SNS COLLEGE OF ALLIED HEALTH SCIENCES

SNS Kalvi Nagar, Coimbatore - 35

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DEPARTMENT OF CARDIO PULMONARY PERFUSION CARE TECHNOLOGY

COURSE NAME : PRINCILES OF PERFUSION TECNOLOGY I

II YEAR

TOPIC : PRIMING SOLUTIONS AND HEMODILUTION

Hemodilution

- The CPB circuit must be primed with fluid solutions (crystalloid or colloid) so that adequate flow rates can be rapidly achieved on initiation of cpb without a risk of air embolism.
- The degree of hemodilution caused by CPB can be calculated before initiating bypass so that the priming solution can be adjusted to incorporate packed red cells.

HCT = Pt Hb * 3 (pre op HCT)

CPB HCT = Pre op HCT * PBV / PBV + CPB prime volume

Acceptable hemodilution 25% - 30 %

Benefits of hemodilution

- Decreased blood viscosity
- Improved regional blood flow
- Improved oxygen delivery to tissues
- Decreased exposure to homologous blood products
- Improved blood flow at lower perfusion pressure, especially during hypothermic perfusion

Disadvantages of hemodilution

Extreme hemodilution may cause,

- Decreased hematocrit level
- Decreased oxygen carrying capacity
- Reduce neuro cognitive outcomes
- Induces ischemic organ failure
- Increases the distance between capillaries, tissue necrosis and cell damage
- Pulmonary and renal dysfunction
- Can cause mortality and morbidity

HCT

- HCT is the main determinant of the oxygen carrying capacity of blood.
- Minimum acceptable HCT should meet the oxygen delivery required to match systemic O2 consumption.
- Oxygen delivery is influenced by pump flow rate and systemic temperature.
- O2 consumptions also alters proportionately with temperature.
- Jehovah's Witness patients who refuse blood transfusions show that cardiac surgery and CPB with low HCTs is not only possible, but is also relatively safe.

Factors affecting the HCT during CPB include

- Patient size
- Preoperative hemoglobin concentration
- Pre CPB blood loss
- Pre CPB fluid administration
- CPB prime volume
- Urine output

Methods to reduce hemodilution

- Autologous blood priming
  a) Antegrade priming
  b) Retrograde priming
- Mini bypass circuits

- **Autologous blood priming**
  a) Antegrade priming

By partial filling of the venous reservoir with the patients own blood from the venous line of the CPB circuit on initiation of CPB, but before initiation of flow through the oxygenator and arterial line of the circuit.

Methods to reduce hemodilution (cont)

b) Retrograde priming

By retrograde filling of the venous reservoir via arterial line of the circuit just prior to the initiation of CPB.

- **Mini bypass circuits**

The mini extracorporeal circulation system is a semi closed circuit with no reservoir and shorter tubing length.

Priming volumes are reduced to only 450ml and this leads to less hemodilution and less blood transfusion and possibly a reduced inflammatory response.

Prime

An isotonic solution which is used to :

- Substitute the blood to provide a safe hemodilution
- Fill the circuit line
- De-air

Purpose

- Adequate flow rates can be rapidly achieved on initiation of CPB without risk of air embolism (without emptying the heart)

Aim of priming

- To allow perfusion to be rapidly established on initiation of CPB without the risk of air embolism
- To fill the circuit
- To check the circuit for leaks or damage
- To test the pump and circuit
- Priming with fluid reduces the blood dependence
- Priming fluid causes hemodilution, which can be beneficial or harmful

History

- John gibbon performed first successful CPB procedure in Philadelphia in 1953.
- Donor blood was used as priming solution
- However; the cost and availability of blood, and side effects such as : the risk of transmitting infectious diseases and immunosuppression
- All these lead to the use of crystalloid or colloid based primes.
- In 1962, Cooley and co workers showed improved outcome by adding 5% dextrose to the prime instead of just blood.

History

- 5% dextrose later fell out of favor for two reasons: Firstly, the realization that metabolism of glucose leads to a hypotonic solution and Secondly, fears about hyperglycemia worsening neurological outcome.

- In part, accumulation of knowledge about the deleterious effects of blood primes and acceptance of crystalloids as priming solutions.

- The introduction of hypothermic bypass in the 1960s, the inability of blood banks to support cardiac surgery with large amounts of whole blood and the prevalence of blood borne infections were also important in the shift to clear primes

SURGEON	YEAR	PRIMING SOLUTION	TECHNIQUE
Gibbons	1953	Whole blood	High flow
Kirklin	1956	Whole blood	High flow
Lillehei	1955	Whole blood	Low flow
Panico	1959	Saline	Hemodilution
Long	1961	Dextran and 5% Dextrose	Hemodilution and hypothermia
Dewall& Lillehei	1962	5% Dextrose	Hemodilution and hypothermia
Cooley	1962	5% Dextrose	Hemodilution and normothermia

Classification of priming fluids

- **Crystalloids** - Fluids with smaller solutes and less atomic weights. Remains in the circulation for smaller times (15mts)
  E.g. : Ringer solution and Dextrose etc…

- **Colloids –** Fluids with higher solutes and greater atomic weights. They help in the preservation of oncotic pressure.
  E.g. : Albumin

- **Blood**

Properties of an ideal prime

Tonicity

- Refers to the relative concentration of solutions that determine the direction and extent of diffusion.

- To avoid red cell lysis

- To avoid third shift from EC to IC

- E.g. : Cerebral pulmonary edema

Classification of crystalloids

- **Hypotonicity** : It refers to a lesser concentration. It has a lower concentration of solutes outside the cell than inside the cell. To balance the concentration of solutes inside and outside the cell water rush into the cell.

- **Hypertonicity** : It refers to a greater concentration. Hypertonic solution is one with a higher concentration of solutes outside the cell than inside the cell. When a cell is immersed into a hypertonic solution, the tendency is water for flow out of the cell in order to balance the concentration of solutes. Eg : Haesterile

- **Isotonicity** : An isotonic solution is one in which its effective osmolarity concentration is the same as the solute concentration of a cell.
- Plasma osmolarity normal range is 275-290 mOsmol/kg

Electrolyte Composition

- Similar electrolyte content and osmolarity to the intravascular and interstitial compartments, providing a fluid that when mixed with blood is capable of maintaining oxygen delivery, CO2 removal and physiological homeostasis.

- pH as same as that of plasma

Electrolytes

Normal serum concentrations	
Sodium	135-145 mEq/ L
Potassium	3.5 – 5.0 mEq/ L
Chloride	100 – 106 mEq/ L
Calcium	8.5 – 10.5 mg/ dl
Phosphorus	3.0 – 4.5 mg/ dl
Magnesium	1.5 – 2.5 mEq/ L
Others	
Glucose	70 – 130 mg/dl
Serum osmolarity	285 – 295 mOsm/ L

Blood

- Historically, blood was used to prime the CPB circuit in an attempt to preserve a high hematocrit

- Problems associated with using blood as priming solution:

  Very high cost compared to crystalloids or colloids.

  Worldwide shortage of blood.

  Risks of transfusion such as; blood borne infections, transfusion reactions and immunosuppression

Crystalloids

- Volume expanding solutions
- Mimics with the normal plasma electrolyte concentrations
- Can be used with effective hemodilution
- Lacks oncotic activity

A) Dextrose

- Dextrose 5% in water is isotonic and acidotic (pH 5.0)

Advantages

- Reduces mechanical damage to RBC.
- Improves intraoperative and postoperative diuresis.
- Decreases perioperative fluid requirement.
- Reduces post operative fluid retention

Disadvantage

- May cause systemic metabolic acidosis.
- May increase the level of blood glucose, especially in diabetic patients.
- Possibility of increase in the risk of neurological complications of CPB

B) Balanced crystalloids

- Are fluids that have a neutral pH as plasmalyte solution (pH 7.4) or slightly low pH as Ringer's (pH 6.6) . Isotonic solutions
- Eg;

i) Plasmalyte solution;

Contains acetate and gluconate for $NaHCO_3$ production, and magnesium (intracellular cation) which is important in cellular process of energy transfer and in myocardial ATP metabolism

ii) Ringer's Lactate/ Hartmann's (Ringer's) solution;

Contains lactate as a source of $NaHCO_3$.

But as lactate may be converted into glucose invivo through the gluconeogenic pathway, as a result of that we must be careful when using a large volume of fluid containing lactate in diabetic patients.

Disadvantages of crystalloids

- Metabolic acidosis
- Edema (interstitial edema)

Colloids

- Colloid solutions are fluids containing large proteins or high molecular weight substance (generally molecular weight > 30000 Dalton's)

- Used to maintain oncotic pressure and to reduce fluid shifts.

- Colloids are divided into two types;

  Natural (Human albumin)

  Artificial (Dextran solutions, gelatin and HES)

A) Albumin

- Most common natural colloid produced by the liver.
- Constitutes 50-60% of all plasma proteins.
- Acidotic (pH 6.9)

Advantage

Maintains colloid osmotic pressure

Disadvantage

Comparatively expensive

B) Dextrans

- Produced from sucrose. Acidotic (pH 4.5)
- Available in two formulations;

  Dextran 40 – molecular weight of 40000 daltons.

  Dextran 70 – molecular weight of 70000 daltons.

Disadvantages

- Anaphylactoid reactions
- Coagulation abnormalities
- Acute renal failure (when renal perfusion is reduced).

C) Gelatins

- Gelofusine is a 4% solution of succinylated gelatin mixed in normal saline.
- Gelofusine is a synthetic colloid.
- Produced from bovine collagen
- Average molecular weight of 30000 daltons to 35000 daltons.

- Two types used as priming fluids for CPB;
  Urea linked Gelatin
  Succinyl linked or modified fluid gelatins (Gelofusine, Plasmagel, Plasmin)

Advantages

- Low cost
- Can be infused without any limit because they are associated with minimum renal impairment as compared to HMW HES.

Disadvantages

- Higher incidence of anaphylactoid reactions.
- Negative effect on blood coagulation

  Increased bleeding time

  Impaired platelet adhissiveness

D) Hydroxy ethyl starch (HES)

- Synthetic non protein colloids with high molecular weight
- Contains hydroxyethyl polymers of glucose derived from amylopectin
- Eg;

  Hetastarch

  Pentastarch

  Tetrastarch (third generation starch/ Volueven)

  Hextenol

Advantages

- Decreased diuresis
- Lower hematocrit
- Reduced coagulopathy

Disadvantages

- Contraindicated in critically ill adult patients, including patients with sepsis or burn injuries in critically ill patients.

Composition of different priming fluids

	Na+	K+	Cl-	Ca2+	Mg2+	HCO3-	pH	Other	mosmol/l
Dextrose 5%	0	0	0	0	0	0	4.2	Glucose 50 g/l	279
Saline 0.9%	154	0	154	0	0	0	5.0	-	308
Hartmann's	131	5.0	111	2.0	0	29 (lactate)	6.5	-	280
Plasmalyte A	140	5.0	98	0	3	27 (acetate) 29(gluconate)	7.4	-	294
Normasol R	140	5.0	98	0	3	27 (acetate) 29(gluconate)	7.4	-	294
Bicarbonate 1.26%	150	0	0	0	0	150	7.0	-	300
Gelofusine	154	0.4	120	0.4	0	0	7.1- 7.7	Gelatine 40g/l	274
Starch	154	0	154	0	0	0	4.5- 5.5	Starch	308
Human albumin 4.5	100-160	<2	100-160	0	0	< 0.1 citrate	7.1	Albumin 40-50 g/l	300

Additives in prime

A number of additives have been trailed as CPB technology evolved inorder to enhance safety and improve outcomes

- Presently, the three most commonly used additives are;

Mannitol

Sodium bicarbonate

Heparin

Mannitol

- Hypertonic, LMW crystalloid
- Molecular weight – 182 daltons
- pH 4.5- 7.0
- Patient osmotic diuretic and preserves renal function
- Free radical scavenger.
- Dose in CPB prime = 0.5 – 1 g/kg

Sodium bicarbonate

- Often added as a buffer to ‘unbalanced’ priming solutions.

- Also being used as an additive in balanced priming solutions for its potential to reduce the incidence of acute renal dysfunction in post cardiac surgery.

- Dose : 25mmol/l prime

Heparin

- It is an anticoagulant
- Added to the prime as an additional safety factor, if systemic heparinization is inadequate.
- Dose: 10 - 25 mg (1000- 2500 IU)/L of priming volume