Vascular access and management of fluids, blood, and blood derivatives

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Objectives

- Discuss about vascular access
- Derangements and monitoring of intravascular volume status
- Strategies for choosing appropriate composition, amount, and timing of intraoperative fluid administration

Intravenous (IV) cannulation

Intravenous (IV) cannulation

- A technique in which a cannula is placed inside a vein to provide venous access
  - Should be avoided by limiting the period of fasting and encouraging patients to consume clear oral liquids up to two hours before surgery
- Venous access allows sampling of blood, as well as administration of fluids, medications, parenteral nutrition, chemotherapy, and blood products

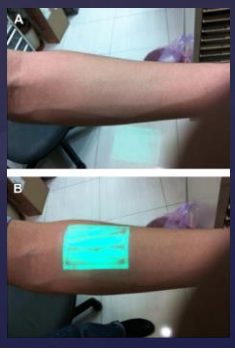
Intravenous (IV) cannulation

- It is advisable to select the smallest gauge of catheter that can still be effectively used to deliver the prescribed therapy
  - This will minimize the risk of damage to the vessel intima and ensure adequate blood flow around the catheter, which reduces the risk of phlebitis
- Largest-gauge and shortest catheter
  - If the situation is an emergency
  - If the patient is expected to require large volumes infused over a short period of time, the largest-gauge and shortest catheter that is likely to fit the chosen vein should be used

Common sites for IV cannulation

- Veins with high internal pressure become engorged and are easier to access
  - The use of venous tourniquets, dependent positioning, "pumping" via muscle contraction, and the local application of heat or nitroglycerin ointment can contribute to venous engorgement
- The superficial veins of the upper extremities are preferred to those of the lower extremities for peripheral venous access
  - Cannulation of upper-extremity veins interferes less with patient mobility and poses a lower risk for phlebitis
  - It is easier to insert a venous catheter where two tributaries merge into a Y-shaped form
  - It is recommended to choose a straight portion of a vein to minimize the chance of hitting valves

Intravenous (IV) cannulation



Indications for IV cannulation

- Repeated blood sampling
- Administration of fluid
- Administration of medications
- Administration of chemotherapeutic agents
- Nutritional support
- Administration of blood or blood products
- Aadministration of radiologic contrast agents for computed tomography (CT), magnetic resonance imaging (MRI), or nuclear imaging

Contraindications for IV cannulation

- No absolute contraindications for IV cannulation exist
- Peripheral venous access in an injured, infected, or burned extremity should be avoided if possible
- Some vesicant and irritant solutions (pH <5, pH >9, or osmolarity >600 mOsm/L) can cause blistering and tissue necrosis if they leak into the tissue
  - E.g. sclerosing solutions, some chemotherapeutic agents, and vasopressors
  - More safely infused into a central vein
  - Through a peripheral vein in emergency situations or when a central venous access is not readily available

Equipment for intravenous cannulation

- Nonsterile gloves
- Tourniquet
- Antiseptic solution
- Local anesthetic solution
- 1-mL syringe with a 30-gauge needle
- 2 × 2 in. gauze
- Venous access device
- Vacuum collection tubes and adaptor
- Saline or heparin lock
- Saline or heparin solution
- Transparent dressing
- Paper tape

Equipment for intravenous cannulation

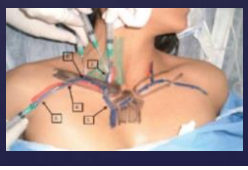
Complications of IV cannulation

- Pain
- Failure to access the vein
- Blood stops flowing into the flashback chamber
- Difficulty advancing the catheter over the needle and into the vein
- Difficulty flushing after the catheter was placed in a vein
- Arterial puncture
- Thrombophlebitis
- Peripheral nerve palsy
- Compartment syndrome
- Skin and soft tissue necrosis

Central venous access

Central venous access

- Time-honored and tested technique of quickly accessing the major venous system
- Femoral, internal jugular, or subclavian site access
- Requires substantial training and supervision to become facile with this techniques



Indications for central venous access

- Volume resuscitation
- Emergency venous access
- Nutritional support
- Administration of caustic medications (e.g. vasopressors)
- CVP monitoring
- Transvenous pacing wire introduction
- Hemodialysis
- Pulmonary artery catheterization

Contraindications for central venous access

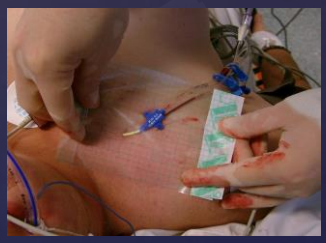
Absolute

- Distorted local anatomy
  - E.g. from vascular injury, prior surgery, deformities, or previous irradiations
- Infection at insertion site
- Coagulopathy (?)
  - Subclavian ± Int. Jugular

Relative

- Presence of anticoagulation or bleeding disorder
- Patient who is excessively underweight or overweight
- Uncooperative patient
- Current or possible thrombolysis

Central venous access – Procedure



Complications of central venous access

Complication	Internal jugular approach (%)	Subclavian approach (%)	Femoral approach (%)
Arterial puncture	6.3-9.1	3.1-4.9	9.0-15.0
Hematoma	< 0.1-2.2	1.2-2.1	3.8-4.4
Hemothorax	N/A	0.1-0.6	N/A
Pneumothorax	< 0.1-0.2	1.5-3.1	N/A
Thrombosis	7.6	1.9	21.5
Total	6.3-11.8	6.2-10.7	12.8-19.4

Arterial line placement

Arterial line placement

- Overall, arterial line placement is considered a safe procedure, with a rate of major complications that is below 1%
- It is not entirely without risks, however, and it requires appropriate knowledge of the anatomy and procedural skills
- Arterial lines can be placed in multiple arteries, including the radial, ulnar, brachial, axillary, posterior tibial, femoral, and dorsalis pedis arteries

Indications for arterial line placement

- Continuous direct BP monitoring
  - Arterial catheter mean arterial pressure measurements are even more accurate than sphygmomanometric blood pressure readings in patients who are morbidly obese, are very thin, have severe extremity burns, or have very low blood pressures
- Inability to use indirect BP monitoring
  - E.g. in patients with severe burns or morbid obesity
- Frequent blood sampling
- Frequent arterial blood gas sampling

Contraindications for arterial line placement

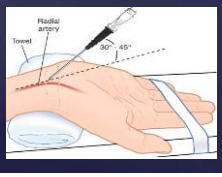
Absolute

- Absent pulse
- Thromboangiitis obliterans (Buerger disease)
- Full-thickness burns over the cannulation site
- Inadequate circulation to the extremity
- Raynaud syndrome

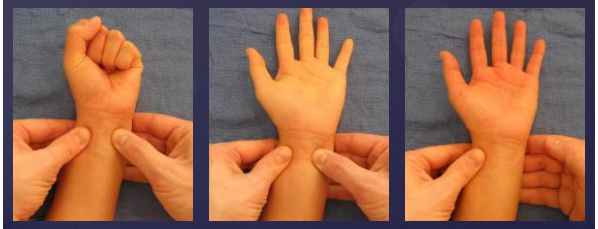
Relative

- Anticoagulation
- Atherosclerosis
- Coagulopathy
- Inadequate collateral flow
- Infection at the cannulation site
- Partial-thickness burn at the cannulation site
- Previous surgery in the area
- Synthetic vascular graft

Arterial line placement – Procedure



Arterial line placement – Allen test



Complications of arterial line placement

Common

- Temporary radial artery occlusion (19.7%)
- Hematoma/bleeding (14.4%)

Less common and rare

- Localized catheter site infection (0.72%)
  - The risk increases with the length of time the catheter is in place Hemorrhage (0.53%)
- Sepsis (0.13%)
- Permanent ischemic damage (0.09%)
- Pseudoaneurysm formation (0.09%)
- Thrombosis
- Arteriovenous fistula
- Air embolism
- Compartment syndrome
- Carpal tunnel syndrome
- Paralysis of median nerve
- Nerve injury
- Femoral artery dissection
- Suppurative thromboarteritis

Management of fluids, blood, and blood derivatives

Causes of intravascular volume derangements

- Preoperative dehydration
  - Should be avoided by limiting the period of fasting and encouraging patients to consume clear oral liquids up to two hours before surgery
- Mechanical bowel preparation
  - May be associated with fluid loss from the gastrointestinal tract, which may reduce preoperative intravascular volume

Causes of intravascular volume derangement – Preoperative factors

- Preoperative dehydration
  - Should be avoided by limiting the period of fasting and encouraging patients to consume clear oral liquids up to two hours before surgery
- Mechanical bowel preparation
  - May be associated with fluid loss from the gastrointestinal tract, which may reduce preoperative intravascular volume
- Several disorders
  - Such as bowel obstruction or pancreatitis may cause intravascular volume loss due to inflammation and interstitial edema
- Ongoing bleeding
  - Typically requires surgical hemostasis in order to allow adequate volume repletion

Causes of intravascular volume derangement – Anesthesia-related factors

- Anesthetic and adjuvant drugs
  - Cause dose-dependent vasodilation and myocardial depression that may lead to hypotension
- Decreased venous return
  - Large tidal volumes, recruitment maneuvers, or PEEP
- Mechanical bowel preparation
  - May be associated with fluid loss from the gastrointestinal tract, which may reduce preoperative intravascular volume
  - Avoiding unnecessarily deep anesthesia avoids hypotension
- Sympathetic blockade during neuraxial anesthesia
  - Can result in relative hypovolemia due to increased venous capacitance and dilation of arteriolar resistance vessels, with resultant hypotension

Causes of intravascular volume derangement – Surgery-related factors

- Hemorrhage
  - Cause dose-dependent vasodilation and myocardial depression that may lead to hypotension
- Coagulopathy due to hemodilution and/or hypothermia, which aggravates blood loss
- Decreased venous return
  - Abdominal insufflation during laparoscopy
  - Compression of the inferior vena cava or other major veins
- Prolonged operative time, particularly with an open abdominal cavity
  - Evaporative/insensible fluid loss from exposed body cavities or wounds
  - May eventually lead to increased bowel edema/sequestration of fluid

Causes of intravascular volume derangements

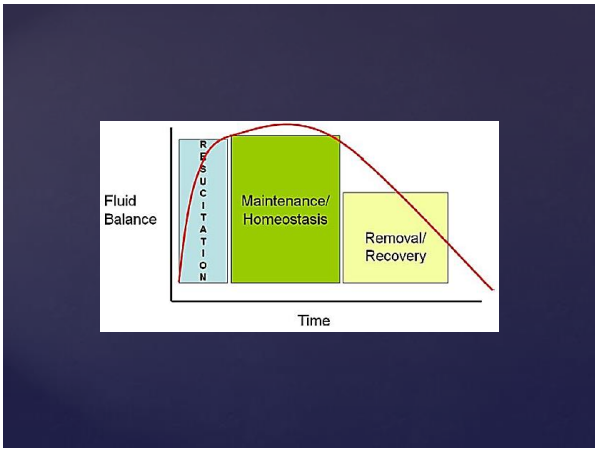
- Maintenance of intravascular euvolemia throughout the perioperative period is ideal
  - Should be avoided by limiting the period of fasting and encouraging patients to consume clear oral liquids up to two hours before surgery
- Avoid hypovolemia
  - Hypovolemia leads to low cardiac output and decreased tissue perfusion and, if severe, can lead to shock and multi-organ failure

Consequences of intravascular volume derangements

- Avoid hypervolemia
  - Common cause during the perioperative period
  - Clinically significant hypervolemia has been associated with increased morbidity, length of stay in the intensive care unit, and mortality
  - In critically ill surgical patients, this association may be spurious since
  - Tissue edema → deleterious effects on various organ systems

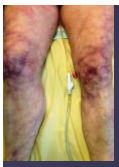
Table 1. The pathophysiologic effects of fluid overload on organ systems

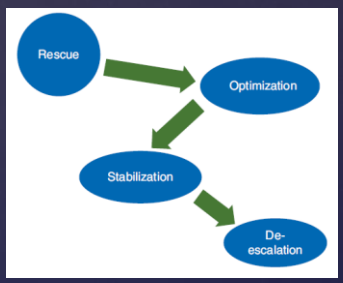
Body system	Effect of fluid overload	Clinical manifestation
Central nervous system	Cerebral edema	Impaired cognition Delirium
Respiratory system	Pulmonary edema Pleural effusions	Increased work of breathing Impaired gas exchange Decreased lung compliance Increased extravascular lung water
Cardiovascular system	Myocardial edema Pericardial effusions	Impaired contractility Diastolic dysfunction Conduction abnormalities
Gastrointestinal system	Gut wall edema Ascites	Malabsorption Ileus Bacterial translocation Intra-abdominal hypertension
Hepatobiliary system	Hepatic congestion	Cholestasis Impaired synthetic function
Renal system	Renal interstitial edema Elevated renal venous pressure	Acute kidney injury Uremia Salt and water retention
Skin and musculoskeletal system	Tissue edema Impaired lymphatic drainage Deranged microcirculation	Poor wound healing Pressure ulcers Wound infection

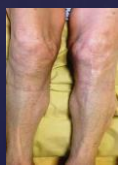


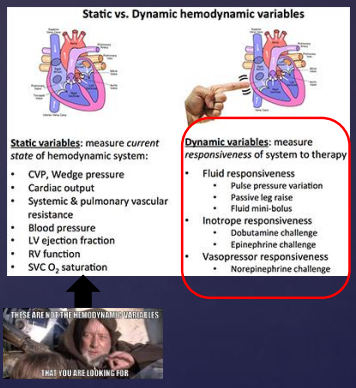
Monitoring intravascular volume status

- Purpose: to guide fluid administration in order to maintain tissue perfusion
- Clinical assessment
- Basic/Advanced monitoring
- Laboratory values
- Regardless of the monitors employed, intraoperative determination of intravascular volume status is challenging
  - Continuously changing cardiovascular responses due to:
    - Suboptimal or unknown preoperative volume status
    - Anesthetic drugs
    - Variable surgical volume losses that are difficult to quantify









Choosing fluid (crystalloid, colloid) and blood ± blood derivatives

Crystalloid solutions

- Solutions of electrolytes and sterile water
- May be isotonic, hypotonic, or hypertonic with respect to plasma
- Balanced electrolyte solutions
  - Also termed buffered crystalloid solutions
  - Have an electrolyte composition similar to plasma with the addition of a buffer (e.g. lactate) are most widely used
  - E.g. Ringer's lactate (also termed Hartmann's solution) or PlasmaLyte

Crystalloid solutions

- We typically select a balanced electrolyte crystalloid solution for routine perioperative fluid administration in order to maintain normovolemia and/or replace lost blood.
- We avoid administration of a large volume of normal saline (0.9% NaCl)

Colloid solutions

- Are human plasma derivatives
  - E.g. human albumin or semisynthetic preparations
    - E.g. hydroxyethyl starch (HES), gelatins
- May be dissolved in isotonic saline or in a solution with a balanced electrolyte concentration similar to plasma
- Increased volume effect
  - The percent of fluid administered that remains intravascular
- However, some clinicians prefer to use colloids in selected patients or situations
  - To expand microvascular volume with minimal capillary leakage
    - Minimizing edema formation and the total quantity of administered fluid

Colloid solutions – Human albumin

- Human serum albumin is available in 4%, 5%, 20%, and 25% solutions
- Human albumin 5%: Has a volume effect of 70%
- Human albumin 25%: Is isosmotic with plasma

Colloid solutions – Human albumin

- Human albumin is pasteurized and does not transmit any known infectious diseases
- Is more expensive than other solutions
- May not be safer or more efficacious than synthetic colloids (e.g. HES) or balanced crystalloid solutions

Colloid solutions – Hydroxyethyl starches

- Are synthetic colloids, identified by three numbers corresponding to concentration, molecular weight, and molar substitution
  - I.e. the average hydroxyethyl groups per one glucose unit
  - E.g. Hespan is HES 6 percent (600/0.75) with a volume effect of 100 percent and a high molar substitution of 0.75
- Concerns regarding renal
  - Risk of HES-induced renal toxicity depends primarily on the molar substitution level in the specific product, with lower risk for low substituted HES products
  - Septic patients
  - Seems safe in elective surgery

Colloid solutions – Hydroxyethyl starches

- Concerns regarding their effects on hemostasis
  - May impair platelet reactivity and decrease circulating plasma concentrations of coagulation factor VIII and von Willebrand factor
  - May weaken clot formation
  - May increase transfusions of blood products including FFP, cryoprecipitate, and platelets compared with other solutions
  - HES products with low molar substitution (e.g. pentastarch and tetrastarch) may have less effect on hemostasis

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Variable	Human Plasma	Colloids										Crystalloids	
		4% Albumin	Hydroxyethyl Starch						4% Succinylated Modified Fluid Gelatin	3.5% Urea-Linked Gelatin	0.9% Saline	Compounded Sodium Lactate	Balanced Salt Solution
			10% (200/0.5)	6% (450/0.7)	6% (130/0.4)		6% (130/0.42)						
Trade name		Albumes	Hemohes	Hestend	Voluven	Volulyte	Venofundin	Tetraspan	Gelofusine	Haemaccel	Normal saline	Hartmann's or Ringer's lactate	Plasmalyte
Colloid source		Human donor	Potato starch	Maize starch	Maize starch	Maize starch	Potato starch	Potato starch	Bovine gelatin	Bovine gelatin			
Osmolarity (mOsm/liter)	291	250	308	304	308	286	308	296	274	301	308	280.6	294
Sodium (mmol/liter)	135–145	148	154	143	154	137	154	140	154	145	154	131	140
Potassium (mmol/liter)	4.5–5.0			3.0		4.0		4.0		5.1		5.4	5.0
Calcium (mmol/liter)	2.2–2.6			5.0				2.5		6.25		2.0	
Magnesium (mmol/liter)	0.8–1.0			0.9		1.5		1.0					3.0
Chloride (mmol/liter)	94–111	128	154	124	154	110	154	118	120	145	154	111	98
Acetate (mmol/liter)						34		24					27
Lactate (mmol/liter)	1–2			28								29	
Malate (mmol/liter)								5					
Gluconate (mmol/liter)													23
Bicarbonate (mmol/liter)	23–27												
Octanoate (mmol/liter)		6.4											

* To convert the values for potassium to milligrams per deciliter, divide by 0.2558. To convert the values for calcium to milligrams per deciliter, divide by 0.250. To convert the values for magnesium to milligrams per deciliter, divide by 0.4114.

In critically ill patients…

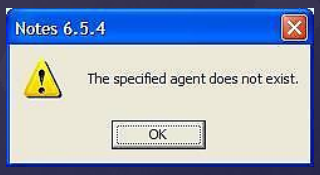
Fluids should be administered with the same caution that is used with any intravenous drug.
Consider the type, dose, indications, contraindications, potential for toxicity, and cost.

Fluid resuscitation is a component of a complex physiological process.
Identify the fluid that is most likely to be lost and replace the fluid lost in equivalent volumes.
Consider serum sodium, osmolarity, and acid–base status when selecting a resuscitation fluid.
Consider cumulative fluid balance and actual body weight when selecting the dose of resuscitation fluid.
Consider the early use of catecholamines as concomitant treatment of shock.

Fluid requirements change over time in critically ill patients.
The cumulative dose of resuscitation and maintenance fluids is associated with interstitial edema.
Pathological edema is associated with an adverse outcome.
Oliguria is a normal response to hypovolemia and should not be used solely as a trigger or end point for fluid resuscitation, particularly in the post-resuscitation period.
The use of a fluid challenge in the post-resuscitation period (≥24 hours) is questionable.
The use of hypotonic maintenance fluids is questionable once dehydration has been corrected.

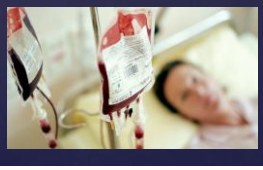
Specific considerations apply to different categories of patients.
Bleeding patients require control of hemorrhage and transfusion with red cells and blood components as indicated.
Isotonic, balanced salt solutions are a pragmatic initial resuscitation fluid for the majority of acutely ill patients.
Consider saline in patients with hypovolemia and alkalosis.
Consider albumin during the early resuscitation of patients with severe sepsis.
Saline or isotonic crystalloids are indicated in patients with traumatic brain injury.
Albumin is not indicated in patients with traumatic brain injury.
Hydroxyethyl starch is not indicated in patients with sepsis or those at risk for acute kidney injury.
The safety of other semisynthetic colloids has not been established, so the use of these solutions is not recommended.
The safety of hypertonic saline has not been established.
The appropriate type and dose of resuscitation fluid in patients with burns has not been determined.

Which is the ideal solution ? ? ?



Blood and derivatives

- Blood transfusion can be a lifesaving procedure
- It has risks, including infectious and noninfectious complications
- There is debate in the medical literature concerning the appropriate use of blood and blood products



Red blood cells (RBCs)

- Are prepared from whole blood by removing approximately 250 mL of plasma
- One unit of packed RBCs should increase levels of hemoglobin by 1 g/dL (10 g/L) and hematocrit by 3%
- Are used to treat hemorrhage and to improve oxygen delivery to tissues
- Transfusion of RBCs should be based on the patient's clinical condition

Plasma

- Plasma products include fresh frozen plasma and thawed plasma that may be stored at 1-6°C (33.8-42.8°F) for up to five days
- Plasma contains all of the coagulation factors
- Fresh frozen plasma infusion can be used for reversal of anticoagulant effects
- Thawed plasma has lower levels of factors V and VIII and is not indicated in patients with consumption coagulopathy (diffuse intravascular coagulation)

Plasma

- Transfusion is recommended:
  - In patients with active bleeding and an International Normalized Ratio (INR) > than 1.6
  - Before an invasive procedure or surgery if a patient has been anticoagulated
- Plasma is often inappropriately transfused for correction of a high INR when there is no bleeding
  - Supportive care can decrease high-normal to slightly elevated INR (1.3 to 1.6) without transfusion of plasma

Platelets

- Transfusion may be indicated:
  - To prevent/treat hemorrhage in patients with thrombocytopenia or platelet function defects
- Contraindications to platelet transfusion include:
  - Thrombotic thrombocytopenic purpura
  - Heparin-induced thrombocytopenia
  - Transfusion of platelets in these conditions can result in further thrombosis
- Spontaneous bleeding through intact endothelium does not occur unless the platelet count is no greater than 5 × 103 per µL (5 × 109 per L)

Cryoprecipitate

- Is prepared by thawing fresh frozen plasma and collecting the precipitate
- Contains high concentrations of factor VIII and fibrinogen
- Is used in cases of hypofibrinogenemia:
  - Most often occurs in the setting of massive hemorrhage or consumptive coagulopathy
- Each unit will raise the fibrinogen level by 5-10 mg/dL
- Goal: maintaining a fibrinogen level of at least 100 mg/dL

Cryoprecipitate – Indications for transfusion

- Adults
  - Hemorrhage after cardiac surgery
  - Massive hemorrhage or transfusion
  - Surgical bleeding
- Neonates
  - Anticoagulant factor VIII deficiency
  - Anticoagulant factor XIII deficiency
  - Congenital dysfibrinogenemia
  - Congenital fibrinogen deficiency
  - von Willebrand disease
- Usual dose in adults: 10 units of pooled cryoprecipitate
- Dosing regimens in neonates vary: from 2 mL/kg to 1 unit of cryoprecipitate (15 to 20 mL) / 7 kg

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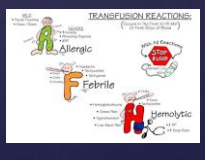
Transfusion complications

- Acute
  - Occur within minutes to 24 hours of the transfusion
  - Delayed
    - May develop days, months, or even years later
- Infectious
  - Are less common because of advances in the blood screening process
  - The risk of contracting an infection from transfusion has decreased 10,000-fold since the 1980s
- Non-infectious serious hazards of transfusion
  - Are up to 1,000 times more likely than an infectious complication

Acute transfusion reactions

- Acute hemolytic reactions
- Allergic reactions
- Transfusion-related acute lung injury
- Febrile non-hemolytic transfusion reactions
- Transfusion-associated circulatory overload



Delayed transfusion reactions

- Transfusion-associated graft-versus-host disease
- Is a consequence of a donor's lymphocytes proliferating and causing an immune attack against the recipient's tissues and organs
- It is fatal in more than 90% of cases
- Patients vulnerable to this condition are those who are immunocompromised or immunocompetent and who are receiving transfusion with shared HLA haplotypes (i.e., donor is a relative)
- Symptoms include rash, fever, diarrhea, liver dysfunction, and pancytopenia occurring one to six weeks after transfusion

Delayed transfusion reactions

- Risk factors include:
  - A history of fludarabine (Oforta) treatment, Hodgkin disease, stem cell transplant, intensive chemotherapy, intrauterine transfusion, or erythroblastosis fetalis
- Other probable risk factors include:
  - A history of solid tumors treated with cytotoxic drugs, transfusion in premature infants, and recipient-donor pairs from homogenous populations
- Gamma irradiation of blood products
  - Keeps the donor lymphocytes from proliferating and can prevent transfusion-associated graft-versus-host disease

Infectious transfusion complications

- Hepatitis B virus
- Hepatitis C virus
- Human T-lymphotropic virus 1 or 2
- Human immunodeficiency virus
- Creutzfeldt-Jakob disease
- Human herpesvirus 8
- Malaria and babesiosis
- Pandemic influenza
- West Nile virus

Non-infectious transfusion complications

Acute

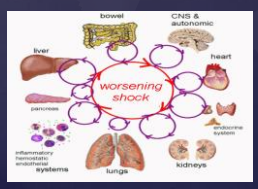
- Acute hemolytic reaction
- Allergic reaction
- Anaphylactic reaction
- Coagulation problems in massive transfusion
- Febrile non-hemolytic reaction
- Metabolic derangements
- Mistransfusion (transfusion of the incorrect product to the incorrect recipient)
- Septic or bacterial contamination
- Transfusion-associated circulatory overload
- Transfusion-related acute lung injury
- Urticarial reaction

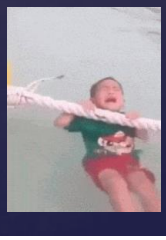
Delayed

- Delayed hemolytic reaction
- Iron overload
- Microchimerism
- Overtransfusion or undertransfusion
- Post-transfusion purpura
- Transfusion-associated graft-versus-host disease
- Transfusion-related immunomodulation

There is a problem…

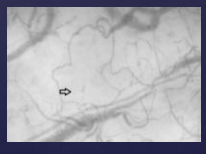
~50% of critically ill patients
do not respond to fluid resuscitation…



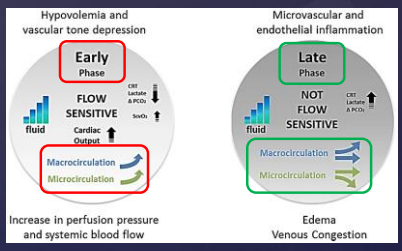


Recognizing the problem…

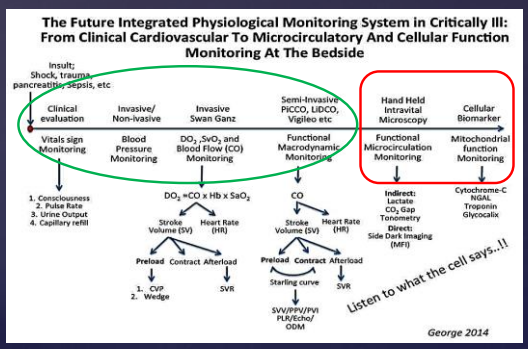
Impaired microcirculation



Microcirculation and fluid resuscitation



Clinical assessment Cellular assessment



MCQ 1

- In which part of the circulatory system is an IV placed?
  1. Vein
  2. Vein and artery
  3. Artery
  4. Lymphatic vessel
  5. Neither

MCQ 2

- Peripheral areas are the preferred sites for IVs. Where would a peripheral area be located?
  1. Upper or lower extremities
  2. Torso
  3. Chest
  4. Buttocks
  5. Head

MCQ 3

- Which of the following is an indication for placing a central venous cannulation?
  1. Administration of 5% D/W solution
  2. Hemodialysis
  3. Administration of antibiotics
  4. Administration of colloids
  5. None of the above

MCQ 4

- Which of the following is not a potential side-effect of blood transfusion?
  1. Acute hemolytic anemia
  2. Electrolyte disorders
  3. Metabolic acidosis
  4. Hemorrhagic stroke
  5. Transmission of viral infection

MCQ 5

- Red cell transfusions are indicated where the desired outcome is to increase the red cell mass and improve oxygen delivery in patients with low hemoglobin levels. What is the expected rise in hemoglobin levels per unit of packed red cells administered?
  1. 5 g/dL Hb
  2. 4 g/dL Hb
  3. 1 g/dL Hb
  4. 2 g/dL Hb
  5. 3 g/dL Hb