ANESTHESIA

(8) Perioperative Fluids Therapy

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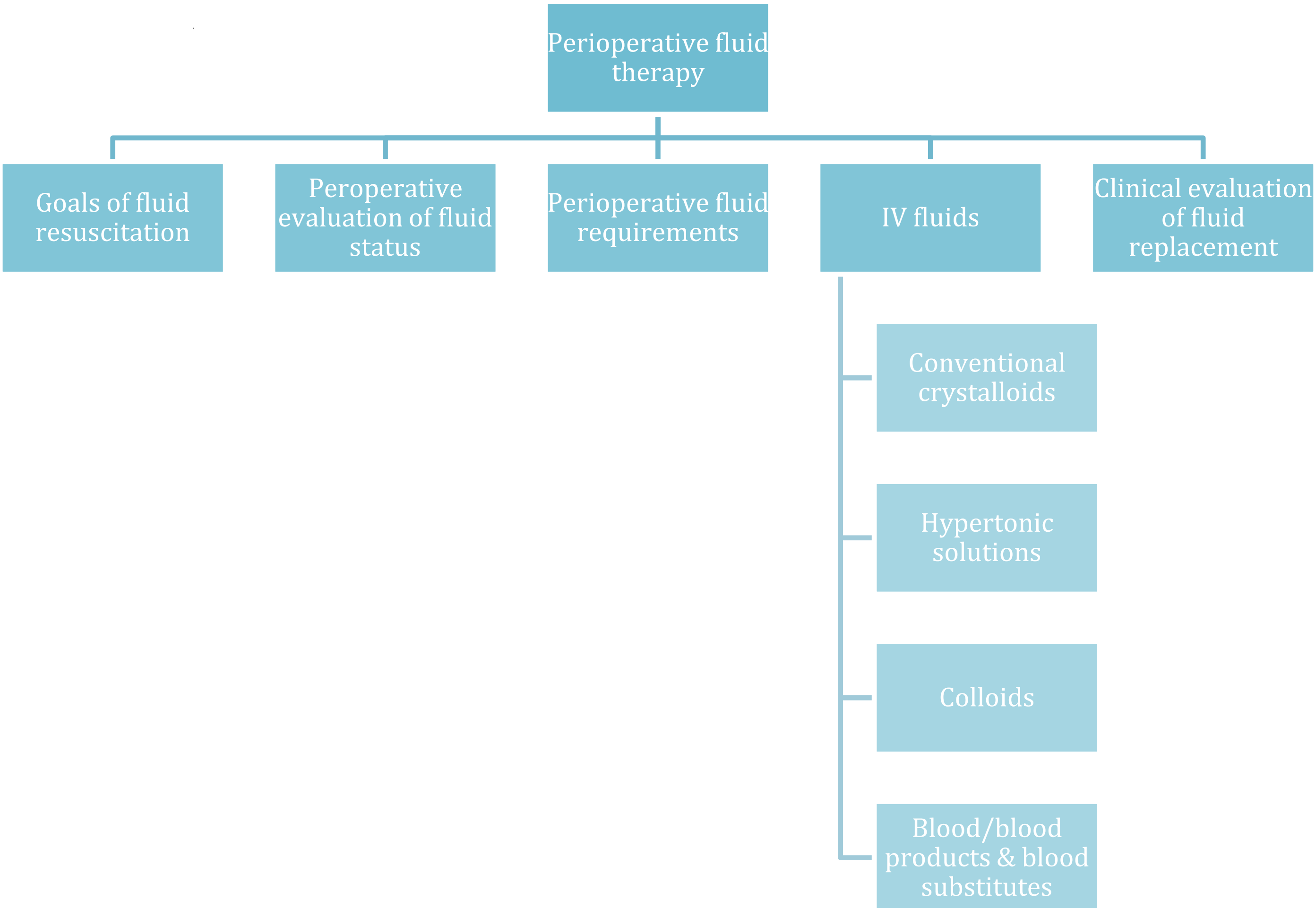
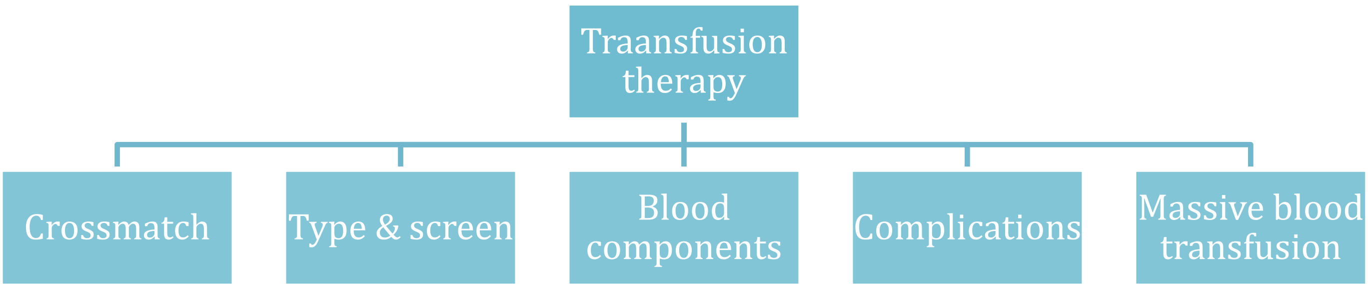
Doctor's note Team's note Not important Important 431 teamwork

Objectives:

Not Given

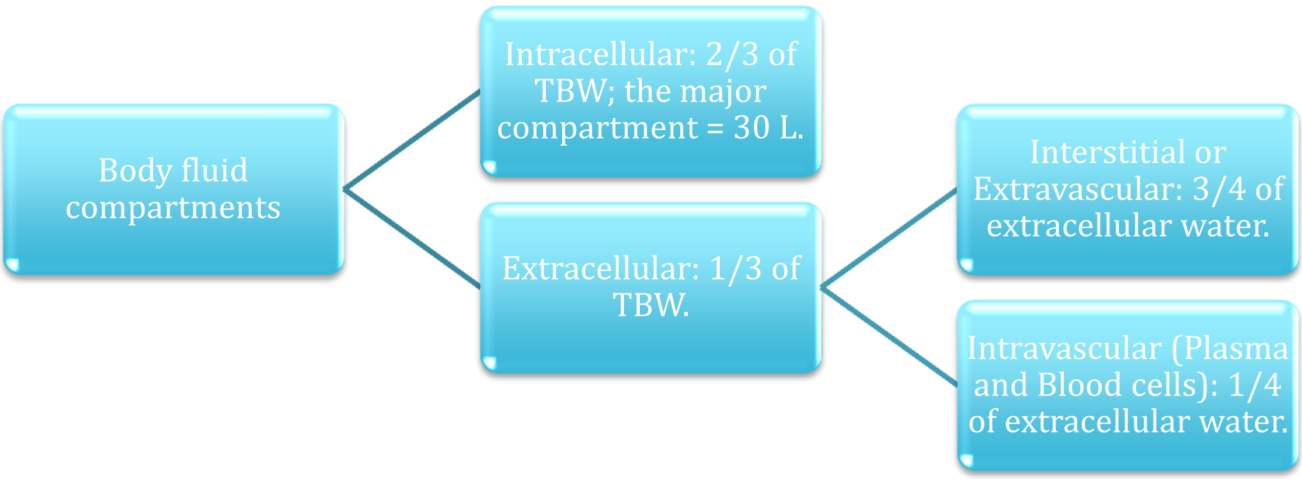




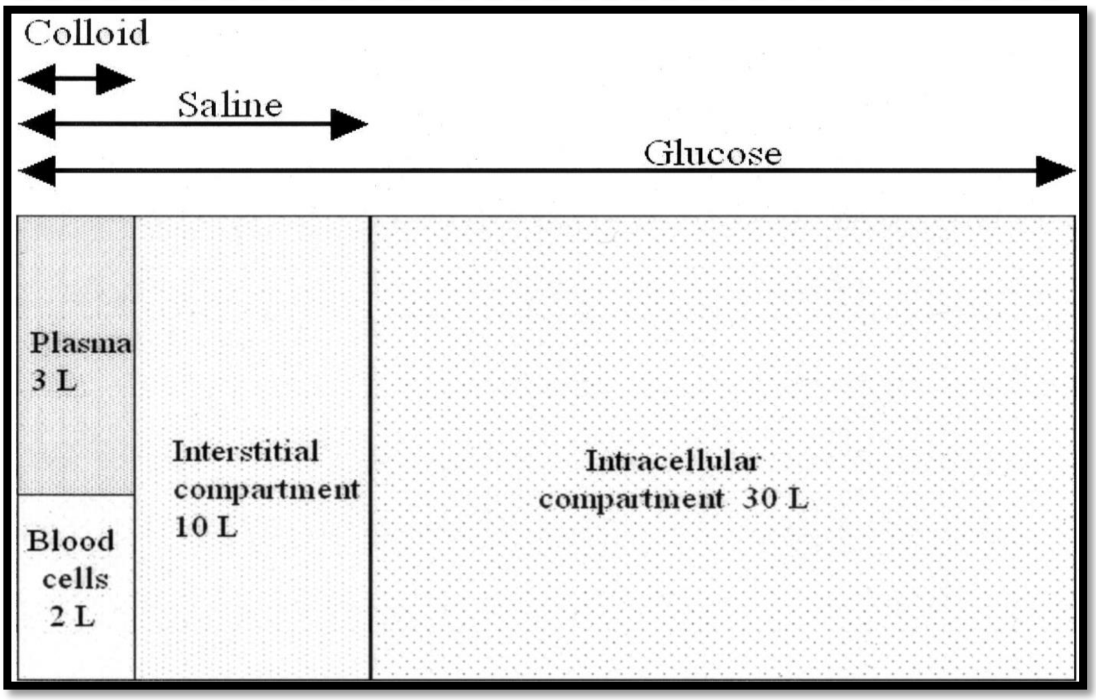
Total Body Water (TBW)

- Varies with age, gender.
- 55% body weight in males.
- 45% body weight in females.
- 80% body weight in infants.
- Less in obese: fat contains little water.

Body Fluid Compartments:



* **Intravascular compartment** holds the smallest amount of water but it is the most important compartment for physicians (fluid, drug… infusions).



Final Goals of Fluid Resuscitation:

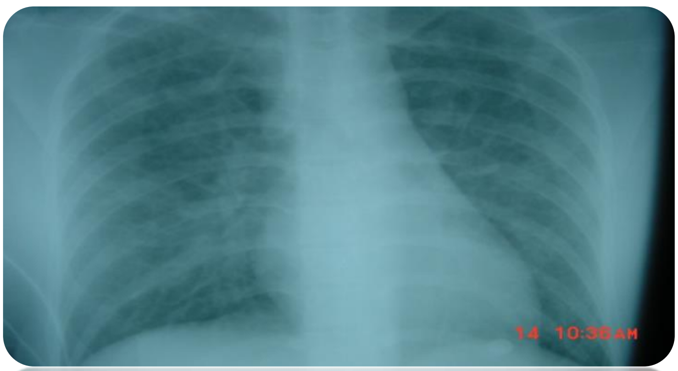
1- Achievement of normovolemia & hemodynamic stability = Good HR and BP.
2- Correction of major acid-base disturbances.
3- Compensation of internal fluid fluxes. Fluxes means the flow (in and out).
4- Improvement of microvascular blood flow (perfusion to the end organs). Perfusion is good -> CVS is good -> microvascular perfusion to the end organs will be good (end part of the body: finger tips, arterioles, microcirculation etc.).
5- Prevention of cascade system activation (prevent DIC since dehydration can lead to it).
6- Normalization of O_2 delivery.
7- Prevention of reperfusion cellular injury. It is the tissue damage caused when blood supply returns to the tissue after a period of ischemia or lack of oxygen. Blood vessel obstruction or embolus > tissue hypoxia > when a surgeon removes the cause and blood flows > the tissue will not take it easy! > need fluid to avoid reperfusion injury.
8- Achievement of adequate urine output. Normal urine output: 0.5 – 1 ml\Kg\hour, so a 60 Kg lady must pass 30-60 per hour.

Desirable Outcome of Fluid Resuscitation:

*** (Not overhydration signs)**

- No peripheral edema.

- No ARDS (Acute respiratory distress syndrome):
With overhydration, the fluids will leak out to the tissue especially to the lungs causing ARDS. The patient will complain of breathlessness, desaturation etc.



Fluid and Electrolyte Regulation:

Volume Regulation (hormonal system):

1- Antidiuretic Hormone. Retain fluid up to certain limit (produce less urine).
2- Renin/angiotensin/aldosterone system (vascular constriction and dilatation).
3- Baroreceptors in carotid arteries and aorta. They sense the amount of circulating volume (sensory neuron that is excited by stretch of the blood vessel).
4- Stretch receptors in atrium and juxtaglomerular apparatus.
5- Cortisol.

Preoperative Evaluation of Fluid Status:

Factors to Assess:

- History of intake and output (do you eat, drink, NPO, do you pass urine…).
- Blood pressure: taken in supine and standing positions (significant difference in dehydration).
- Heart rate: tachycardia if dehydrated.
- Skin.
- Urinary output: low if dehydrated.
- Mental status: confused and irritated if dehydrated.

Orthostatic Hypotension (taken in supine and standing):

- Systolic blood pressure decreases of greater than **20mmHg** from supine to standing.
- Indicates significant fluid loss:

a) Heart rate should **increase** as a compensatory measure.
b) If no increase in heart rate, may indicate autonomic dysfunction or antihypertensive drug therapy.

- DM can eventually lead to autonomic dysfunction and compensation is lost.

The rate of fluid replacement depends on:
Arterial and central venous pressure
Heart rate
Urine output
Peripheral temperature

Fluid replacement should be:
Balanced.
Controlled.
Calculated.
Correspond to the need of the patient.

Perioperative Fluid Requirements:

The following factors must be taken into account:
1- **M**aintenance fluid requirements.
2- **NPO** and other deficits: NG suction, bowel preparation.
3- **T**hird space and invisible losses.
4- **R**eplacement of blood loss.
5- Special additional losses: diarrhea.

1- Maintenance fluid requirements:

- ***Insensible losses*** such as evaporation of water from respiratory tract, sweat, feces, urinary excretion. Occurs continually.
- Adults: approximately **1.5 ml/kg/hour.** 1.5 x Kg x hrs. (Surgery duration)
- **"4-2-1 Rule" applies to children:**

• 4 ml/kg/hr for the first 10 kg of body weight.
• 2 ml/kg/hr for the second 10 kg body weight.
• 1 ml/kg/hr subsequent kg body weight.
• Extra fluid for fever, tracheotomy, open wounds.

Example: 40 kg: 1st 10 x 4 ml\hr, 2nd 10 x 2ml, 3rd 20 x 1 ml.

2- NPO and other deficits:

- NPO deficit = number of hours NPO x maintenance fluid requirement.
- Bowel prep may result in up to 1 L (1000 ml) fluid loss (in bowel surgery).
- Measurable fluid losses, e.g. NG suctioning, vomiting, ileostomy output, biliary fistula etc.

3- Third space and invisible losses:

A) Third space:

- Isotonic transfer of ECF from functional body fluid compartments to non-functional compartments. The first space is intracellular, the second space is intravascular, and both are contributing in metabolism and regulation. Third space is an abnormal space (pathological) as in ascites, pleural effusion, joint effusion, hematoma etc.
- Depends on location and duration of surgical procedure, amount of tissue trauma, ambient temperature, and room ventilation.

B) Replacing invisible losses (differs from insensible losses; depends on the degree of **tissue exposure** and occurs during surgery on pads, gloves):

- Superficial surgical trauma: 1-2 ml/kg/hr, Example: hand surgery.
- Minimal Surgical Trauma: 3-4 ml/kg/hr
  Example: head and neck, hernia, knee surgery.
- Moderate Surgical Trauma: 5-6 ml/kg/hr
  Example: hysterectomy, chest surgery.
- Severe surgical trauma: 8-10 ml/kg/hr (or more)
  Example: abdominal aortic aneurysm (AAA) repair, nephrectomy.

4- Replacement of blood loss:

- Replace 3 cc of crystalloid solution per cc of blood loss (crystalloid solutions leave the intravascular space). E.g. 800 ml blood loss -> 800 x 3 = 2400 ml = 2.4 L Ringer's. (Ringer's 1:3), (Blood 1:1).
- When using blood products or colloids replace blood loss volume per volume.

5- Special additional losses:

- Ongoing fluid losses from other sites:
  - Gastric drainage.
  - Ileostomy output.
  - Diarrhea.
- Replace volume per volume with crystalloid solutions.

Example:

- 62 Y/O, male, 80 kg, for hemicolectomy
- NPO after 10 PM, surgery at 8 AM,
- Received bowel preparation
- 3 hours long procedure with blood loss of 500 ml
- What is his estimated intraoperative fluid requirement?

Fluid requirement of this patient:

* NPO = NPO hrs. x 1.5 x Kg x hrs.
* Maintenance = 1.5 x Kg x surgery duration.

- **Fluid deficit (NPO):** 1.5 ml/kg/hr x 10 hrs = 1200 ml + 1000 ml for bowel preparation = 2200 ml is total deficit: (Replace 1/2 first hour, 1/4 2nd hour, 1/4 3rd hour). NPO: 1.5 x 80 x 10 = 1200 ml. Total deficit: 1200 +1000 (bowel prep) = 2200 ml.
- **Maintenance:** 1.5 ml/kg/hr x 3hrs = 360 ml. (1.5 x 80 x 3)
- **Invisible Losses:** 6 ml/kg/hr x 3 hrs =1440 ml.
- **Blood Loss:** 500 ml x 3 = 1500 ml.
- Total = 2200 + 360 + 1440 + 1500 = 5500 ml.

* 3 hrs.: the duration of surgery.
* Since hemicolectomy is a moderate surgical trauma so the invisible losses: 6 ml/kg/hour.

Intravenous Fluids:

A) Crystalloids:

- Combination of water and electrolytes (they have small molecular weight).

- Balanced salt solution: electrolyte composition and osmolality similar to plasma; example: lactated Ringer and normal saline (0.9 tonicity).
- Hypotonic salt solution: electrolyte composition lower than that of plasma; example: D5W (5% dextrose in water).
- Hypertonic salt solution: 2.7% NaCl.

Crystalloids in trauma:

Advantages	Disadvantages
1- Balanced electrolyte solution. 2- Easy to administer. 3- No risk of adverse reactions (no anaphylactic shock). 4- No disturbance of hemostasis. 5- Promote diuresis. 6- Inexpensive.	1- Poor plasma volume support (because it leaks out from vessels). 2- Large quantities needed. 3- Reduced plasma oncotic pressure. 4- Risk of edema. 5- Risk of hypothermia if you give large volume.

B) Hypertonic Solutions:

- Fluids containing sodium concentrations greater than normal saline.
- Available in 1.8%, 2.7%, 3%, 5%, 7.5%, 10% solutions.
- Hyperosmolarity creates a gradient that draws water out of cells; therefore, cellular dehydration is a potential problem.

Hypertonic Saline:

Advantages	Disadvantages
1- Small volume for resuscitation. 2- Osmotic effect. 3- Inotropic effect (increase calcium influx in sarcolemma) ↑ heart contractility & BP. 4- Direct vasodilator effect. 5- Increase renal, mesenteric, splanchnic, coronary blood flow and arterial blood pressure.	1- Increase hemorrhage from open vessels. 2- Hypernatremia. 3- Hyperchloremia. 4- Metabolic acidosis.

Crystalloids: Lactated Ringer's (LR)

- Composition: Na 130, Cl 109, K 4, Ca 3, Lactate 28, Osmolality 273 mosm/L.
- Ringer's Lactate is known as: physiological saline because its osmolality is similar to that of plasma.
- Sydney Ringer a British clinician who formed the basis of Ringer's solution in 1880s.
- Hartmann added Lactate=LR
- Minor advantage over NaCl (saline).

Disadvantages:

- Not to be used for dilution of blood (Ca citrate). In theory, the calcium in Ringer's lactate may bind with the citrate in the blood preservative, potentially raising the risk for clotting.

Crystalloids: Dextrose 5% (hypotonic)

- Composition: 50 gm /liter, provides 170 kcal /liter.

Disadvantages:

- Enhance CO_2 production (it is metabolized to carbon dioxide and water).
- Enhance lactate production (in patients with circulatory compromise, abnormal glucose metabolism can transform glucose from a source of useful energy to a source of toxin production; lactate).

Composition:

Fluid	Osmolality	Na	Cl	K
D5W	253 hypo	0	0	0
0.9 NS	308	154	154	0
LR	273*iso	130	109	***4.0***
Plasma-lyte (280-303mlosm/kg)	294*iso	140	98	***5.0***
Hespan	310	154	154	0
5% Albumin	308	145	145	0
3% Saline	1027 hyper	513	513	0

C) Colloids:

- Fluids containing molecules sufficiently large enough to prevent transfer across capillary membranes.
- Solutions stay in the space into which they are infused (intravascular compartment).
- Examples: hetastarch (Hespan), albumin, dextran.
- Colloids help in ↑ BP.

C) Colloids (Cont.):

Advantages	Disadvantages
1- Prolonged plasma volume support. 2- Moderate volume needed. 3- Minimal risk of tissue edema. 4- Enhances microvascular flow.	1- Risk of volume overload (edema). 2- Adverse effect on hemostasis. 3- Anaphylactic reaction. 4- Expensive.

Crystalloids vs. Colloids:

Character	Crystalloids	Colloids
In the vein	Poor	Good
Hemodynamics	Transient	Prolong
Infusion volume	Large	Moderate
Plasma colloid oncotic pressure (COP)	Reduced	Maintain
Tissue edema	Obvious	Insignificant
Anaphylaxis	Non-exist	Low-moderate
Cost	Inexpensive	Expensive

Clinical Evaluation of Fluid Replacement:

1. Urine Output: at least 1.0 ml/kg/hour.
2. Vital Signs: Blood pressure and heart rate.
3. Physical Assessment: texture of skin and mucous membranes; thirst in an awake patient.
4. Invasive monitoring: CVP may be used as a guide.
5. Laboratory tests: periodic monitoring of hemoglobin and hematocrit.

Summary:

- Fluid therapy is critically important during the perioperative period.
- The most important goal is to maintain hemodynamic stability and protect vital organs from hypoperfusion (brain, heart, kidneys, liver).
- All sources of fluid losses must be accounted for.
- Good fluid management goes a long way toward preventing problems.

Transfusion Therapy:

- **60% of transfusions occur perioperatively.**
- Responsibility of transfusing perioperatively is with the anesthesiologist.

Blood Groups:

Blood Group	Antigen on Erythrocyte	Plasma Antibodies	Incidence	
			White	African-Americans
A	A	Anti-B	40%	27%
B	B	Anti-A	11	20
AB	AB	None	4	4
O	None	Anti-A Anti-B	45	49
Rh	Rh		42	17

Crossmatch:

- Major:
- Donor's erythrocytes incubated with recipient's plasma.

- It tests directly for the presence of antibodies against a sample of donor tissues or blood and is checked for agglutination.

- Agglutination:
- It is a sign of incompatibility.

- Type Specific:
- Only ABO-Rh determined.

Four main ways of estimating blood loss:
Clinical observation
Weighing of swabs (1 ml of blood = 1gm)
Volume of suction
Dilution techniques (concentration of Hb in the suction fluid, rarely used)

Type and Screen:

- Donated blood that has been tested for ABO/Rh antigens and screened for common antibodies (**not mixed** with recipient blood).
- Used when usage of blood is unlikely, but needs to be available (hysterectomy).
- Chance of hemolytic reaction: 1:10,000.

Cardiovascular variables we relay on to transfuse blood:
Heart rate
Arterial and central venous blood pressure
Measurements of haematocrit or haemoglobin.

Blood Components:

- Prepared from whole blood collection.
- Whole blood is separated by differential centrifugation:
  - Red Blood Cells (RBC's).
  - Platelets.
  - Plasma
    * Cryoprecipitate.
    * Others include Plasma proteins— Coagulation Factors, albumin, Growth Factors.
    * Fresh frozen plasma.

Transfusion Complications: mostly because of human error.

A) Acute Transfusion Reactions (ATR's)	B) Chronic Transfusion Reactions	C) Transfusion related infections
1- Acute Hemolytic Transfusion Reactions (AHTR) (next page). 2- Febrile Reactions. 3- Allergic Reactions. 4- TRALI: transfusion related acute lung injury (congested lung looks like pulmonary edema, ARDS, hypoxia). 5- Coagulopathy with Massive transfusions. 6- Bacteremia.	---	- Transmission of Viral Diseases: 1- Hepatitis C; 1:30,000 per unit. 2- Hepatitis B; 1:200,000 per unit. 3- HIV; 1:450,000-1:600,000 per unit. - Parasitic and bacterial transmission is very low.

- ATR's can be minor (chills, rigors, fever): common and also known as febrile reaction. Or major: Acute hemolytic reaction, which mostly occurs because of human mistake as wrong labels or blood type.
- **Blood shouldn't be out of refrigerator more than 30 min**.
- Double check labels: Name, File No., blood group.

Complications (Cont.): Acute transfusion Reactions

Hemolytic (AHTR):

- Wrong blood type administered (oops) → due to ABO-Rh incompatibility.
- Activation of complement system leads to intravascular hemolysis, spontaneous hemorrhage.

Signs:

- Hypotension
- Fever and chills
- Dyspnea and skin flushing
- Substernal pain, Back/abdominal pain
- Oliguria, dark urine, and pallor

- Signs are easily masked by general anesthesia.
  - Free hemoglobin in plasma or urine (hemoglobinuria).
  - Acute renal failure due to acute tubular necrosis.
  - Disseminated Intravascular Coagulation (DIC).

What to do if an AHTR occurs?

(Management is supportive based on symptoms)

- STOP TRANSFUSION.
- Maintain IV access and run IV fluids (NS or LR).
- Monitor and maintain BP/pulse.
- Give diuretic; maintain urine output and fluid therapy.
- Obtain blood and urine for transfusion reaction workup.
- Send remaining blood back to Blood Bank.

Monitoring in AHTR:

- Monitor patient clinical status and vital signs.
- Monitor renal status (BUN, creatinine).
- Monitor coagulation status (DIC panel– PT/PTT, fibrinogen, D-dimer/FDP, Platelets, Antithrombin-III).
- Monitor for signs of hemolysis (hypotension, dark urine, fever…).

Massive Blood Transfusion:

Massive transfusion is generally defined as the need to transfuse one to two times the patient's blood volume. For most adult patients, that is the equivalent of 10–20 units (5 L/24 hrs.). A unit is 500 ml of blood.
- Massive transfusion is when you replace the whole body blood volume in 24 hrs.
- It occurs mainly in OBGYN, trauma, vascular and cardiac cases.

Problems of massive transfusion:

- Dilutional thrombocytopenia and coagulopathy.
- Citrate toxicity → metabolic acidosis (initially). Citrate is a substance used in blood reservation.
- Hypothermia.
- Metabolic alkalosis (occurs later).
- Hyperkalemia (stored blood).
- DIC.

How to avoid problems of massive transfusion?

- Use autologous blood transfusion.
- Cell saver technology.
- Substitute to blood: artificial blood (perfluorocarbons).

Blood Substitutes:

- Potential Advantages:
  - No cross-match requirements.
  - Long-term shelf storage.
  - No blood-borne transmission.
  - Rapid restoration of oxygen delivery in traumatized patients.
  - Easy access to product (available on ambulances, field hospitals, hospital ships).

- Plasma proteins are responsible of any anaphylactic or allergic reactions that happen after blood transfusion.
- Rapid infusion of large volumes of stored blood may result in acidosis, and it is treated with calcium chloride.

Summary

- Fluids are given to maintain blood volume, electrolyte balance, and urine output.
- Signs of hypovolemia: abnormal skin turgor, tachycardia, hypotension, orthostatic heart rate and BP changes from supine to standing positions, and decreased urinary output.
- **Perioperative fluid requirements:**

1- Maintenance:

- Adults: 1.5 x Kg x hrs.
- Children: "4-2-1 Rule".

2- NPO & other deficits (bowel prep = 1000 ml):

NPO deficit = number of hours NPO x maintenance fluid requirement.

3- Third space & invisible losses:

- Minimal Surgical Trauma: 3-4 ml/kg/hr
- Moderate Surgical Trauma: 5-6 ml/kg/hr
- Severe surgical trauma: 8-10 ml/kg/hr

4- Replacement of blood loss:

- Replace 3 cc of crystalloid solution per cc of blood loss.
- When using blood products or colloids replace blood loss volume per volume.

5- Additional losses:

- Replace volume per volume with crystalloid solutions.

- Crystalloids are usually considered as the initial resuscitation fluid. Colloids may be included in resuscitation following initial administration of crystalloid solutions.
- The most commonly used fluid is lactated Ringer's solution.
- Assessment of fluid replacement: check HR, BP, urine output, skin and mucous membranes, CVP, and periodic monitoring of Hb and hematocrit.
- Blood screen: donated blood that has been tested for ABO/Rh antigens and screened for common antibodies (**not mixed** with recipient blood). If mixed → crossmatch and check for agglutination.
- Blood transfusion can result in transmission of viral infections.
- The 1st step of management in acute hemolytic transfusion reactions (AHTR) is stop transfusion.
- The management of AHTR is supportive.
- The most common cause of nonsurgical bleeding following massive blood transfusion is dilutional thrombocytopenia.

MCQ's:

Q1: A 65-year-old man who resides in a skilled nursing facility becomes febrile, tachycardic, dyspneic, and hypotensive 90 minutes after bladder catheterization. His past medical history is notable for Alzheimer's disease, renal insufficiency, and anemia. His heart rate is 115 bpm, and his blood pressure is 85/55 mm Hg.

- What is the first step in the management of this patient?

A) Administer 6% hetastarch in a 500 mL 0.9% sodium chloride injection.

B) Administer 20 mL of albumin (human) 25% through a large-bore IV line.

C) Rapidly administer 500 mL of normal saline through a large-bore intravenous (IV) line.

D) Transfuse 1 U of packed red blood cells.

Q2: Which of the following factors is most important for determining when patients should be transfused?

A) When the hemoglobin level decreases to less than 7 g/dL.

B) When the surgeon decides transfusion is necessary.

C) When oxygen delivery must be increased.

D) When lost blood volume must be replaced.

Q3: Which organ is at greatest risk due to the effects of hemolytic anemia?

A) Heart.

B) Spleen.

C) Kidney.

D) Liver.

Answers:

Q1:

C) Rapidly administer 500 mL of normal saline through a large-bore IV line. This patient is most likely in septic shock following bladder catheterization. In the early phases of fluid resuscitation in a septic patient, rapid volume expansion is the key to achieving a good outcome. Adequate and early volume expansion is generally more important than immediate insertion of a central venous catheter or a pulmonary artery catheter if adequate peripheral access is available. The choice of fluid administered is not as critical as early volume expansion. The target mean arterial blood pressure is 65 mm Hg or greater. Pressor therapy may be necessary later; however, adequate volume replacement would be necessary initially to "prime the pump" for more effective pressor function.

Q2:

C) When oxygen delivery must be increased. In the best of all possible worlds, blood should be used only to improve oxygen delivery in the case of a documented decrease. Blood should not be used to restore volume—crystalloids and colloids can perform this function adequately in most patients. Hemoglobin is only one determinant of when a patient should be transfused. Some patients can withstand hemoglobin values less than 7 g/dL without any adverse effects, whereas other patients may require higher levels of hemoglobin. The transfusion decision is never a simple choice—the surgeon must examine the patient's clinical condition and make a reasoned decision about using blood, weighing the potential benefit against the known risks.

Q3:

C) Kidney. For all causes of hemolysis, a major focus of treatment is to maintain renal function. When RBCs are hemolysis, the hemoglobin molecule is released and filtered by the kidneys. The accumulation of hemoglobin molecules can obstruct the renal tubules and lead to acute tubular necrosis.

For mistakes or feedback

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