Abstract

Transfusion practices vary widely among neonatal intensive care units. The risks and benefits of transfusion as well as the disease being treated and the condition of the patient must be considered in determining whether to give blood products. Additionally, a thorough understanding of available blood components and indications for each are critical when making the decision whether to transfuse. The purpose of this review is to discuss types of blood components, blood banking techniques, and indications for and risks of transfusion.

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Transfusion Therapy

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Premature infants, especially those less than 1,500 grams, often receive multiple blood product transfusions. Approximately 300,000 infants are transfused per year.^{1,2} The more preterm an infant, the more likely blood transfusions will be required. Improved preterm survivability has resulted in an increase in the number of neonates requiring multiple transfusions, often from several donors. Despite this improved survival at earlier gestation and overall complexity of care, the number of transfusions per neonate and number of donors an infant is exposed to is decreasing.³ The mean number of red blood cell (RBC) transfusions per infant in a neonatal intensive care unit (NICU) has been decreasing with an estimated 8 to 10 per infant during the 1970s to 1980s and 1.7 to 5 per infant in the early 1990s.³⁻⁸ An even further decrease is seen with increasing gestational age. Hume and Bard⁸ found a significant decrease in the number of transfusions required between infants born at 27 to 28 weeks' gestation and those born at 31 to 32 weeks' of gestation (96 versus 40%, respectively).

Transfusion practices vary widely among neonatal intensive care units. Transfusion of blood components is done for numerous reasons, including to improve oxygen delivery, preserve intravascular volume, decrease the risk of infection, correct coagulopathies, reduce fatigue while feeding, and improve growth and overall homeostasis.^{1,9-11} The risks and benefits of transfusion as well as the disease being treated and the condition of the patient must be considered in determining whether to use blood products. Additionally, a thorough understanding of available blood components and indications for each are critical when making the decision whether to transfuse.

The purpose of this review is to discuss types of blood components, blood banking techniques, and indications for and risks of transfusion.

Storage

Preparation and storage of blood products has evolved over time as whole blood transfusion was replaced with component therapy in which whole blood is separated into plasma, platelets, and RBCs.¹² The separation of whole blood into components is done shortly after donation. This allows for individual components to be given for specific illnesses rather than giving whole blood, which exposes the recipient to blood components they do not need. Component therapy enables more than one individual to benefit from one unit of blood.

A single unit of blood consists of approximately 450 mL collected from one donor and then stored in bags with an anticoagulant preservative. One unit of whole blood produces one unit of RBCs, one unit of platelets, a unit of cryoprecipitate, and a unit of platelet- and cryoprecipitate-poor plasma.¹ An infant's blood volume is approximately 80 mL/kg. Thus, several transfusions of 10 to 15 mL/kg are possible from a single donor. One donor red cell unit can

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be stored in satellite bags using a sterile docking device to transfer the blood without altering the expiration date. Stored RBCs generally have a shelf life of 35 to 42 days. Lee¹³ found a 64% reduction in multiple donor exposure by using dedicated eight-packs of unwashed packed RBCs up to the date of expiration. Thus, the risk of infection theoretically decreases as the number of different donors decreases.¹³ Research continues to focus on further extending the life of RBCs to reduce both blood wastage and the number of donors to whom an infant is exposed.

Many neonatology groups prefer to use fresh blood (<5 to 7 days) because of concerns regarding storage and hyperkalemia, shortened RBC life, hyperglycemia, hypernatremia, acidosis, renal toxicity (adenine, mannitol), and increased oxyhemoglobin affinity (decreased 2,3-DPG levels).³ Currently, RBCs expire after approximately 6 weeks due to the condition of storage rather than the lifespan of the RBCs.¹² A decrease in RBC adenosine triphosphate (ATP), 2,3-diphosphoglycerate (2,3-DPG), membrane integrity, hemoglobin, and viability occurs over time during storage. A variety of additive solutions and combinations for the anticoagulation and storage of RBC components have been developed.^{12,14} These storage systems improve RBC availability, safety, and overall effectiveness. RBC components used for small-volume transfusions in neonates are usually stored in citrate–phosphate–dextrose–adenine solution (CPD or CPDA1), saline–adenine–glucose–mannitol (SAGM), or an extended-storage preservative solution (additive solution or AS-1, AS-3, or AS-5) consisting of varying amounts of combinations of dextrose, sodium chloride, adenine, mannitol, trisodium citrate, citric acid, and sodium phosphate or phosphate buffer. One unit of whole blood is centrifuged to allow the separation of plasma from RBCs and then suspended to a hematocrit of 70% (CPDA1) or 55 to 60% (AS-1, AS-3, or AS-5). An alternative method used to improve volume and RBC mass is to centrifuge the RBC components before transfusion thus attaining a uniformly packed RBC concentrate with a HCT of 80 to 90%.¹⁵ Mannitol, phosphate, and citrate are inexpensive to produce, lightweight for transport, and easy to infuse rapidly through 14-gauge catheters.¹² Estimated RBC recoveries at 6 weeks after donation are between 80 to 84% with 0.5% hemolysis.¹²

Factors important to RBC viability during storage include the ATP concentration (improved with glucose, phosphate, and adenine), reticuloendothelial blockade to allow for more rejuvenation time and slower clearance of damaged cells, stabilization of the RBC membrane to reduce hemolysis (mannitol or citrate), and shape change (storage in polyvinyl chloride bags with a plasticizer that enters the RBC membrane and reduces membrane loss).¹² 2,3-DPG binds to hemoglobin A thereby lowering oxygen

affinity resulting in the release of additional oxygen to the tissues.^{16,17} Oxygen delivery improves as pH rises due to the subsequent increase in 2,3-DPG production. This is at the cost of losing ATP and thus lowering RBC storage time: as RBCs metabolize glucose to make additional ATP, lactate and protons are produced, which lower the pH, inhibit metabolism, and decrease 2,3-DPG levels and oxygen delivery.¹² Mahapatra and coworkers¹⁸ found that an increase in oxygen affinity (decrease in oxygen delivery) from the depletion of 2,3-DPG over time in stored blood did not cause a significant clinical problem in infants receiving small-volume RBC transfusions. Strauss¹⁵ compared fresh CPDA1 to stored AS-1 and found no significant differences between pre- and posttransfusion blood chemistries or levels of 2,3-DPG.

Concern among practitioners continues regarding neonatal hyperkalemia as a result of transfused stored blood. Hume,³ in a systematic review of four studies, found no correlation between hyperkalemia and the age of the RBCs stored.^{19–22} She concluded that it is safe to assign a fresh (<5–7 days) RBC unit to one infant and use it for up to 35 or 42 days.³ The potassium concentration in a 10 to 15 mL/kg transfusion is only a fraction of the 2 to 3 mmol/kg/day potassium requirement and should not harm the infant if the blood is transfused slowly.^{2,21}

Anticoagulants, the exception being heparin, are necessary when preparing blood components for storage. Heparin is the anticoagulant used for extracorporeal membrane oxygenation (ECMO) or exchange transfusions. Heparinized blood does not maintain RBC function and viability thus the blood must be used within 24 to 48 hours of collection.¹

Overall, anticoagulants and preservatives are tolerated well by premature infants and are believed safe under most circumstances.^{15,22,23} Infants in severe renal failure or those receiving large volume transfusions (ECMO, exchange transfusions, major surgery) should continue to use fresh blood.^{15,18} Thus, with a few exceptions, using stored blood has been shown to be safe and effective in neonates while also reducing the number of donors to whom an infant is exposed.

Blood Components: Red Blood Cells, Granulocytes, Fresh Frozen Plasma, Albumin, Platelets, and Cryoprecipitate

Cellular Components

Red Blood Cells

III neonates receive RBC transfusions more frequently than any other blood component available in an attempt to

improve tissue oxygenation as well as to correct anemia. An infant with a hemoglobin or hematocrit value greater than two standard deviations below the mean for a given gestational age or chronological age is considered anemic.^{24,25} Physiologic anemia is a common and normal finding in term infants with a gradual and symptomatic presentation.²⁴ In contrast, pathologic anemia usually is symptomatic and results from both acute and chronic blood loss (most frequently repeated blood sampling), red blood cell destruction or defect, or anemia of prematurity.²⁴ Signs and symptoms of anemia include tachycardia, tachypnea, lethargy, pallor, apnea, bradycardia, poor feeding, poor growth, and elevated lactic acid.^{24,26}

There is a lack of evidence-based guidelines for neonatal transfusion practices as seen by the diverse RBC transfusion practices among individuals and institutions.^{3,5,27-32} The US Multicenter Erythropoietin Study developed specific transfusion guidelines based on hematocrit and reticulocyte levels, ventilatory support, percentage of supplemental oxygen required, apnea and bradycardia, methylxanthine requirement, heart rate, and weight gain.^{3,33} Many institutions utilize these guidelines or similar versions when making the decision to transfuse an infant. Thus far, there is no proven benefit from the routine replacement of asymptomatic phlebotomy blood loss. Rather, RBCs should be transfused to maintain a HCT level deemed appropriate for the clinical condition of each infant. Often, the HCT is maintained above 40% in infants with severe cardiopulmonary disease, greater than 30% for those with moderate cardiopulmonary disease or major surgery, and above 25% in infants with apnea or poor growth.¹⁵ Transfusion of asymptomatic infants with anemia has not been shown to be beneficial. Blank and colleagues³⁴ found no difference in the length of hospitalization, weight gain, length, and morbidities when comparing asymptomatic infants receiving prophylactic transfusions and infants receiving transfusions for symptomatic reasons only.

The most frequent type of RBC transfusion given to neonates is small-volume RBC transfusions of packed RBCs (hematocrit of 70 to 90%) at 15 mL/kg over 2 to 4 hours.¹⁸ The RBC concentrates can be prepared from anticoagulated whole blood unless the whole blood has been anticoagulated with heparin.

Washed RBCs, leukocyte-poor RBCs, and irradiated RBCs are three methods used to reduce white blood cells (WBCs) from RBCs. Washed RBCs refers to the process of washing RBCs with 0.9% sodium chloride to remove >95% of the nonviable RBCs and 85 to 90% of the WBCs as well as extracellular potassium. This technique is very effective at reducing the risk of graft versus host disease (GVHD) but is limited by having a 24-hour shelf life.¹

Leukocyte-poor RBCs refers to RBC concentrates after

approximately 70% of WBCs are removed using one of the following techniques: inverted spin, manual removal or an automated processor, sedimentation, neutralization, centrifuging, washing, freezing, or filtration. These processes are time consuming, expensive, and result in a significant loss of RBC mass.^{1,35}

A third method utilized to remove WBCs from RBCs is irradiation. Irradiating RBCs with 1,500 to 5,000 Gy of radiation prohibits T lymphocyte proliferation. The combination of irradiation and washing RBCs can remove up to 95% of the T lymphocytes.^{1,36}

Murray and Roberts³¹ evaluated neonatal RBC transfusion practices and developed the British Committee for Standards in Hematology Transfusion Task Force recommendations, which include using cytomegalovirus seronegative PRBCs, dedicated aliquots from a single donor for neonates who are likely to receive multiple transfusions, and packed RBCs from donors who have donated at least once within the previous 2 years and were negative for the mandatory screens.³¹ Recommendations also include using strict transfusion guidelines and larger (20 mL/kg) RBC transfusions to reduce the number of transfusions and donor exposure.³¹

Exchange Transfusions

Exchange transfusions are usually performed for hyperbilirubinemia, polycythemia, or in severe anemia where transfusion of additional RBCs without exchanging the volume may lead to fluid overload and heart failure.³¹ Neonatal jaundice is found relatively frequently in both term and preterm infants. Many institutions have adopted standard bilirubin screening protocols to avoid missing cases and to establish appropriate follow-up for infants who are discharged but still at risk for worsening jaundice. Causes of hyperbilirubinemia are many, with the most frequent being hemolytic disease of the newborn due to disorders such as blood group incompatibility, hemoglobinopathies, autoimmune disease, and red cell membrane or enzyme disorders. Newborn infants are at increased risk of hyperbilirubinemia during a hemolytic process because the immature liver often cannot keep up with the degradation of hemoglobin to effectively and timely remove the byproducts. Kernicterus results when the bilirubin level rises to a sufficient level so as to allow for diffusion across the blood-brain barrier. The level of bilirubin that this occurs at is lower in preterm infants. The need for exchange transfusion has been reduced due to improved bilirubin surveillance, phototherapy, immunoprophylaxis with anti-Rh immunoglobulin, and intrauterine transfusions of nonmaternal red blood cells.¹¹ Exchange transfusions are necessary in infants where other methods to

reduce bilirubin have failed or the rate of rise in bilirubin demands immediate exchange.

Partial volume exchange is typically performed for polycythemia ($HCT > 65\%$). As the packed red blood cell volume increases beyond 65 to 70%, the viscosity of the blood rises exponentially.^{11,31,37,38} The most common cause of polycythemia in the term newborn is delayed clamping of the cord. Other causes include twin–twin transfusion, maternal–fetal transfusion, iatrogenic transfusion, and increased RBC production in utero due to hypoxia.

Exchange transfusions are usually done through an umbilical venous catheter taking 5 to 10 mL/kg of blood out at a time and replacing it milliliter for milliliter. Single blood volume exchange (80 to 100 mL/kg) is usually performed for anemia with heart failure while double blood volume exchange (160 to 200 mL/kg) is used for severe hemolytic disease of the newborn. Partial or dilutional exchange transfusion, done for polycythemia, consists of removing whole blood and replacing it milliliter for milliliter with albumin, plasma, or normal saline to lower the hematocrit to approximately 55%.

Granulocytes

Neonates are exceptionally susceptible to severe infection. Infants, especially those born prematurely, have immature immune systems with impaired responses to infection. Collectively, WBCs are responsible for protecting against infection. Neutrophils serve as the primary defense system against bacterial infection and act via phagocytosis. Eosinophils are involved in antigen–antibody reactions. Elevated levels are seen with allergic/asthmatic disease, drug reactions, and parasitic infections. Basophils provide histamine and platelet-activating factors to inflamed tissues. Monocytes are phagocytic cells responsible for the removal of injured and dead cells. Granulocytes refer to neutrophils, eosinophils, and basophils.

Neutropenia is relatively common in this population and is typically due to infection, intrauterine growth restriction from severe preeclampsia, hemolysis from Rh incompatibility, neonatal alloimmune neutropenia and less commonly due to intrinsic diseases of the bone marrow.³⁹ In addition to granulocyte depletion, chemotaxis and bactericidal activity of granulocytes in septic infants is reduced.⁴⁰ Mortality from a bacterial infection is significant ranging from 20 to 30%.^{41,42} However, mortality may be as high as 80 to 90% in infants with bone marrow neutrophil depletion.⁴³ Severely infected neonates may develop profound neutropenia and because of the general immaturity of the immune system may benefit from transfusions of WBCs.¹¹ Specifically, granulocyte therapy may be considered, in addition to antibiotics, in neonates with severe

sepsis, neutropenia ($<3.0 \times 10^9/L$ in the first week of life or $<1.0 \times 10^9/L$ thereafter), or severe bone marrow neutrophil depletion ($<10\%$ of nucleated marrow cells being postmitotic neutrophils).⁴⁴

Granulocytes are collected from a unit of fresh (<24 hours from collection) whole blood by automated leukopheresis or apheresis.^{1,10,32} Before transfusion, granulocytes should be irradiated and matched to the recipient's blood type. It is crucial to transfuse granulocytes within a few hours of collection to avoid the rapid deterioration in function.¹⁸ Alternatively the cells may be stored for no more than 24 hours with gentle agitation of the concentrate to prevent clumping.^{1,2,10,18,45,46} Daily granulocyte doses (up to 1×10^9 granulocytes/kg/d) for a minimum of 4 days are recommended.⁴⁰

Plasma

Plasma is a component of blood, composed of 91 to 92% water and 7 to 9% solids, including proteins involved with the coagulation cascade, albumin, electrolytes, and enzymes.¹ Plasma is extracted by centrifugation of a unit of whole blood to yield a platelet-rich plasma, which is further centrifuged to remove the plasma. Both the platelets and plasma are frozen within 6 hours for future use. Fresh frozen plasma (FFP) contains adequate levels of all soluble coagulation factors as well as albumin, immunoglobulins, and naturally occurring anticoagulants.^{1,10,11,47,48}

Fresh Frozen Plasma. Indications for FFP include disseminated intravascular coagulation (DIC), the prevention of thrombocytopenia, liver failure, congenital clotting factor deficiencies, and sepsis (used for the opsonins).^{31,32} Maternal clotting factors do not cross the placenta, thus a congenital deficiency may present at or close to birth.¹⁸ Evidence supports the use of fresh frozen plasma only for the treatment of DIC, vitamin K–dependent bleeding, and inherited coagulation deficiencies.^{31,49–56} The dose of FFP is 10 to 15 mL/kg every 12 to 24 hours as clinically indicated.

Albumin

Albumin is a plasma protein that maintains colloid osmotic pressure, contributes to pH and electrolyte balance, and serves as a carrier protein for many substances including bilirubin.¹ Approximately 80% of the intravascular colloid oncotic pressure in normal individuals is provided by albumin.⁵⁷ Five percent albumin has been used for volume expansion during the resuscitation of an infant in shock in the attempt to enhance fluid reabsorption from the interstitial space into the vascular system. Recent meta-analyses regarding the use of albumin versus crystalloid

(normal saline) in critically ill adults patients concluded that albumin either produces similar results or increases mortality in patients with hypovolemia, burns, or hypoalbuminemia.⁵⁸⁻⁶¹ A Cochrane review on preterm infants found no overall significant clinical benefit to using albumin compared with saline.⁶² These conclusions regarding the use of albumin as well as the increased cost, potential for pulmonary edema, anticoagulant properties, and minor risk of infection must seriously be taken into consideration before making the decision to give albumin over a crystalloid solution. Twenty-five percent albumin (usual dosage is 0.5 to 1 g/kg intravenously) is sometimes used for hypoalbuminemic infants often secondary to poor nutrition. In these infants albumin administration is not as effective as optimizing nutrition.³¹ Identifying and then treating the cause of hypoalbuminemia is most effective.⁶³

Platelets

Platelets interact with injured blood vessel walls to aid in coagulation. Causes of neonatal thrombocytopenia (platelets $<150 \times 10^9/L$) include infection, DIC, immune thrombocytopenia (due to maternal idiopathic thrombocytopenic purpura, ITP), and alloimmune neonatal thrombocytopenia. Platelet transfusion occurs in approximately 2 to 9.4% of infants admitted to the NICU.^{31,64-66} Half of infants receiving platelet transfusions will receive one or more additional transfusions. Guidelines suggested by Murray and Roberts³¹ include transfusing infants with platelets below $30 \times 10^9/L$ unless the infant is unstable or at increased risk for hemorrhage (such as an extremely low birth weight infant <1 week of age). Platelet transfusion for platelets greater than $50 \times 10^9/L$ should be reserved for infants actively bleeding.³¹ Infants on ECMO are usually transfused to maintain a platelet count above 100×10^9 . PLA-1 negative platelets from a single donor are used in alloimmune thrombocytopenia to avoid maternal antibodies that formed against an antigen on the infant's platelets (inherited from the father).¹¹ The platelet transfusion dose is generally 10 to 15 mL/kg. Platelets can be irradiated and washed to avoid GVHD and to remove incompatible plasma.¹⁸ Immune mediated thrombocytopenia may also be treated with intravenous immunoglobulin.

Cryoprecipitate

Cryoprecipitate is the cold-insoluble fraction prepared from FFP by slow thawing and refreezing at 2 to 4°C. Cryoprecipitate is rich in factor VIII and fibrinogen and also contains, to a lesser degree, factor XIII and von Willebrand factor.^{1,47,48} Recipients of factors VIII and IX are exposed to 2,000 to 20,000 donors per transfusion since the factors are pooled from many plasma donors.

One bag of cryoprecipitate contains approximately 80 to 120 units of factor VIII and 250 mg of fibrinogen in 5 to 10 mL of plasma. Factor concentrates are utilized for DIC, liver disease, and specific factor deficiencies.¹

Donors

As previously stated, multipack RBC collection systems with additive preservative from one donor are preferred to decrease the number of donors and can be used for approximately 4 weeks.¹⁸ Preferred donors are individuals with blood type O— who frequently donate such that a record of safety can be established. Family members frequently inquire about donating for their infant. Family blood donation is generally discouraged as they are often first time or infrequent donors and do not have a safety history established. Additionally, mothers may have antibodies that react against RBC, leukocyte, platelet, or HLA antigens expressed on neonatal cells. These antibodies may escape detection when the blood components are screened. Maternal antiplatelet antibodies have been found in as high as 59% of women without thrombocytopenia and 75% of women with preeclampsia.^{15,67,68} Paternal transfusions carry a theoretical risk of exposing the infant to RBC, leukocyte, and platelet antigens that the neonate might have been passively immunized to by the placental transfer of maternal anti-paternal antibodies to the fetus.¹⁵ Because of the risk of GVHD, donated blood from a first- or second-degree relative should be irradiated to inactivate the donor T lymphocytes.^{18,69}

Potential Adverse Reactions to Blood Component Therapy

Knowing the potential risks of transfusion therapy is crucial when deciding whether to transfuse an infant. Adverse reactions include both infectious diseases and noninfectious complications such as cardiovascular complications and GVHD.^{1,35}

Infectious Complications

Infectious complications, including HIV, cytomegalovirus (CMV), and hepatitis B and C, increase proportionally to the number of donors to whom the infant is exposed.¹³ Donor screening and serologic testing have significantly decreased the risk of HIV, hepatitis B, and hepatitis C in blood transfusion recipients. CMV transmission differs since a history before donation cannot determine carriers. Transfusion-induced CMV infection has been estimated to be greater than 10%.⁷⁰ While most cases

are subclinical, significant morbidity and mortality can occur, especially in preterm infants.^{70,71} Signs and symptoms of CMV infection in transfused neonates include respiratory distress, hepatosplenomegaly, thrombocytopenia, hemolytic anemia, jaundice, gray pallor, and atypical lymphocytosis with potential long-term sequelae including microcephaly, motor disorders, and mental retardation.^{71,72} Leukocytes are believed to be the site of CMV latency and thus mediate CMV transmission.^{71,73,74} Selection of CMV seronegative cellular blood components or the use of leukocyte filters are two options for reducing the risk of a transfusion-induced CMV infection. Leukocyte filters can be used to remove 93 to 99% of leukocytes in a relatively safe and inexpensive manner.^{71,72} Additional benefits of leukodepletion over serological screening include prevention of allosensitization in >97% of transfusion recipients and nonhemolytic febrile transfusion reactions.^{72,75}

Noninfectious Complications

Noninfectious complications include coagulation abnormalities, GVHD, cardiovascular abnormalities, electrolyte abnormalities, hypothermia, and air embolism. Thrombocytopenia and coagulation factor deficiency may occur due to the lack of viable platelets and clotting factors V and VIII in stored RBCs.¹¹ Catheterization for transfusion may cause damage to vessel walls increasing the risk for thrombosis of the vessel.¹¹

Posttransfusion GVHD may occur in immunodeficient infants following a transfusion of platelets, whole blood, packed red blood cells, washed erythrocytes, fresh frozen plasma, and leukocytes.⁷⁶ Histocompatible differences are present between the donor blood product and the immunodeficient recipient, which allows the transfused donor lymphocytes to mount an attack against the recipient.⁷⁶ Symptoms of GVHD occur within 100 days of the transfusion and can include dermatitis, wasting, diarrhea, hepatitis, bone marrow suppression, and death.^{11,76} Posttransfusion GVHD can be prevented by the irradiation of blood products with at least 3,000 to 4,000 rad before transfusion to prevent the transmission of viable lymphocytes.^{76,77} Indications for irradiation include congenital immunodeficiency syndrome and bone marrow recipients. The American Association of Blood Banks recommends that all cellular blood products from first-degree relatives undergo irradiation before being used for transfusion since cases of posttransfusion GVHD have occurred due to the HLA similarities between families leading to recognition and destruction of foreign lymphocytes.^{76,78} In summary, irradiation is recommended for all cellular blood products donated from first-degree relatives, patients with congenital immunodeficiencies (proven or suspected), all lym-

phocyte-enriched blood products (platelets, leukocytes) for preterm infants less than 6 months of age, exchange transfusions, and in utero transfusions.⁷⁶

Cardiovascular complications resulting from blood transfusion include volume overload, congestive heart failure, and arrhythmias. In particular, failure to warm the blood may lead to fatal arrhythmias.¹¹ Metabolic abnormalities, more often with exchange transfusions, include hyperkalemia, hypoglycemia, and hypocalcemia.¹¹

Care with transfusing through a venous line is imperative. Negative pressure on a venous line can cause air to enter the venous system risking damage to vessel walls and thrombosis. Transfusion should take place gently through a vein with preference given to the umbilical vein. Transfusion through the umbilical artery should be avoided as this can lead to spasm of the artery and ischemia of the spinal cord with resultant paralysis.¹¹

Conclusions and Future Directions

Transfusion therapy in the preterm neonate, while decreasing in overall frequency, is still a common and necessary therapy. Despite tremendous improvements in the safety of blood product transfusions, serious consideration must be made as to the risks compared with benefits for each transfusion. Neonatal transfusion guidelines and strategies remain controversial with variations among institutions. This will continue to be the case until more definitive, evidence-based guidelines are developed.

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Objectives: At the end of this article the readers will be able to: 1) Discuss advances in the management of newborns and infants with hematological problems. 2) Identify the changes over time in the management of newborns and infants with hematological problems. 3) Describe the responsibilities of the nurse in caring for newborns and infants with selected hematological problems.

Article: Transfusion Therapy

- Multiple transfusion are often required in preterm infants less than
 - 1500 grams
 - 2000 grams
 - 2500 grams
- In today's neonatal intensive care units (NICU), the number of transfusions required per patient is
 - decreasing
 - increasing
 - the same
- In today's neonatal intensive care units (NICU), the donor exposure per patient is
 - decreasing
 - increasing
 - the same
- According to Hume, the greatest decrease in the number of transfusions was seen in preterm infants born at
 - 25-26 weeks gestation
 - 27-28 weeks gestation
 - 29-30 weeks gestation
- An infant's total blood volume is approximately
 - 70 ml/kg
 - 80 ml/kg
 - 90 ml/kg
- The shelf life of stored red blood cells (RBC) is
 - 1-2 weeks
 - 3-4 weeks
 - 5-6 weeks
- Advantages of fresh blood transfusions in the neonate include decreased
 - 2, 3 diphosphoglycerate (DPG) levels
 - fetal hemoglobin
 - RBC life span in the circulation
- The purpose of mannitol or citrate used to preserve blood is to
 - increase the ATP concentration
 - reduce hemolysis of the RBCs
 - stabilize the membrane to avoid shape change
- Heparinized blood must be used within what time frame after collection?
 - 24-48 hours
 - 24-72 hours
 - within 96 hours
- According to general guidelines, the hematocrit in neonates with severe cardiorespiratory disease should be maintained greater than
 - 30%
 - 40%
 - 50%
- According to general guidelines, the hematocrit in preterm infants with apnea should be maintained greater than
 - 25%
 - 30%
 - 35%
- Saline washing of RBCs removes
 - extracellular sodium
 - non-viable RBCs
 - platelets
- To prevent graft versus host disease, granulocyte transfusions must be
 - filtered
 - irradiated
 - saline-washed

14. During the collection process, plasma and platelets are frozen within
 - A. 6 hours
 - B. 12 hours
 - C. 18 hours
15. According to research, an appropriate indication for the use of fresh frozen plasma (FFP) is
 - A. hemoglobinopathies
 - B. pulmonary hemorrhage
 - C. vitamin K dependent bleeding
16. The intravascular colloid oncotic pressure in healthy infants is maintained by
 - A. hemoglobin concentration of RBCs
 - B. serum albumin levels
 - C. sodium and potassium concentrations
17. Intravenous use of albumin increases the critically ill neonate's risk of
 - A. pulmonary edema
 - B. severe sepsis
 - C. thrombi formation
18. Immune mediated thrombocytopenia can be treated with
 - A. albumin solution
 - B. fresh frozen plasma
 - C. intravenous immunoglobulin
19. The donors per transfusion exposure for recipients of cryoprecipitate-derived factor VIII and IX is
 - A. 100
 - B. 1,000
 - C. 10,000
20. The best method of preventing cytomegalovirus (CMV) exposure from a blood transfusion is
 - A. leukocyte filtration
 - B. saline washing
 - C. using CMV seronegative blood
21. According to the current recommendation of the American Association of Blood Banks, irradiation is required for all blood products donated by
 - A. first-degree relatives
 - B. paid donors
 - C. Rh positive donors
22. The best intervention to avoid transfusion related fatal arrhythmias is to
 - A. administration calcium prior to the transfusion
 - B. transfuse over a minimum of 4 hours
 - C. warm the blood via a blood warming device
23. A complication of transfusing blood products through an umbilical artery catheter is
 - A. cardiac arrhythmias
 - B. hypotension
 - C. spinal cord ischemia
24. Indications for irradiation include
 - A. extracorporeal membrane oxygenation
 - B. platelet transfusion in preterms <6 months of age
 - C. severe neonatal septicemia
25. To avoid a rapid deterioration in function, the blood cell product that should be transfused as soon as possible after collection is
 - A. granulocytes
 - B. platelets
 - C. red blood cells