BLOOD CONSERVATION TECHNIQUES

Introduction

The ***danger of using the banked blood*** has been recognized and there is a growing move to find new ways to conserve blood.

Much of the decreased blood usage has come from the perfusionists developing way to ***remove all blood*** from the perfusion circuit at the end of the case.

Manufacturers contributions like ***lower prime oxygenators, circuits and other equipments*** are fast becoming the routine.

Advantages of blood conservation techniques

- Transmitting infections is avoided
- Prevention of blood borne diseases
- Reducing the requirements from blood bank
- Preventing sepsis
- Using patients autologous blood
- Preserving even the mediastinal shed blood
- To give all the blood from the perfusion circuit at the end of the case.
- Jehovah's witness

Autologous blood

- Patients own blood = autologous blood
- Disease transmission is eliminated
- Helpful in Jehovah's witness patients
- Cross matching errors are eliminated
- Patients with multiple red blood cell antibodies or with unusual blood phonotypes cannot use the homologous blood.

Autologous blood

- There are several ways that the patients blood can be salvaged and returned to the patient

Conservation techniques of autologous blood

- Patient can donate his / her blood prior surgery
- Autologous blood priming
- Cell saver
- Hemoconcentrator or Hemofiltration

Blood removal from patients

BLOOD DONATION BY PATIENT:

- The patient can **donate** his or her blood in preparation of a major surgery ***(i.e., for non emergent cases)***
- The patient blood is collected before week of surgery
- The total amount collected is equivalent to 2 units of packed red blood cells.

DRAWBACKS:

- Multiple visit of the patient
- Cost of drawing and storing the blood
- Time consumable

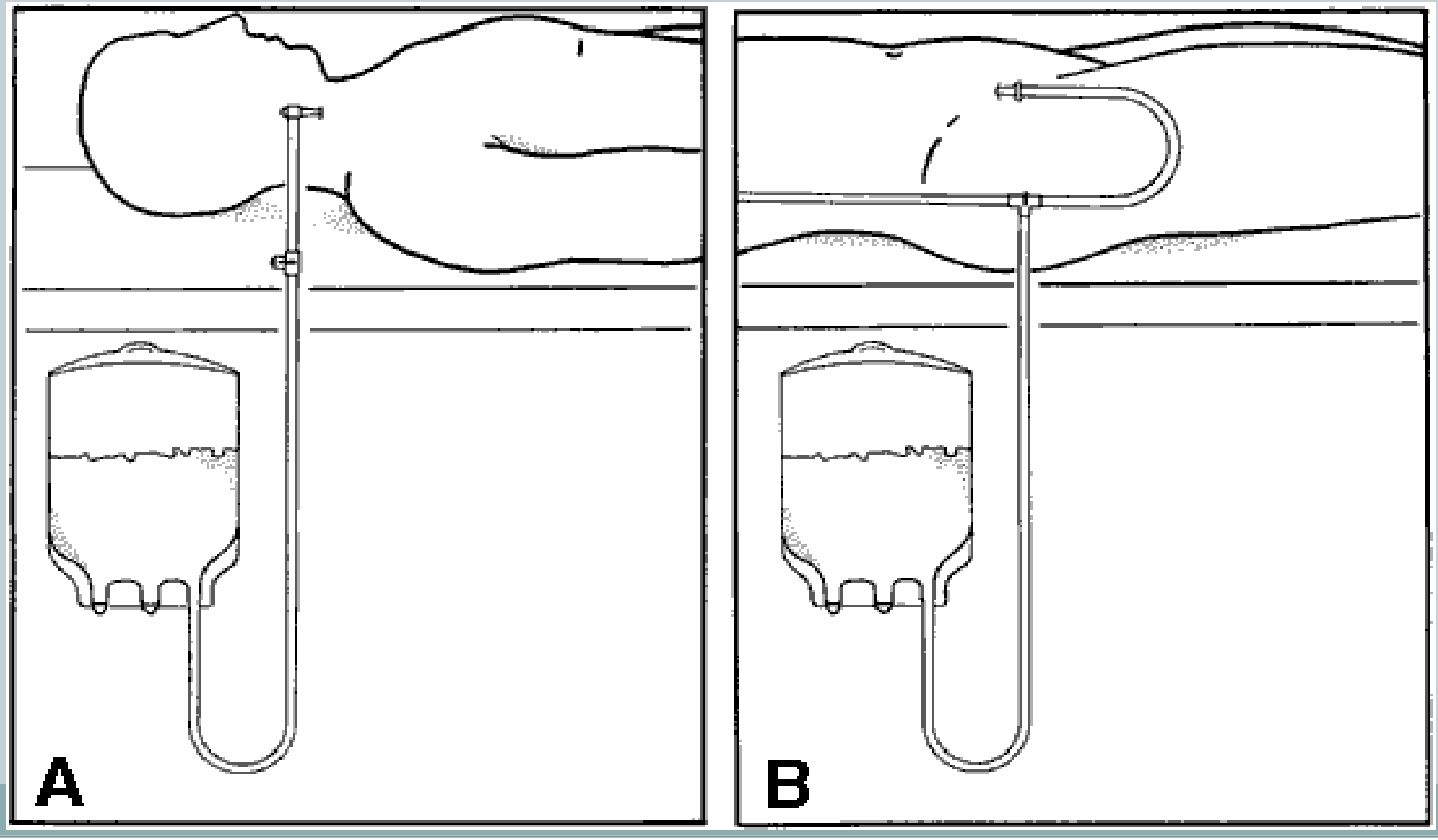
Other methods

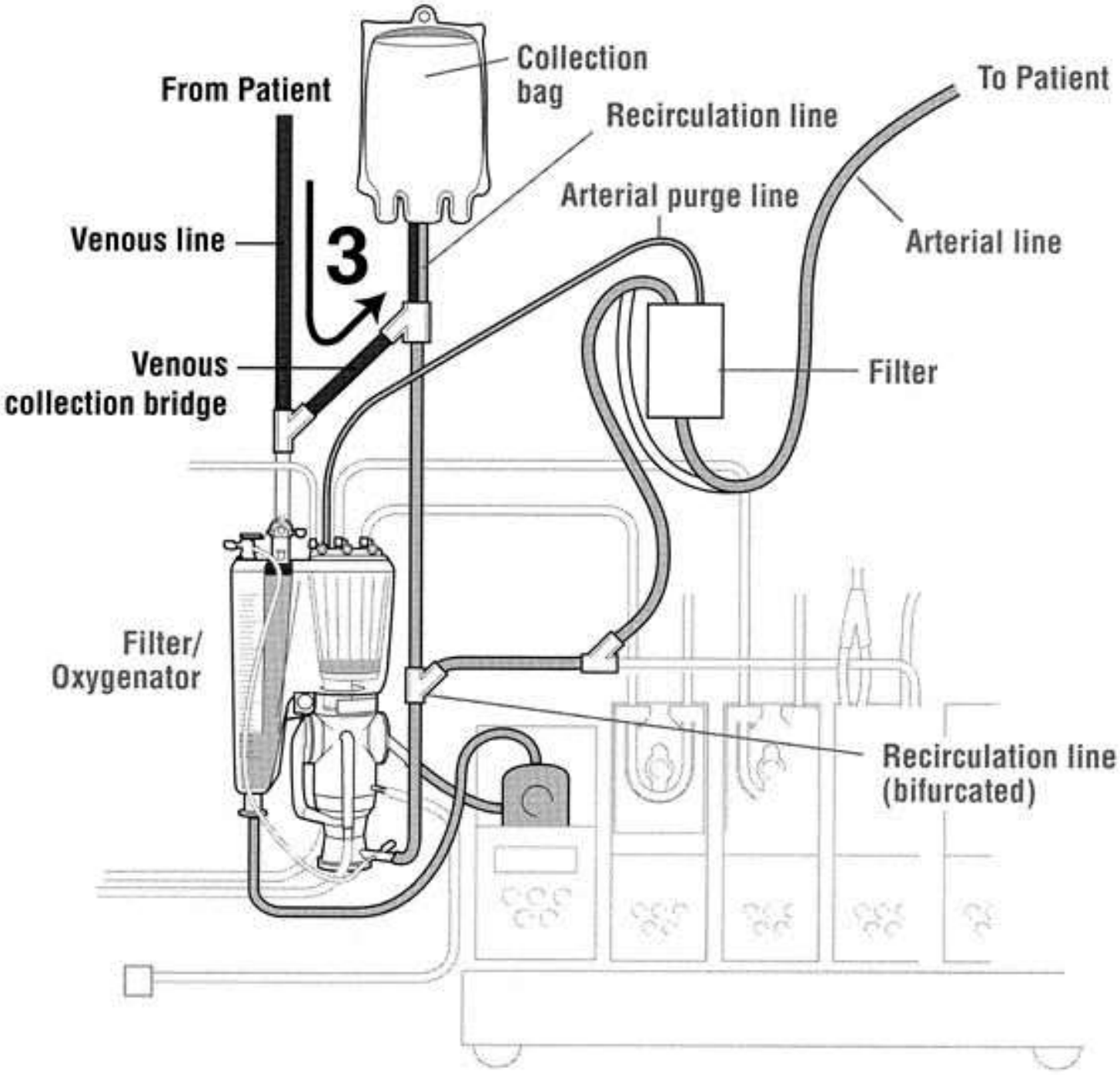
- In cardiac surgery another method of obtaining patient blood is, ***removing blood prior to starting CPB***
- After heparinization and cannulation, blood can be collected by the way of the venous line and a Y – connection to a collection bag.

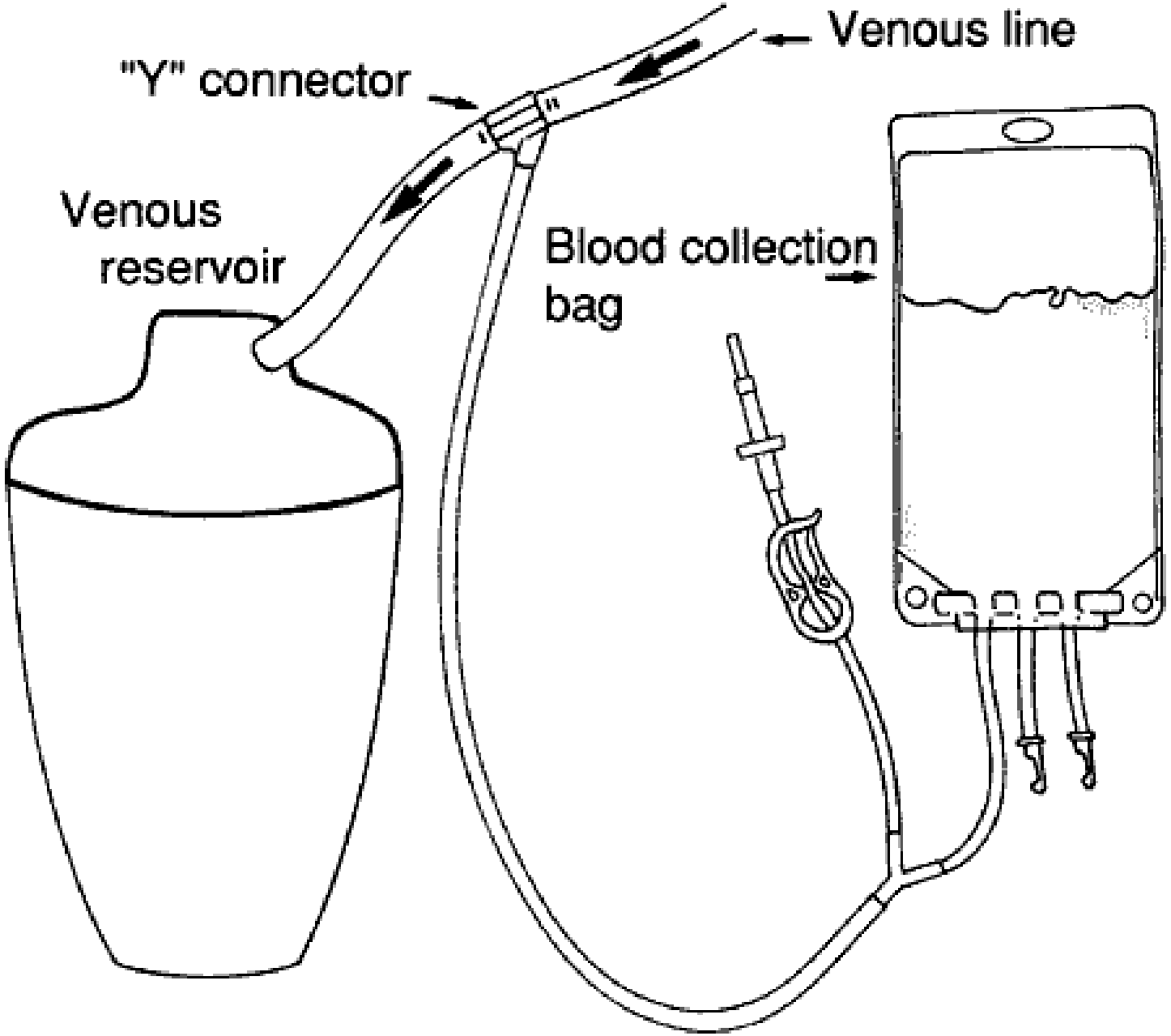
METHOD TO OBTAIN:

- Venous line unclamped
- Priming volume added in the reservoir and arterial flow started to maintain the adequate pressure
- When blood reaches the Y connector, then clamp applied and blood diverted to the collection bag.

Intraoperative collection of blood from central venous & femoral arterial catheter




From Patient
Collection bag
To Patient
Recirculation line
Arterial purge line
Arterial line
Venous line
3
Venous collection bridge
Filter
Filter/ Oxygenator
Recirculation line (bifurcated)


Venous line
"Y" connector
Venous reservoir
Blood collection bag

PRECAUTIONS:

- Process should be done slowly to prevent arrhythmias and drop in blood pressure
- After heparinization alone this procedure should be followed

CONTRAINDICATIONS :

Patients with more hemodilution

Patients with hypovolumic

Patients with less Hematocrit

Patients with clotting factor deficiencies

Autologous Priming

- Autologous priming (AP) utilizes the patient's blood to re-prime the CPB circuit upon initiation of CPB.

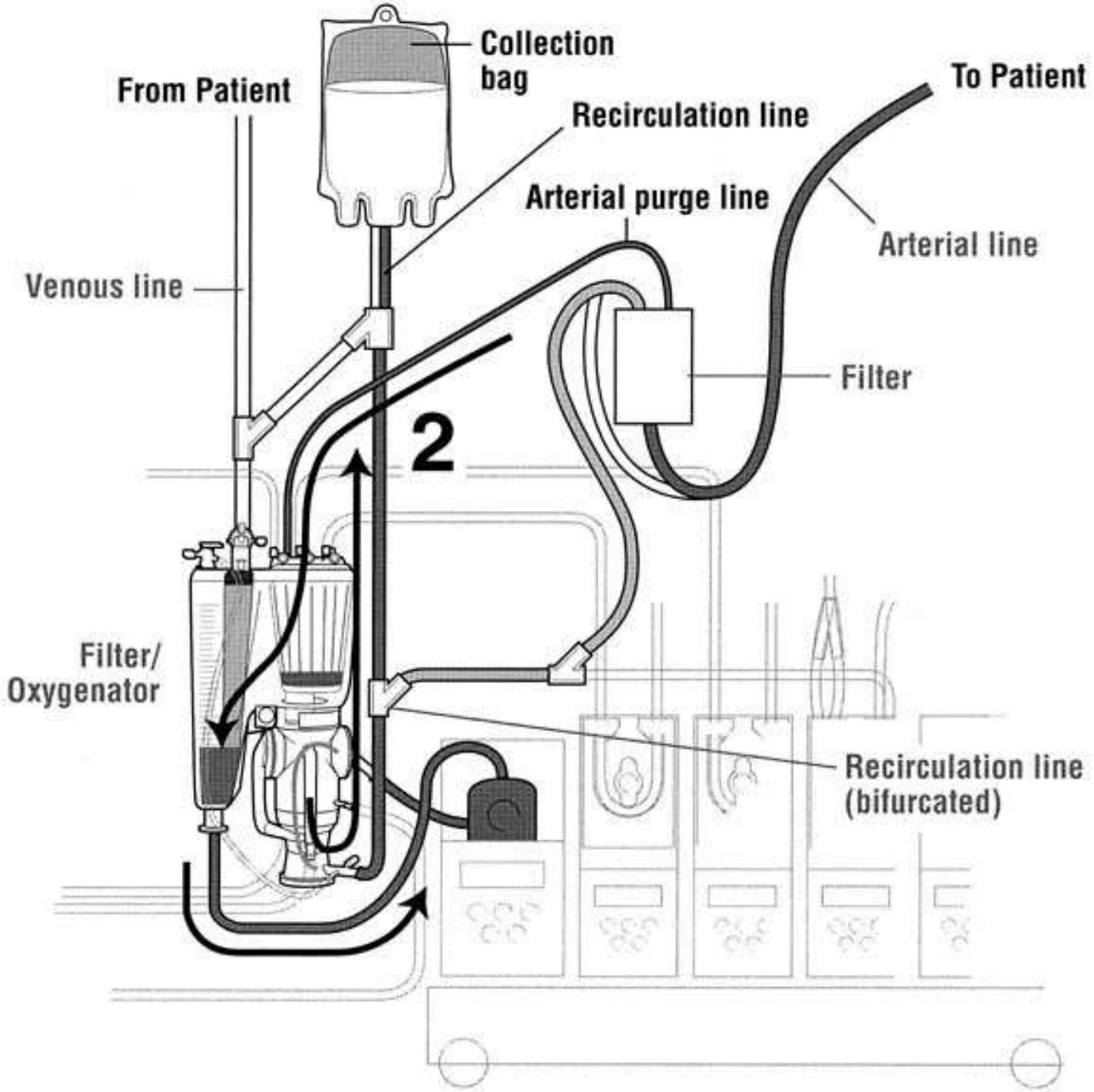
ANTEGRADE AUTOLOGOUS PRIMING:

- Normal blood flow through the CPB circuit displaces the circuit prime with the patient's venous blood while diverting the crystalloid into a sterile bag.

RETROGRADE AUTOLOGOUS PRIMING:

- Partial priming with autologous arterial blood can be achieved by retrograde drainage of 100–400 ml of blood via the arterial cannula, by replacing with 400–500 ml of the patient's blood.

- Safe autologous priming relies on good teamwork between perfusionist, anesthetist and surgeon to select appropriate patients and to ensure hemodynamic stability, usually with the help of ***vasopressors***, during the period of partial exsanguination of the patient.


Collection bag
From Patient
Recirculation line
To Patient
Arterial purge line
Arterial line
Venous line
Filter
2
Filter/ Oxygenator
Recirculation line (bifurcated)

Hemoconcentrators

- Hemoconcentrators (ultrafilters) blood filter are devices mainly consisting of a ***hollow fiber semipermeable membrane*** to allow the passage of water and electrolytes from the blood to a filtrate chamber and waste bag.

- Hemoconcentrators are used during extracorporeal circulation to ***remove excess fluid*** and electrolytes (e.g. excess potassium levels)

- ***Remove inflammatory mediators*** generated

- Raise ***hematocrit.***

- The hemoconcentrator works by ***forcing fluid and small solutes across a semipermeable membrane***
- Hemoconcentrator pore size ranges from ***15,000 – 55,000 daltons***
- The hollow fibers are of ***180 – 200 µm*** in diameter
- **Molecules up to 20000 Daltons are removed** (e.g. water, electrolytes, creatinine, urea, glucose, heparin and various inflammatory mediators)
- The size of Heparin is ***6,000 – 20,000 daltons***, therefore a small portion will cross the membrane.

- Hemoconcentrators filter cannot remove plasma proteins and blood coagulation factors (albumin, AT III, immunoglobulins,) because the **plasma protein molecules mass are above 65,000 Daltons**

- ***Sieving coefficient*** ***is the ability of the solutes to filter depends on molecular weight of the solute compared with the pore size, proportion of the solute*** that is membrane bound and the surface charge of the solute

- It is the ratio of ultrafiltrate solute to plasma concentration

Value as 1 --- means equal conc. (solute passes freely through membrane)

Value as 0 --- means none of solutes passes through membrane

Hemoconcentrator connection

Hemoconcentrator is connected to the CPB Circuit at,

- ***Arterial line (with Y – connector)***
- ***Recirculation line***

The speed of fluid removal is usually ***30 to 50 ml/minute***, and depends on,

- The hematocrit level
- The membrane pore size
- The pressure in the hemoconcentrator membrane.

Transmembrane pressure

- The pressure gradient between the blood and the ultrafiltrate is called transmembrane pressure (TMP).

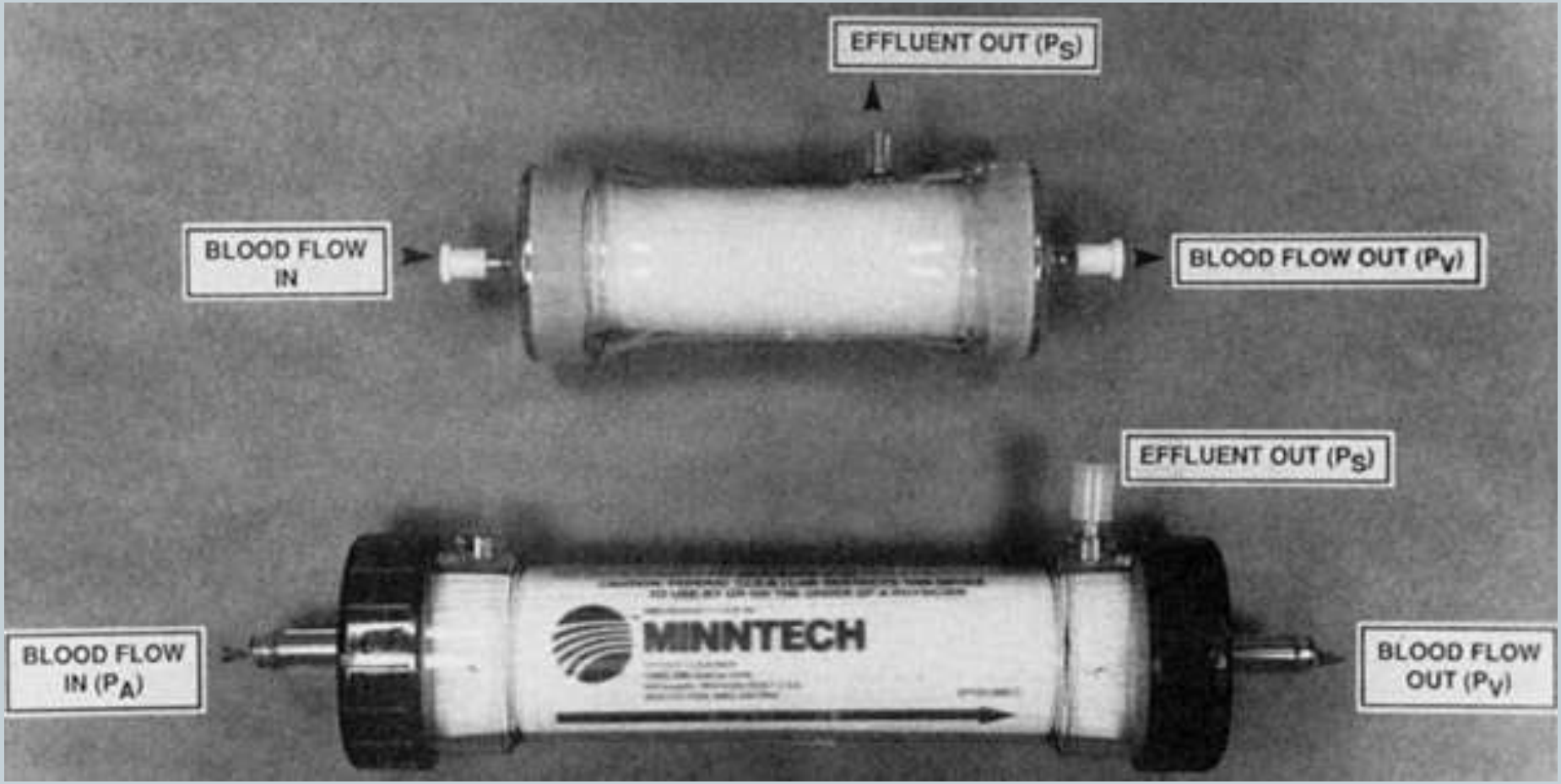
- **TMP = (P in + P out) / 2 + V**

TMP = Transmembrane gradient

P in = blood inlet pressure

P out = blood outlet pressure

V = negative pressure applied on the effluent side of the hemoconcentrator


EFFLUENT OUT (P_S)
BLOOD FLOW IN
BLOOD FLOW OUT (P_V)
EFFLUENT OUT (P_S)
MINNTECH
BLOOD FLOW IN (P_A)
BLOOD FLOW OUT (P_V)

Transmembrane pressure

- TMP should not exceed ***500 – 600 mmHg*** to avoid rupture of membrane

Rate of UF depends on,

- Membrane permeability
- Blood flow
- Tmp
- Hematocrit

Membrane permeability is related to,

Pore size, membrane thickness , material.

Advantage of Hemoconcentration

- ***Reduction of homologous blood*** and blood products needed
- ***Increasing hematocrit level***, that improves arterial oxygen content and maintains an adequate oxygen delivery to body.
- ***Decreases post-operative bleeding*** as platelets and clotting factors are kept.
- ***Controls the intracellular water*** level by retaining plasma proteins, and decreases tissue edema and organ dysfunction.

- Improves ***LV systolic*** function
- Improves A-a ***O2 gradient***
- Increases ***pulmonary compliance***
- Decrease duration of postop ventilation
- Increase COP

Contraindications for Ultrafiltration

- Leukopenia
- Biocompatibility
- Complement activation
- RBC trauma
- Retention of heparin in hemoconcentrated blood
- Cost analysis

Types of UF

- Conventional UF
- Modified UF
- Zero – balanced UF

CONVENTIONAL ULTRAFILTRATION

Conventional ultrafiltration

- ***To remove excess fluids during CPB*** in patients with acute or chronic fluid overload and to remove compliment activators

PREPARATION OF EQUIPMENT:

- Securely attach the hemoconcentrator holder
- Remove hemoconcentrator from wrapper and inspect for shipping damage
- Mount hemoconcentrator vertically in holder with capped filtrate port at bottom and filtrate line at top
- Bloodlines must be connected to flow in at the bottom and out at the top.

- Place collection container on the floor
- The inlet going into the hemofilter line is connected to the three way stop cock of the arterial filter or bubble trap
- Connect outlet line from hemoconcentrator to top of venous reservoir or to the venous line three way stop cock
- Connect suction tubing from filtrate port at the top of hemoconcentrator to collection container and clamp.

PRIMING:

THE HEMOCONCENTRATOR MAY BE PRIMED BEFORE & DURING BYPASS

- Pump blood / prime through the hemoconcentrator and deair
- After the blood circulates through the hemoconcentrator for several minutes and all bubbles are removed, unclamp the filtrate line to begin the ultrafiltration process.

Maintenance of Hemoconcentration:

- The transmembrane pressure gradient between the blood in the capillary and the surrounding ultrafiltrate determines the ultrafiltration rate.

  TMP – Decreases by occluding the ultrafiltrate outlet

  TMP – Increasing the blood flow through device
- **ACT** should be monitored
- If suction is used to remove filtrate, **pressure** in the blood path must always greater than the pressure in the filtrate side.
- Do not shut off blood flow through the hemoconcentrator as this may cause clotting, reduced performance and excessive TMP
- **BLOOD FLOW should not exceed 400ml/min**
- Observe HCT & Electrolytes.

MODIFIED ULTRAFILTRATION

Modified Ultrafiltration (MUF)

- **Modified ultrafiltration(MUF)** is a technique used to concentrate the patient's circulating blood volume and the residual volume in the extracorporeal circuit ***at the end of cardiopulmonary bypass.***

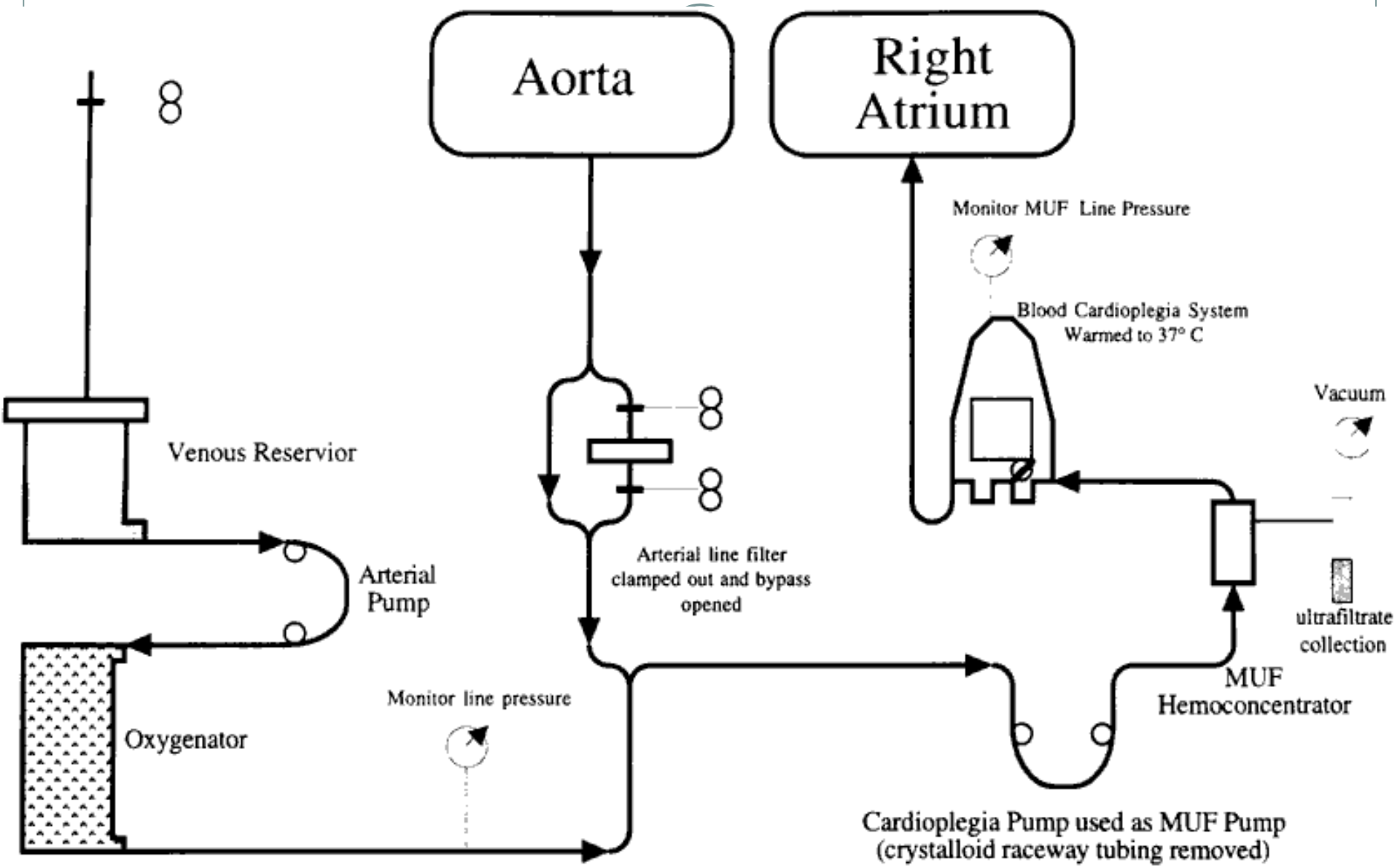
- The technique of modified ultrafiltration was introduced in the early 1990s, to concentrate and reinfuse the residual blood from the ECC.

- MUF's done on all paediatric and neonates patients weighing less than 10 kgs and with severe PAH

MUF connection:

- The hemoconcentrator inlet is connected to the arterial line and ***the outlet to the right atrium***.
- Blood is drawn retrograde from the arterial cannula along from the venous reservoir (through the membranes) by a roller pump which is connected to the ultrafilter to allow the precise control of the blood flow through the hemoconcentrator.
- A negative pressure can be applied to the ultrafilter to increase the rate of filtration

MUF


Aorta
Right Atrium
Monitor MUF Line Pressure
Blood Cardioplegia System Warmed to 37° C
Vacuum
Venous Reservior
Arterial Pump
Arterial line filter clamped out and bypass opened
ultrafiltrate collection
MUF Hemoconcentrator
Monitor line pressure
Oxygenator
Cardioplegia Pump used as MUF Pump (crystalloid raceway tubing removed)

Maintenance of Hemoconcentrator:

- MUF done for a period of ***10 – 15 minutes*** or till all the residual volume in the venous reservoir and oxygenator is utilized

- MUF is started by allowing the arterial blood to flow from aortic cannula to the hemofilter, at a rate of ***10–15 ml/kg/min,*** which is controlled by the cardioplegia pump.

- The amount of blood removed from the aorta is not more than ***5ml/kg*** and should not exceed 30ml in pediatric to prevent ***"Cerebral Steal"***

- Ensure no clamps in the arterial and venous line
- Observe for ECG changes for air entry into coronaries
- Monitor CVP and no significant changes in filling pressures
- Ensure no significant drop in aortic pressure
- Use vacuum at filtrate component (-150 to 200 mmHg)

ADVANTAGES OF MUF

- It's a volume control
- Blood preservation
- Improve Hematocrit Level
- Improve Blood pressure
- Improve Cardiac Output
- Improve arterial oxygen content
- Improve Myocardial contractility
- Decrease Myocardial oedema
- Reduce blood loss & transfusion requirements
- Improvements in postoperative morbidity because to remove of plasma inflammatory mediators

DISADVANTAGES OF MUF

- The ***risk of air embolism*** formation in systemic organs
- The need to ***maintain heparinization*** during the period of ultrafiltration
- The ***additional time*** required in the operating room.
- The arterial cannula must be left in place during the MUF

that may cause obstruction of the ascending aorta, especially in a small ascending aorta.

- The necessity of an ***additional complicated circuit***.

ZERO BALANCED UF

Z – BUF

- Z-BUF is used to allow continuous UF during the rewarming phase, ***replace the ultrafiltrate with a balanced electrolyte solution***
- The ultrafiltration rate is matched with infusion rate by loading the ultrafiltration effluent line and the electrolyte solution infusion tubing into a roller pump.
- Z – buf used to ***correct Hyperkalemia***
- Electrolyte solutions are Hartman's, ringer lactate

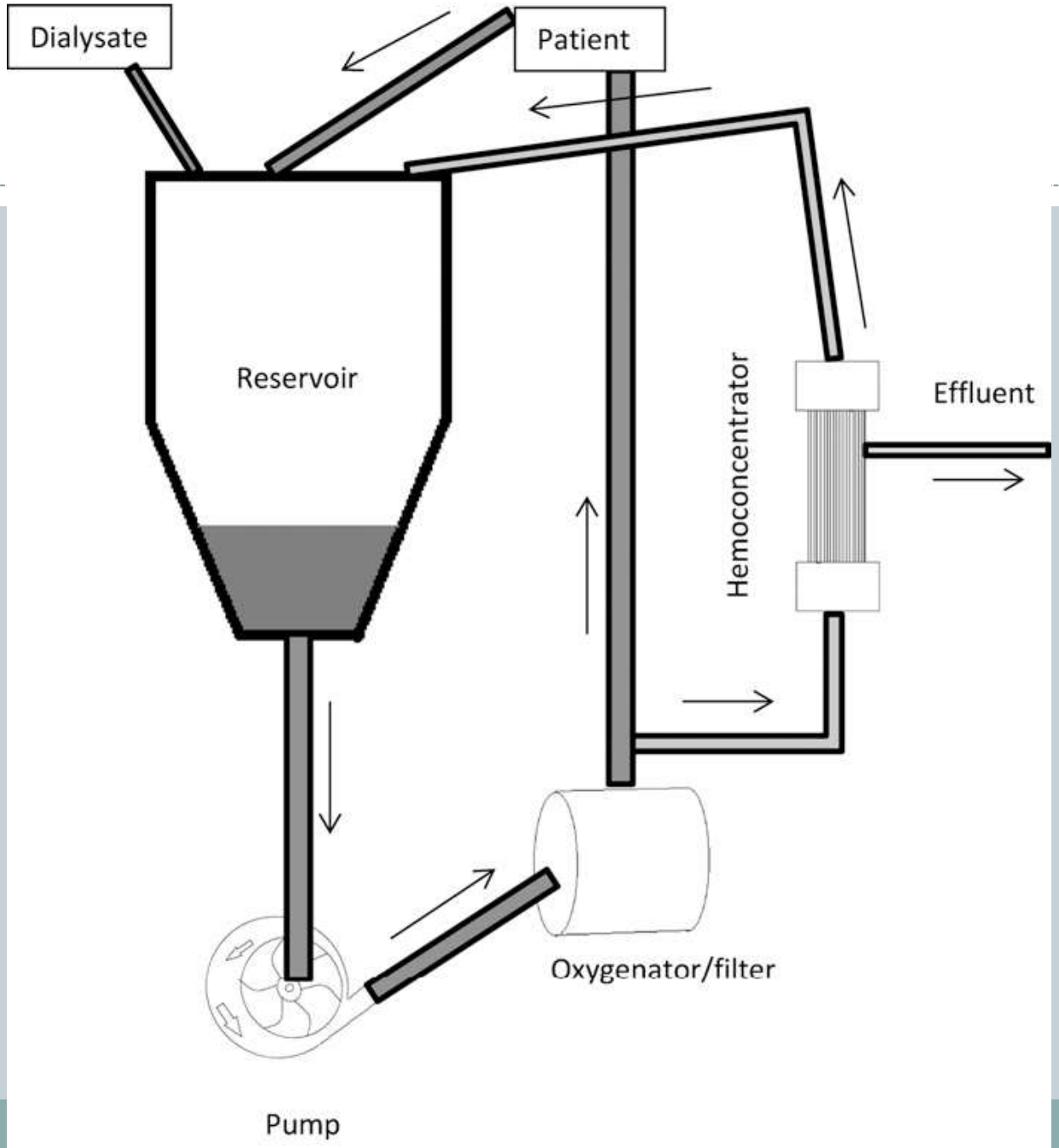


Figure 1 Schematic layout of CRR circuit

CELL SAVER

Cell saver

The cell saver (Autotransfusion) is a machine used to collect lost blood from the operative field and separate RBCs from whole blood, then washes them reinfuse them back to the patient as a red blood cells.

Indications for cell saver

- Patient has a ***rare blood groups*** or multiple antibodies.
- The anticipated ***blood loss*** during surgical procedure is large.
- Patient has risk factors for ***bleeding.***
- Low preoperative ***hemoglobin***
- Patients are ***unwilling*** to receive donor blood
- Used in ***aortic aneurysm*** patients.

Contraindications of Cell saver

- Blood contaminated with ***bacterial infections***
- Patient has ***sickle cell disease***, or abnormal red cell disorders.
- Patient has ***malignant cells***.
- ***Blood contaminated*** with gastrointestinal contents in the surgical field
- ***Caesarean section*** (amniotic fluid should not be aspirated)
- use of topical ***haemostatic agents***

Detrimental factors affecting processors use

- ***Antibiotics*** aspirated should be washed slowly and thoroughly
- ***Betadine solution*** should not be aspirated due to hemolysis
- ***Hot solutions*** should not be aspirated due to hemolysis

Equipment

- Cell Saver disposable set
- 1000 cc bag NaCl 0.9% (3 – 5 units).
- Transfer pack
- 30,000 units of heparin

Process

There are four main processing stages of the intraoperative cell sever (ICS):

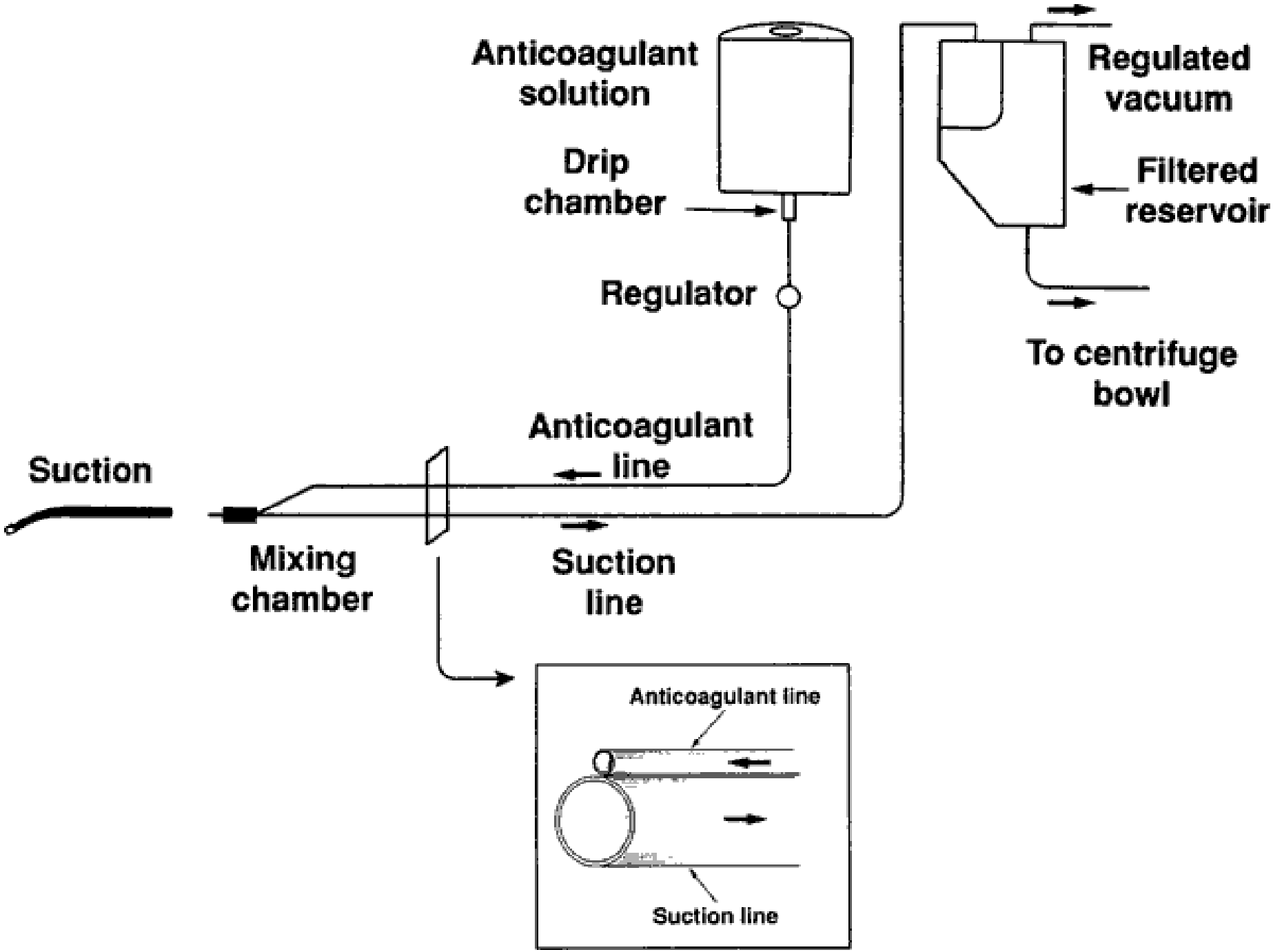
- Collection
- Separation
- Washing
- Reinfusion

Collection

- The blood is collected using a double-lumen suction tubing. It consists of two part, larger lumen connects with the reservoir to provide the suction of blood, and the smaller lumen connects with heparinized **normal saline (0.9% NaCl**) bag to carry **heparinized saline (30,000 IU\ L)** to the suction catheter tip and drip into a mixing chamber to prevent blood from clotting.

- The anticoagulated blood is aspirated by low suction into a collection reservoir.

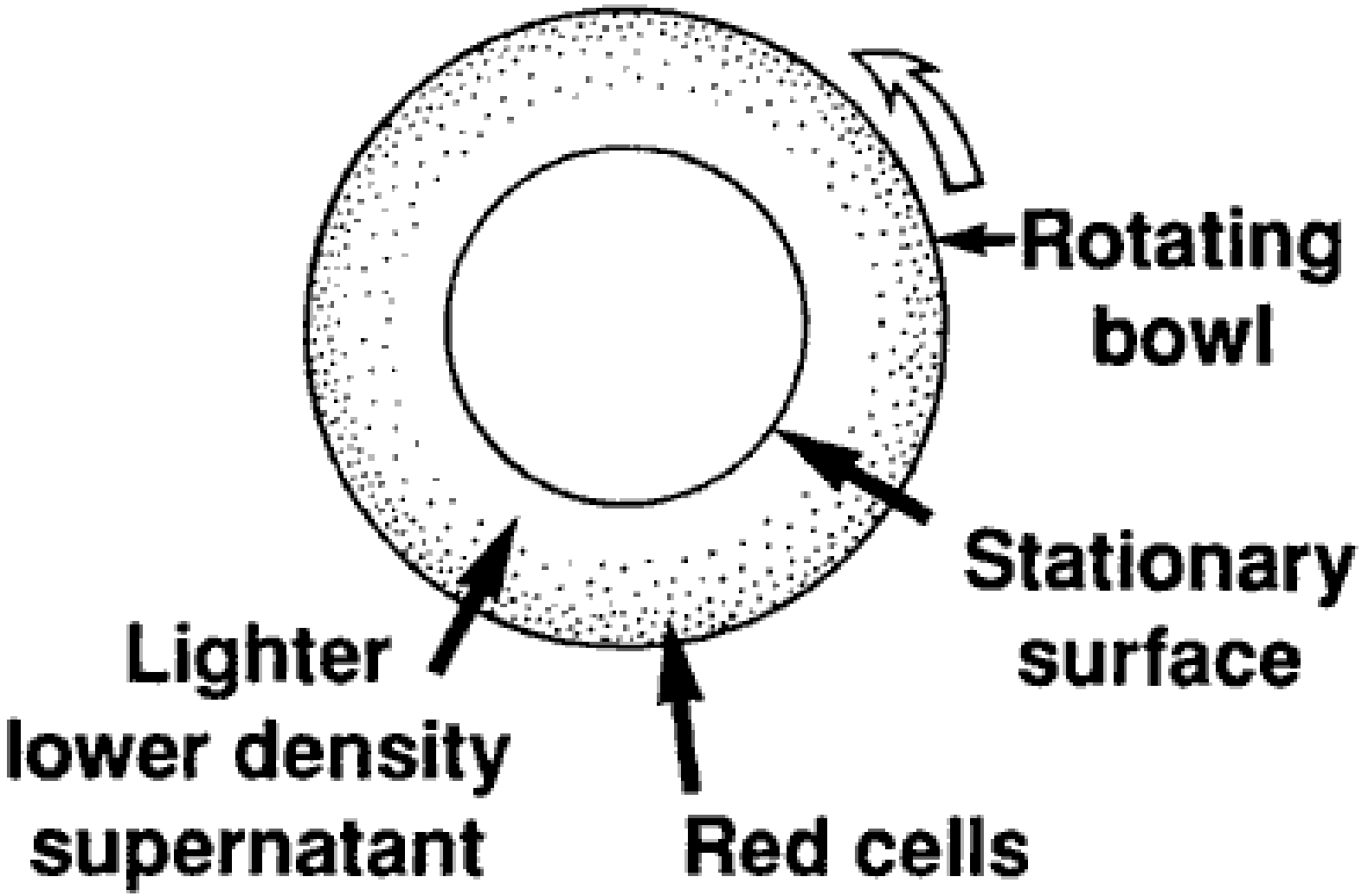
- In the reservoir the blood passes through defoamer, and filter that removes clots, body tissues, damaged platelets, and other cellular debris.


Anticoagulant solution
Drip chamber
Regulator
Regulated vacuum
Filtered reservoir
To centrifuge bowl
Anticoagulant line
Suction
Mixing chamber
Suction line
Anticoagulant line
Suction line

Separation

- The filtered ***anticoagulated blood is pumped*** into the spinning bowl (centrifuge bowl).
- In the ***centrifuge bowl (or latham bowl)*** *blood is separated into its constituent components, based on the differential densities of the components.*
- The most dense component of blood are ***red blood cells***, therefore will settle ***at the bottom*** and the perimeter of the bowl.
- The ***lower density components*** (plasma, remaining components and anticoagulant) float inward toward the bowl ***center***
- While the bowl is filling, the RBC component is retained within the bowl while the lighter components are displaced from the bowl through the outlet line to the waste bag.

Cross section of centrifuge bowl



Cell saver

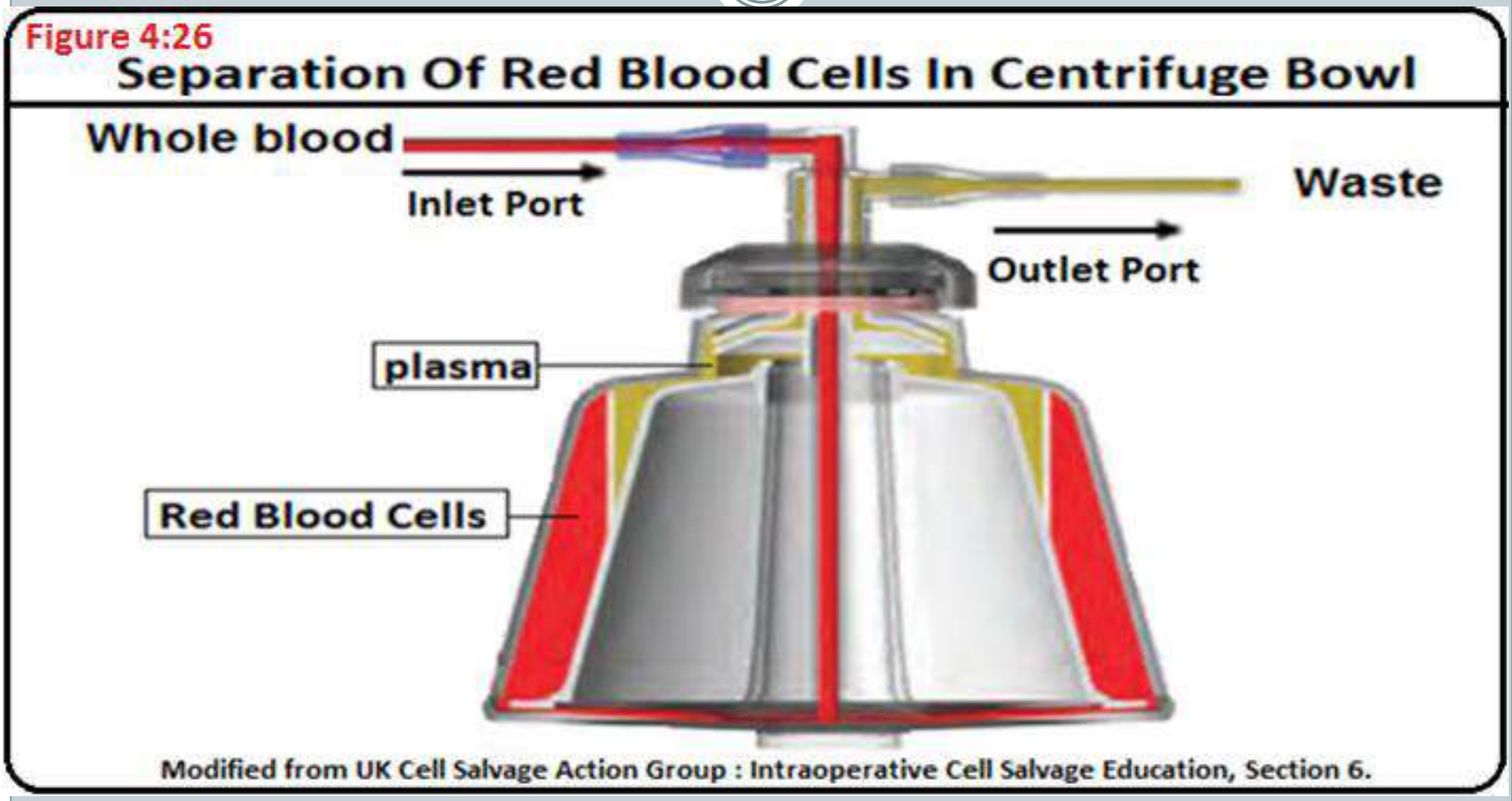


Figure 4:26
Separation Of Red Blood Cells In Centrifuge Bowl
Whole blood
Inlet Port
Waste
Outlet Port
plasma
Red Blood Cells
Modified from UK Cell Salvage Action Group : Intraoperative Cell Salvage Education, Section 6.

Washing

- After the bowl is filled with red blood cells, the **red blood cells are washed by infusing a normal saline** solution(0.9% NaCl) into the centrifuge bowl and circulated through the red cell layer, **to displace the remainder of contaminants** (debris, plasma and anticoagulants) that weren't removed during the separation phase.
- The remaining components and excess normal saline (0.9% NaCl) overflows through the outlet port and into the waste bag.
- After the wash cycle finishes, the centrifuge is stopped.
- The washed red blood cells are aspirated from the inlet port and pumped into a collection bag, this blood can have haematocrit as high as 60%

Reinfusion

- The washed Red Blood Cells contain only the RBCs with trace amounts of WBCs and platelets but Unfortunately, is devoid of all clotting factors.
- Washed **red blood cells** usually re-infused immediately after collection and cannot be **stored** for more than **4 hours at room temperature** and within **24 hours when stored at 6° C**.
- The blood can be returned to the patient in a transfer bag with note (Red Blood Cells), date and time.
- The washed blood will be re-infused directly into the patient

Preparation for cell saver

- Before auto transfusing discuss the procedure with the surgeon and anaesthetist
- Calculate the blood volume and volume to be removed pre cpb and replace the volume with fluids
- Use cardiotomy reservoir to collect the oozing blood and use a prime to transfuse back the collected blood
- Retropriming is done to conserve blood
- Retropriming is done by carefully watching the patient blood pressures, retropriming is done once cannulation is done.
- Stop retrograde priming if the patients BP are unstable and communicate with the surgeon and anaesthetist before and during RAP.

Plasmapheresis and Plateletpheresis

- This process used in removal of these portions from the blood.
- These products may then be given to the patient ***after bypass***
- The purpose is to ***conserve platelets and other clotting factors***

THANK YOU