused for further dialysing the patient’s blood. There is no direct contact between the patient’s blood and the adsorber columns

- Maintenance of fluid, electrolyte, acid base balance, and body temperature applied over 6-8 hours
- Wider range of clearance including lipid soluble and protein-bound molecules
- Requires expert users, more difficult set-up
- Redistribution of drugs/substances in between treatment (rebound)
11 Components of HP therapy

Basic requirements to perform hemoperfusion are: a hemoperfusion cartridge, bloodlines, vascular access, anticoagulant, the Prismaflex system.

11.1 Hemoperfusion cartridge

Hemoperfusion cartridges are available for use with either a hemodialysis or Prismaflex systems. A list of HP devices is included in table 6.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Device</th>
<th>Sorbent type</th>
<th>Amount of sorbent</th>
<th>Polymer coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asahi</td>
<td>Hemosorba</td>
<td>Petroleum-based spherical charcoal</td>
<td>170 g</td>
<td>Polyhema</td>
</tr>
<tr>
<td>Clark</td>
<td>Biocompatible System</td>
<td>Charcoal</td>
<td>50,100,250 cc</td>
<td>Heparinized polymer</td>
</tr>
<tr>
<td>Gambro</td>
<td>Adsorba cartridge</td>
<td>Norit</td>
<td>150 or 300 g</td>
<td>Cellulose acetate</td>
</tr>
<tr>
<td>Organon-Teknika</td>
<td>Hemopur 260</td>
<td>Norit-extruded charcoal</td>
<td>260 g</td>
<td>Cellulose acetate</td>
</tr>
</tbody>
</table>

Table 6: Example of hemoperfusion devices and characteristics.[3]

11.2 Adsorba cartridge

Benefits of Adsorba cartridge:

- High efficiency. Outstanding adsorptive capacity for wide spectrum for both hydrophilic and lipophilic drugs, large adsorption area, low resistance to blood flow, design facilitates optimal access to granules and assures complete inner blood flow distribution.
- Patient safety. Cellulose membrane reduces undesired deposition of blood components, resists erosion of particles.
- Easy set-up and handling. Packed in sterile saline solution, compatible with existing HP monitor system, including hemodialysis machines and the Prismaflex system.
**Priming:**

Priming is an important step since air in the circuit will decrease surface area and thus clearance.

It is recommended to rinse Adsorba cartridge with 500 ml of 5% dextrose/glucose solution followed by 2000 ml of heparinized normal saline solution (2500 units of heparin/liter of NS (NaCl 0.9%).

Rinsing with dextrose prevents a drop in blood glucose level at the start of treatment. It is important to rinse the cartridge with NS after the dextrose/glucose to eliminate the hypotonic medium, which may cause hemolysis.

**Table 7: Specific product characteristics of Adsorba cartridge by Gambro:**

<table>
<thead>
<tr>
<th></th>
<th>150°C</th>
<th>300°C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adsorbent material</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td>Activated charcoal 150 g</td>
<td>Activated charcoal 300 g</td>
</tr>
<tr>
<td>Total surface area</td>
<td>150,000 m²</td>
<td>300,000 m²</td>
</tr>
<tr>
<td><strong>Coating material</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Membrane thickness</td>
<td>Cellulose 3–5 µm</td>
<td>Cellulose 3–5 µm</td>
</tr>
<tr>
<td><strong>Internal resistance at Q_b</strong></td>
<td>20–30 mmHg</td>
<td>20–30 mmHg</td>
</tr>
<tr>
<td>Priming volume</td>
<td>140 ml</td>
<td>260 ml</td>
</tr>
<tr>
<td><strong>Disposable set: internal volume</strong></td>
<td>107 ml</td>
<td>107 ml</td>
</tr>
<tr>
<td><strong>Total extracorporeal volume</strong></td>
<td>247 ml</td>
<td>367 ml</td>
</tr>
<tr>
<td>Filter mesh</td>
<td>450 µm</td>
<td>450 µm</td>
</tr>
<tr>
<td><strong>Housing material</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filler for housing</td>
<td>Polypropylene balls</td>
<td>Polypropylene balls</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>245 mm</td>
<td>245 mm</td>
</tr>
<tr>
<td>Max diameter</td>
<td>87 mm</td>
<td>87 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>0.9 kg</td>
<td>1 kg</td>
</tr>
</tbody>
</table>

**Note:** Consult Adsorba IFU for proper handling of the cartridge.
The Prismaflex hemoperfusion set is connected to the Adsorba cartridge during set up. It includes the pressure monitor connectors, deaeration chamber, PBP line and anticoagulant line. The drainage bag is needed during priming only.

11.4 Prismaflex and hemoperfusion
The Prismaflex system takes the hemoperfusion set specifically designed for the treatment. The bloodlines connect to the inlet and outlet of the hemoperfusion device such as the Adsorba cartridge. It contains the same color-coded lines as the standard Prismaflex CRRT hemofilter set, except for dialysate and replacement lines, which are not present in the set. The pre-blood pump line may be used to infuse solution to dilute the blood before the blood pump segment.

It is easy to set up, prime, connect and disconnect patient using the same step-by-step instructions that ICU nurses are familiar with.
The Prismaflex system complements CRRT with another option, the hemoperfusion mode.

11.5 Vascular access:
A central venous catheter is usually used for patients requiring this therapy, although an existing hemodialysis access, such as an AV fistula or graft may also be used. The access must be sufficient to maintain a blood flow of at least 200–300 ml/min.

11.6 Anticoagulant
An anticoagulant is required to maintain the patency of the extracorporeal circuit. Heparin is most commonly used, either intermittently or continuously, with a therapeutic goal of twice the baseline activated clotting time (ACT). It is recommended that clotting time be measured at regular intervals and heparin administered according to patient requirements.

No experience has been reported on the use of citrate as an anticoagulant in hemoperfusion.

11.7 Quiz
Match column one to column two:

1. Hemoperfusion         A. Drop in blood glucose
2. Conventional hemodialysis B. Adsorba + HP bloodlines
3. CRRT                  C. 2X baseline ACT
4. MARS                   D. Hemolysis
5. Adsorba                E. Highly diffusible solutes
6. Dextrose priming       F. Gambro charcoal sorbent
7. Prismaflex system      G. Controlled rebound of solutes
8. Heparin                H. Combines HP and HD
9. Hypotonic medium       I. Used with HD or CRRT
12 Treatment considerations

12.1 Set-up and priming the Prismaflex® hemoperfusion kit

Here is a summary of the step-by-step on-line instructions provided on the Prismaflex screen.

Set-up and priming:

1. Install HP set on machine.
2. Connect selected anticoagulant to appropriate line.
3. If necessary, connect PBP (pre-blood pump) line to prescribed solution.
4. Connect and prime with first priming solution as pre-programmed on machine.
   - Use 500 ml of 5% dextrose/glucose.
5. Connect to hemoperfusion device.
6. Perform the remaining priming phase. Connect and prime with second priming solution.
   - Use 2 l NS (NaCl 0,9%), with 2500UI of heparin.
7. If necessary, connect and prime with plain NS (NaCl 0,9%) to rinse out heparinized saline (for patients with bleeding tendencies).
8. Set treatment parameters on machine.
   - Monitor patient’s vital signs at least every hour or more often if necessary.
### 12.2 Prismaflex®, hemoperfusion prescription guidelines

<table>
<thead>
<tr>
<th>Orders</th>
<th>Rational/additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hemoperfusion device (Check one):</strong>&lt;br&gt;______ Adsorba 150 C&lt;br&gt;______ Adsorba 300 C</td>
<td>Adsorba cartridge 150 C:&lt;br&gt;Internal volume: 140 ml (+ set: 247 ml.)&lt;br&gt;Adsorba cartridge 300 C:&lt;br&gt;Internal volume: 260 ml (+ set: 367 ml.)&lt;br&gt;&lt;strong&gt;Note:&lt;/strong&gt; the total amount of fluid in the HP set and the Adsorba cartridge should be considered as patient’s fluid input and counted as such in the patient fluid balance.</td>
</tr>
<tr>
<td><strong>Priming solutions:</strong>&lt;br&gt;______ 1st cycle: 500ml of 5% dextrose/glucose&lt;br&gt;______ 2nd and 3rd cycle: 2l of 0.9% NS (NaCl 0,9%) with 2500IU of heparin/l in each bag</td>
<td>Priming with dextrose/glucose is recommended to prevent drop in blood glucose at start of treatment. NS (NaCl 0,9%) rinse after dextrose/glucose priming eliminates hypotonic medium, which may cause hemolysis.</td>
</tr>
<tr>
<td><strong>Treatment time:</strong> ________ &lt;br&gt;<strong>Frequency:</strong> ________ hrs. &lt;br&gt;<strong>Number of treatments:</strong> ________</td>
<td>Saturation point of HP device is 2-4 hrs depending on its surface area and effective change in drug/poison level in the blood. Repeat treatment every 12 hrs to control toxic rebound. Repeat until optimal toxin removal and/or decreased clinical symptoms.</td>
</tr>
<tr>
<td><strong>Blood flow rate:</strong> ________ ml/ min</td>
<td>Slowly increase blood flow from 50 to 150 ml/min, then to prescribed blood flow rate, to optimize blood contact with charcoal granules. Monitor filling of blood into the Adsorba cartridge and patient hemodynamic parameters at start up.</td>
</tr>
<tr>
<td><strong>PBP solution:</strong>  &lt;br&gt;<strong>PBP solution flow rate:</strong> ________ ml/hr</td>
<td>Pre-blood pump (PBP) solution may be used to dilute blood to reduce clotting. PBP rate cannot exceed the blood flow rate. &lt;br&gt;&lt;strong&gt;Note:&lt;/strong&gt; the total amount of fluid infused through the PBP should be considered as patient’s fluid input and counted as such in the patient fluid balance.</td>
</tr>
<tr>
<td><strong>Syringe pump for anticoagulant: Prismaflex</strong>  &lt;br&gt;<strong>Type:</strong> Heparin  &lt;br&gt;<strong>Syringe size:</strong> ______________________  &lt;br&gt;<strong>Concentration in syringe:</strong> u /ml  &lt;br&gt;<strong>Initial Bolus:</strong> ______________________ ml  &lt;br&gt;<strong>Continuous:</strong> ______________________ [ml/hr]</td>
<td>Heparin is most commonly used to maintain an ACT level of twice the baseline.</td>
</tr>
<tr>
<td><strong>Monitoring:</strong>  &lt;br&gt;<strong>Lytes:</strong> ________  &lt;br&gt;<strong>CBC:</strong> ________  &lt;br&gt;<strong>ACT:</strong> ________  &lt;br&gt;<strong>Other:</strong> ______________________</td>
<td>Monitor levels of drugs and other vital substances for supplementation (i.e., glucose, calcium, amino acids, 25-hydroxycholecalciferol, and other hormones.) Monitor coagulation factors, which may be affected by HP (i.e., platelets, fibrinogen, etc.).</td>
</tr>
</tbody>
</table>
13 Answers to quiz

Sections: 1-5

1. False
2. False
3. True
4. False
5. True
6. Ideal characteristics of a charcoal filter:
   - Maximal adsorptive capacity with high surface area and porosity
   - Allow wide spectrum adsorption including water and lipid-soluble drugs
   - Minimal release of toxic ions
   - Highly biocompatible which prevents considerable destruction of blood elements
   - Low toxicity and pyrogenecity
   - Free from particulate fines, easy to wash, resist erosion
   - Easy to sterilize
7. True

Sections 6-7

1. b. Lipid-soluble
2. False. Hemoperfusion targets molecules that tend to be more difficult to remove with CRRT.
3. b. Saturation point
4. a. Up to 30,000 Da
5. d. All of the above
6. False. A solute with a high Vd, means less removal compared to those with small Vd.
7. True

Sections 8-9

1. d
2. a. Severe toxicity
3. a
4. c
5. a
6. b
Sections 10-11

1. Hemoperfusion
2. Conventional hemodialysis
3. CRRT
4. MARS
5. Adsorba
6. Dextrose priming
7. Prismaflex system
8. Heparin
9. Hypotonic medium

i. Used with HD or CRRT
ii. Highly diffusible solutes
iii. Controlled rebound of solutes
iv. Combines HP and HD
v. Gambro charcoal sorbent
vi. Drop in blood glucose
vii. Adsorba + HP bloodlines
viii. 2X baseline ACT
ix. Hemolysis
14 References

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