Blood transfusions in anemic Pets

Careful patient and product selection help improve the outcome of blood transfusions in anemic patients.

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The goal of anemia therapy is to improve oxygen delivery to tissues. Hypoxemia causes a cascade of reactions that can lead to cell death if not treated, as shown in *Figure 1* (page 41). In certain situations, blood transfusions can help stabilize the patient and allow the clinician more time to identify the underlying cause of the anemia.

This article will cover triggers for transfusion, supportive patient care before transfusion, blood product selection, sources of product, blood typing and crossmatching, administration of product and transfusion reactions and their treatment.
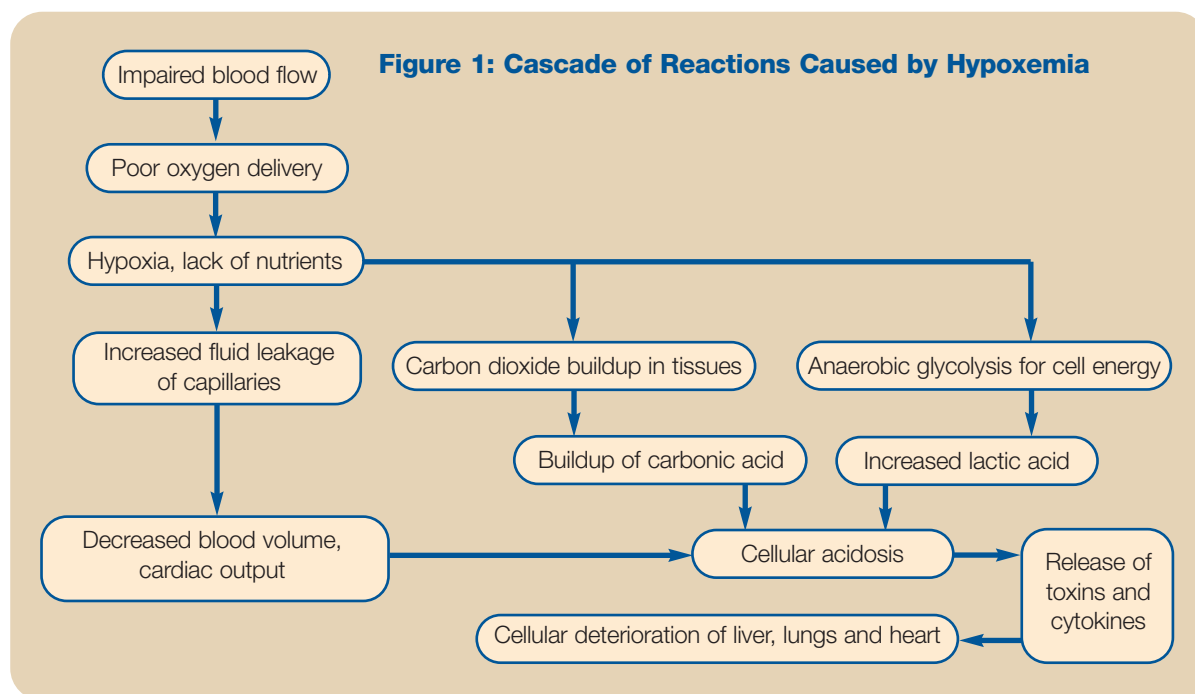
Transfusion triggers

Practitioners need to consider many factors when deciding to transfuse a patient. Transfusions are not given solely to make patients feel better. They carry potentially life threatening risks to patients, and the transfusion benefits must outweigh the risks. Only symptomatic anemic patients should be transfused with a red blood cell (RBC) product to improve oxygen delivery to tissues.[1] In addition to the risks, blood products are costly and should not be used as volume expanders when other means, such as crystalloid or colloid therapy, would suffice.

Identifying clinical signs associated with anemia is the key to evaluating patients for transfusion. The numbers represented by RBC parameters, such as the hematocrit, are not the most important factor to evaluate when deciding if a patient needs a transfusion. For example, a patient may have a normal hematocrit due to splenic contraction; however, the patient may actually be dying due to hemorrhagic shock. A chronically anemic patient may have an abnormally low hematocrit but be able to walk, eat and drink normally because the patient's cells have slowly adjusted to the decreased oxygen supply. Physical examination findings and laboratory values are used concurrently when evaluating a patient's transfusion need.

In people, a hematocrit below 12 percent increases the probability of multiple organ failure.[1] Human and veterinary patients' hemoglobin levels, rate of decline and the ability to compensate are also considered before the decision to transfuse is made. Transfusions do not cure disease;

Figure 1: Cascade of Reactions Caused by Hypoxemia

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Impaired blood flow
        │
        ▼
Poor oxygen delivery
        │
        ▼
Hypoxia, lack of nutrients ──────────────────────────────────┐───────────────────────┐
        │                                                      │                       │
        ▼                                                      ▼                       ▼
Increased fluid leakage          Carbon dioxide buildup in tissues      Anaerobic glycolysis for cell energy
   of capillaries                            │                                         │
        │                                    ▼                                         ▼
        │                          Buildup of carbonic acid              Increased lactic acid
        │                                    │                                         │
        ▼                                    ▼                                         ▼
Decreased blood volume,  ──────────────▶   Cellular acidosis   ──────────▶   Release of
   cardiac output                                                               toxins and
                                                                                cytokines
                            Cellular deterioration of liver, lungs and heart  ◀───┘
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they stabilize the patient to buy the clinician time to diagnose and treat the underlying cause of the anemia. Transfusions also dampen the patient's ability to respond to anemia.[2] More transfusions will be required if the patient cannot produce erythrocytes. A decrease in the RBC mass leads to tissue hypoxia. Hypoxia is a trigger for the release of erythropoietin, which leads to reticulocytosis.

The following factors should be considered when determining transfusion needs:
■ Ongoing hemorrhage
■ Need for surgery or other procedures
■ Poor response to shock therapy.

Practitioners should ask the following questions before transfusing a patient:
■ Is transfusion necessary?
■ What is the need and which product will best support this?
■ Does the benefit justify the risk?
■ Will the transfusion have the expected benefit?

Treat shock, not the hematocrit
One of the important discoveries, I believe … is the realization that anemia is well tolerated … providing blood volume is maintained.[3] –Daniel J. Ullyott

Patients with anemia have many clinical presentations. Anemic patients may present with signs of trauma or a disease that led to the anemia. When a symptomatic patient presents, determine what degree of the clinical signs are due to anemia versus hypovolemic shock (*e.g.*, dehydration from chronic disease or active bleeding). How many veterinarians have had a patient present with a hematocrit of 15 percent and have used intravenous fluids sparingly or not at all, with the fear that providing fluids will worsen the anemia? If you have, it is likely that you are in the majority. The question then becomes, "Will intravenous fluid therapy worsen the anemia?" The answer is no.

Anemia is influenced not only by the patient's RBC mass, but also by the plasma volume.[3] A dehydrated patient in hypovolemic shock does not have a true hematocrit of 15 percent. Dehydration increases the blood's viscosity, which

impedes the flow of RBCs to the tissues to deliver oxygen. Filling the intravascular volume with either crystalloids or colloids will *not* lower the patient's original RBC mass; rather, it will remarkably improve the ability of the RBCs to deliver oxygen to the tissues. An important fact to keep in mind is that 75 percent to 85 percent of the crystalloid fluid will redistribute to the interstitial space within one hour after administration.[4]

Failure to correct hypovolemic shock leads to continued tissue hypoxia, acidosis, release of cytokines and initiation of acute respiratory distress syndrome and organ failure, which will eventually lead to the patient's death.[5] If blood pressure and circulatory volume normalize, normal myocardial oxygen is maintained until the hematocrit is <15 percent.[6] Shock will often precede a decrease in the hematocrit due to splenic contraction or loss of RBCs and plasma at the same time. Without treatment, a decrease in the hematocrit may not be noted until three days after initial bleeding because splenic contraction artificially raises the hematocrit, but a hematocrit decrease may be noted within 24 hours when intravenous fluid therapy is given.

The initial treatment plan for anemic patients should include the following steps:
- Give anemic patients supplemental oxygen until blood pressure, respiratory rate and heart rate normalize. A small amount of oxygen (even if dissolved in plasma) will usually make a difference clinically.[7]
- Manage shock (*e.g.*, crystalloids, colloids, drugs).
- Prevent further bleeding (*e.g.*, pressure, ligation, abdominal wraps, exploratory surgery once stable).
- Minimize stress (*e.g.*, keep patient in a quiet area, avoid painful procedures such as subcutaneous injections, sample blood

Table 1: Properties and Indications

Component	Contains
Fresh whole blood	RBCs, WBCs, platelets, coagulation factors, plasma proteins
Stored whole blood	RBCs, WBCs, plasma proteins, some coagulation factors, platelets
Packed RBCs	RBCs
Oxyglobin	Hemoglobin-based, oxygen-carrying solution
Autotransfusion	Patient's own blood

only when needed).[8]
- Monitor respiratory rate and effort, mucous membrane color, neurologic status and hematocrit/total protein as indications of hemorrhage.

Proper selection of blood products to treat anemia

Once the practitioner decides to transfuse, it

for Use of Different Blood Products

Indications	Advantages	Disadvantages
Hemorrhage, trauma coagulopathy, DIC, thrombocytopenia, anemia	Provides both RBCs and clotting factors	Risk of volume overload in normovolemic patients, difficulty in accessibility to donors
Hypovolemia, anemia, hemorrhage	Readily available if hospital has blood donors; helps to replace volume as well as RBCs	Labile clotting factors (V, VIII) and platelets reduced over time; risk of volume overload in normovolemic patients
Clinically symptomatic anemia, normovolemic anemia, chronic anemia, hemorrhage, cardiac patients, liver patients	Preferred in liver disease; has less ammonia, citrate and sodium	No clotting factors present
Shock, anemia, including immune mediated hemolytic anemia	No cross-matching or blood typing required Long shelf life Does not rely on 2,3-diphosphoglycerate to offload oxygen	Risk of volume overload Hematocrit is not an accurate indicator of successful treatment; need to monitor hemoglobin levels instead Rapidly broken down by body; 30- to 40-hour half-life Interferes with colormetric serum chemistry analyzers and urine dip sticks; hemograms, electrolyte assays and coagulation assays not affected Historically sporadic availability from manufacturer
Rapid hemorrhage during surgery, hemoabdomen or hemothorax	Does not require cross-matching	Reduced coagulation factors and platelets

is important to transfuse the appropriate blood product to minimize risk to the patient. The simplest rule of thumb is to only replace what is lost. If hematocrit is reduced but total protein is normal, packed red blood cells (pRBCs) are the most appropriate choice. If both hematocrit and total protein are low, whole blood or a combination of pRBC and fresh frozen plasma would be appropriate.[8] Specific blood products are summarized in *Table 1*.

Anemia decreases the oxygen-carrying capacity of blood,[3] and oxygenation of tissues is critical to support life. It is a misconception that giving a stored blood product will immediately benefit the anemic patient. RBCs require 2,3-diphosphoglycerate to offload oxygen to

> ### Table 2: Recommended Infectious Disease Screening for Donors
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> **Dogs** Brucellosis, leishmaniasis, heartworm disease, ehrlichiosis, bartonellosis, Rocky Mountain spotted fever, Lyme disease
>
> **Cats** FeLV, FIV, FIP, feline infectious anemia, toxoplasmosis, heartworm disease

tissues,[9] and 2, 3-diphospho-glycerate levels decrease with time in stored blood. Because of this, the longer blood is stored, the less effective it is in oxygen delivery. In people, it takes 24 to 48 hours for the transfused RBCs to replenish the level of 2,3-diphosphoglycerate. Therefore, blood stored for less than 14 days or fresh blood should be used for patients severely compromised by anemia.[3]

Acquiring blood products

Sources of blood products. Blood products may be obtained from animal blood banks, a pool of client- or staff-owned donors, from the patient or from other hospitals.

The benefits to using processed blood products are the relative ease of acquisition, the reduced time and labor to collect blood, the fact that the blood is typed and screened for infectious diseases and that universal donors are often used. Disadvantages are cost and expiration of the products if they are not used.

Unless the hospital has a refrigerated centrifuge, in-house blood products are limited to pRBC, fresh whole blood, stored whole blood and stored plasma. Disadvantages to having a pool of donors are that it is costly to properly type and screen each donor, clients and staff may not be able to bring donors to the hospital when needed and time is required to sedate, prepare and collect blood from the donor.

Many referral or emergency hospitals will sell units of blood to other hospitals if staff members or clients pick up the blood. In some communities, a central blood bank is stationed for the purpose of collecting and storing blood products.

Donor screening. Blood donors should be healthy Pets and must be screened for infectious diseases (*Table 2*). Donors should be current on heartworm prevention and vaccinated. Pets that have had litters or previous transfusions are excluded from the donor pool. Look for good-natured Pets that are easily handled. Breeds with thick skin (Rottweilers) or skin folds on the neck (Bassett Hounds, Mastiffs) make blood collection more difficult than long-necked dogs (Greyhounds). Donor cats should live only indoors to avoid the risk of disease acquisition after disease screening has been done. Predonation hematocrit must be at least 40 percent in dogs and at least 30 percent in cats. All cats and most dogs will require light sedation for blood collection.

Some reference laboratories have a blood-donor profile for dogs that includes screening tests for tick-borne diseases, brucellosis, blood type and thyroid screening as well as a standard blood panel. In cats, it can take three months for feline leukemia virus (FeLV) to become patent; therefore, it is recommended practitioners test potential feline donors for FeLV monthly for three consecutive months.

In some cases when blood is not available in the hospital or from screened donors, a healthy Pet, current on preventive care and heartworm prevention, may be the best option available. Sometimes the owner may have another Pet or a friend or family member's Pet that can be brought into the hospital. A thorough physical examination, complete blood count, manual differential, internal organ function screen and an in-house heartworm/Lyme disease/ehrlichiosis

test or FeLV/feline immunodeficiency virus test should be performed. Crossmatching is required in cats before every transfusion. Cat blood-typing cards and canine DEA 1.1 cards are available.

If time is of the essence and the patient is not doing well, treat shock if present and consider referral to an emergency or specialty facility.

Autotransfusion. Transfusion of the patient's own blood (autologous transfusion) has several advantages over homologous transfusions. The blood is readily available, decreases costs to the client, is compatible, eliminates infectious disease risk, has adequate levels of 2,3-diphosphoglycerate and decreases circulatory overload. Autotransfusion therapy is most commonly used for hemorrhagic shock. Common scenarios are trauma (splenic, hepatic rupture) and hemorrhage during surgical procedures.

Blood that has been sitting in the peritoneal cavity for an hour does not require anticoagulants due to defibrination and platelet destruction at the peritoneal surface. Anticoagulants are required in the case of rapid ongoing hemorrhage from trauma or during surgical hemorrhage. Hemolysis occurs when blood rests against serosal or peritoneal linings, so blood left sitting more than four to six hours should not be autotransfused.[10] It is recommended to add 25 to 30 mL CPDA-1 to 500 mL of blood. Complications associated with autotransfusions are hemolysis, thrombocytopenia, coagulopathies, sepsis (due to fecal contamination of the blood) and dissemination of malignancy.[10]

In nonemergency situations, blood may be collected from the patient in preparation for surgery where there is a potential for extreme blood loss. Blood is either collected and stored up to three weeks before surgery,

or blood is withdrawn the day of surgery and the patient is given 3 mL crystalloids for every 1 mL blood withdrawn. Blood can be stored at room temperature for up to six hours before being discarded (to preserve platelet function).[10]

Administration of products

Blood typing. Different blood types are found in both canine and feline patients. Blood types are categorized by genetic markers on erythrocytes that are both antigenic and species-specific.[11] Cats have a blood grouping system consisting of types A and B with three blood types: A, B and AB. All feline donors should be typed. If the blood type is not known, performing a major crossmatch will detect incompatabilities.[12] The vast majority of cats in the United States are type A (99 percent). Some breeds have a higher prevalence of type B (*e.g.*, Exotic and British Shorthair, Devon Rex, Cornish Rex, Abyssinian, Japanese Bobtail, Birman, Scottish Fold, Persian, Himalayan, Somali, Sphinx, Maine Coon).[13] In comparison, no type Bs are found in Siamese, Burmese, Tonkinese, Russian Blues, Oriental Shorthairs or Ocicats.[7]

There are eight commonly recognized canine blood types, although as many as 12 may exist.[13] Canine blood types are classified in terms of the dog erythrocyte antigens (DEA) that are present in their blood. Of these, DEA 1.1, DEA 1.2 and possibly DEA 7 are thought to be significant in causing RBC lysis.[14] Canine donors should be DEA 1.1- and 1.2-negative. The blood type most prone to reactions is DEA 1.1. If a DEA 1.1-negative dog is given DEA 1.1-positive blood, the patient is sensitized to the DEA 1.1-positive antigen. If that patient is given DEA 1.1-positive blood again, an acute hemolytic reaction may

occur. However, it is safe to give DEA 1.1-positive blood to an already DEA 1.1-positive patient.[11]

Crossmatching. Crossmatching detects antibodies in the serum of one patient against the RBC antigen of another. It does not predict future compatibility or confirm blood type. Two crossmatching procedures are used: a major and minor. The major crossmatch looks for alloantibodies of recipient plasma against the donor RBCs, whereas the minor looks for alloantibodies of the donor plasma against the recipient's RBCs. The minor crossmatch is of less concern when pRBCs are being used because most of the plasma and donor antibodies have been removed.[11]

In dogs, the first transfusion is typically compatible. Any transfusion given thereafter may not be compatible even if using blood from the same donor, and crossmatching should be performed. Cats are different in that they possess naturally occurring alloantibodies and must always be crossmatched. Type B cats possess strong antibodies against type A RBCs. A type B cat receiving either A or AB blood may have a fatal reaction with as little as 1 mL of transfused blood.[11] Type A cats have mild antibodies against type B RBCs. Because of these naturally occurring antibodies, a quick crossmatch for cats may be performed by mixing one drop of blood from the donor with two drops of plasma from the recipient and observing for agglutination. This will evaluate the major crossmatch. To perform a minor crossmatch, use one drop of blood from the recipient and two drops of plasma from the donor and observe for agglutination.[11]

Dogs require a more involved crossmatching process as outlined below:

1. Collect 2 mL of blood into EDTA tubes from the recipient and donor. Previously collected bags should have crossmatching segments in the tubing to use.

2. Centrifuge samples for five minutes at 1,000 rpm.

3. Pipette plasma from the RBCs and save. Use separate pipettes for donor and recipient and label appropriately.

4. Wash RBCs with saline by mixing 0.5 mL RBC with 3 mL to 4 mL saline, and spin for 30 seconds. Pipette off supernatant and discard. Repeat two more times. After discarding supernatant the third time, mix 0.2 mL RBCs with 4.8 mL saline.

5. Place 0.1 mL of donor RBCs in three test tubes with 0.1 mL patient serum for major crossmatching (0.1 mL recipient RBCs with 0.1 mL donor serum for minor crossmatching).

6. Incubate one tube at body temperature ($37^{\circ}C$), one at room temperature ($25^{\circ}C$) and one at refrigerator temperature ($4^{\circ}C$) for 15 minutes.

7. Centrifuge samples for one minute at 1,000 rpm.

8. Observe for hemolysis, which shows as a red color to the plasma that does not clear after the blood is spun.

9. Gently agitate tubes to resuspend cells, place one drop on the slide from each tube and observe for agglutination.

Key points to remember are that crossmatches may not be able to be properly interpreted in patients autoagglutination or with patients that have very low hematocrits (<10 percent),[4] A-B mismatch in cats should be avoided and DEA-positive blood should not be given to DEA-negative dogs.

Determining dose. RBC products should be transfused with a goal of reaching 25 percent to 30 percent hematocrit in recipient dogs and 20 percent in recipient

cats.[14] The volume of whole blood to be administered is calculated from the following equation:

$$\text{Dogs: [Recipient weight (kg) x 90*]} \times \frac{\text{(Desired hematocrit – Recipient hematocrit)}}{\text{Donor hematocrit}}$$

*In cats, multiply weight by 60

Warming products. It is usually not required to warm whole blood or pRBCs unless the patient is at risk for hypothermia (*e.g.*, small or pediatric patients) or the volume to be transfused is large.[1] If warming is required, the product should be warmed to room temperature and is not to exceed 37ºC (98.6ºF). This minimizes the risk of hemolysis and degradation of coagulation factors and proteins.[15]

Premedication. Allergic reactions are one of the most common transfusion reactions in Pets, so administer diphenhydramine 2 to 4 mg/kg intramuscularly 15 to 20 minutes before beginning the transfusion.[15]

Administration. Blood products must be given through a dedicated intravenous fluid line that is solely used for the transfusion during the time which a blood product is administered. No medications or other fluids other than saline may be given through this line during the transfusion. The line should contain a 170 μm filter to remove microthrombi.[1] Any blood product should be transfused within four hours to minimize the risk of bacterial contamination.[14] Additional guidelines for administration are shown in *Table 3* (page 50).

Table 3: Recommended Rates and Guidelines for Blood Product Administration

Product	Dose	Rate	Special considerations
Whole blood	10 to 22 mL/kg	5 to 10 mL/kg/hr	Slow to 1 to 4 mL/kg/hr in cardiac, hypertensive or hyperviscosity disorders
pRBCs	6 to 12 mL/kg	5 to 10 mL/kg/hr	Same as whole blood
Oxyglobin	Dogs 10 to 30 mL/kg Cats 5 to 15 mL/kg	10 mL/kg/hr 5 mL/kg/hr	Use with extreme caution in cardiac patients and cats

Monitoring the patient during and after the transfusion. When patient stability allows, transfusions should be started slowly for the first 30 minutes and the patient carefully monitored. There are exceptions, such as hypovolemic shock and severe hemorrhage, which may dictate a more rapid administration rate.

1. Obtain pretransfusion body temperature, heart rate, mucous membrane color, capillary refill time and respiratory rate, including a subjective evaluation of the respiratory effort.

2. Start transfusion at 0.25 mL/kg for the first 30 minutes.

3. Monitor body temperature, heart rate, mucous membrane color, capillary refill time and respiratory rate 15, 30 and 60 minutes into the transfusion and every 30 minutes thereafter until transfusion is completed. Also watch for vomiting, urticaria, hemoglobinuria and hemoglobinemia.

4. Obtain and evaluate hematocrit/total protein at one, 24 and 72 hours after transfusion.

Hematocrit will fluctuate over the next 24 hours depending on the patient's initial state and the product given. Hemoglobin increases after transfusion; however, the intravascular volume will take 12 to 24 hours post-transfusion to stabilize due to fluid shifts to and from the extravascular space.[16] A hypovolemic patient given whole blood is expected to have a higher hematocrit 24 hours after a transfusion due to fluid shifts into the extracellular space as compared to a hypovolemic patient given pRBCs, which will draw fluid from the extracellular space into the vascular space.[3] Compare the expected hematocrit with the actual value to help determine if the transfusion had the desired effect. If the hematocrit is lower than expected, look for evidence of continued hemorrhage or hemolysis.

Transfusion reactions

Transfusion reactions are adverse effects resulting from the administration of blood products. They are classified as immunologic or nonimmunologic and acute or delayed.

Most reactions will happen acutely, but there may be delayed reactions, such as delayed immune-mediated hemolysis, neonatal isoerythrolysis, post-transfusion purpura and transmission of an infectious disease to the patient. The client should be warned of these possibilities. Acute nonimmunologic reactions can include potential hemolysis due to blood product storage issues, bacterial contamination, volume overload and citrate toxicity.

Acute immunologic transfusion reactions

Acute hemolytic transfusion reaction. An

Table 4: Treating Transfusion Reactions

Transfusion reaction	Clinical signs	Therapy
Acute hemolysis	Tachypnea Fever Hemoglobinemia Hemoglobinuria Shock	Stop transfusion, administer dexamethasone sodium phosphate (Dex SP) 4 to 6 mg/kg IV, saline diuresis, maintain urine output at 1 to 2 mL/kg/hr, blood pressure at 80 to 100 mm Hg systolic. Consider dopamine 5 µg/kg/min IV, furosemide 1 to 2 mg/kg IV. Monitor for DIC, renal failure and shock.
Acute lung injury	Bilateral pulmonary edema one to six hours after administering plasma-containing product Fever; Hypotension	Administer IV fluid therapy and oxygen. Treatment should last 96 hours. Do not give diuretics. This will increase the viscosity of fluid.[13]
Allergic reaction	Fever Pruritus Urticaria Angioedema Vomiting Erythema Tachypnea	Stop transfusion, administer diphenhydramine 2 mg/kg IM +/- Dex SP 0.5 to 1.0 mg/kg IV in mild cases. Consider Dex SP 4 to 6 mg/kg IV and epinephrine 0.01 mg/kg IV in severe cases. Restart transfusion at slower administration rate.
Anaphylactic shock	Collapse	Stop transfusion, initiate fluid support and administer epinephrine and Dex SP as above.
Bacterial contaminant	Fever Shock Tachypnea Tachycardia Vomiting	Stop and remove contaminated lines/catheters, collect donor blood sample and patient blood and urine for culture and begin empirical IV antibiotic treatment and IV fluids (colloids or crystalloids) to maintain blood pressure.
Citrate overdose	Hypocalcemia Tremors Cardiac arrhythmias Seizures	10 percent calcium gluconate or calcium chloride 90 to 140 mg/kg slow IV (20 minutes) under ECG monitoring (bradycardia, sudden elevation of ST segment or shortened QT interval).
Febrile nonhemolytic	>1.0ºC over initial body temp Bradycardia	Stop transfusion. If mild without other signs, try to restart in 10 to 15 minutes. Monitor temp, give Dex SP 1 mg/kg IV[13] or ketoprofen 1 mg/kg SQ.

Table 4: Treating Transfusion Reactions, Cont.

Transfusion reaction	Clinical signs	Therapy
Hyperkalemia	ECG abnormalities	Stop transfusion, administer IV 0.9 percent saline, dextrose 0.5 g/kg with 0.25 to 0.5 U/kg regular insulin and 2 g dextrose per U insulin administered.
Hypothermia	Low body temperature	Stop transfusion, warm blood products and begin external warming of patient.
Neonatal isoerythrolysis	Failure to thrive Weakness Hemoglobinuria	Pull puppies from bitch for 72 hours, administer universal blood transfusion via intramedullary catheter to the puppies.
Post-transfusion purpura (thrombocytopenia)	Petchiae Ecchymoses Epistaxis Pale mucous membranes	Blood transfusions as needed, corticosteroids (prednisone 2 to 4 mg/kg/day PO).
Volume overload	Tachypnea Pulmonary edema Increased CVP	Stop transfusion, administer furosemide (2 to 8 mg/kg IV), oxygen, restart transfusion at lower rate and consider a different blood product

acute hemolytic transfusion reaction is a potentially life-threatening type 2 hypersensitivity reaction that occurs when a patient has preexisting antibodies to a donor's erythrocytes.[13] Common causes are administration of feline type A blood to a type B patient or sensitization from previous transfusions or pregnancy.[1] Compatible canine erythrocytes have a half-life of 21 days; in comparison, DEA 1.1 and DEA 1.2 incompatible RBCs have an expected half-life of only 12 hours.[15]

Clinical signs associated with an acute hemolytic transfusion reaction may include the following: vomiting, pyrexia, tachycardia, dyspnea, hypotension, seizures, restlessness, salivation, tremors, urine or fecal incontinence and collapse.[1,6,15] Intravascular hemolysis results in hemoglobinemia and hemoglobinuria shortly after the transfusion starts. Disseminated intravascular coagulation (DIC), shock and possible renal damage may result. Extravascular hemolysis leads to hyperbilirubinemia and bilirubinuria and tends to cause a milder reaction than intravascular hemolysis.[13]

When a reaction is suspected, stop the transfusion; then treat the shock using IV fluids, dexamethasone and pressors as needed to maintain blood pressure. Blood from the patient and the donor bag should be spun down and observed for hemoglobinemia. Luckily, these reactions are rare in dogs.

Allergic reactions. Allergic reactions are type 1 hypersensitivity reactions that occur when IgE antibodies on the patient's mast cells or basophils interact with antigens from the donor's blood.[13] More

commonly associated with plasma transfusions than with RBC products, clinical signs are usually mild and range from pruritus to erythema, urticaria and pyrexia. However, type 1 hypersensitivities can progress to anaphylactic shock in some cases.[1]

Febrile nonhemolytic transfusion reactions. A 1ºC or greater rise in body temperature during or after a transfusion is called a febrile nonhemolytic reaction. This is the most common transfusion reaction in both veterinary and human medicine.[13] Febrile nonhemolytic reactions are caused by antigens on donor leukocytes and platelets reacting with antibodies in the recipient's plasma. To treat this condition, in-line filters can be used to help remove leukocytes from the donor's blood. Slowing or temporarily stopping the transfusion is recommended, as is administration of diphenhydramine with or without a nonsteroidal anti-inflammatory to control fever.[15] The patient must be assessed to determine whether the fever is an early sign of a more serious reaction.

Transfusion-related acute lung injury. Most commonly associated with plasma-containing products, transfusion-related lung injury results in pulmonary edema, fever and hypotension one to six hours after administration.[13] It is crucial to rule out cardiac disease and volume overload as potential causes, as standard diuretics will not resolve the condition due to the high protein content of the edema.

Treatment of transfusion reactions

The key to treating a transfusion reaction (see *Table 4*, page 52) is early recognition and initiation of treatment.

Systematic approach for transfusion reactions:

1. Stop the transfusion.

2. Inspect the donor blood (*e.g.*, type, species, expiration date).

3. Review medical record of patient—previous transfusions or pregnancy? Review transfusion procedure.

4. Collect blood and urine samples from the patient. Look for hemolysis, icterus, hemoglobinuria or bilirubinuria. Save for possible Coombs testing and culture.

5. Spin down samples from donor's blood and recipient's pretransfusion blood and inspect for hemolysis. Check donor's blood for contamination, Gram stain if indicated and culture if questionable.

6. Evaluate ECG, blood pressure, potassium and calcium of patient—treat electrolyte abnormalities and shock if indicated. Auscultate the lungs and perform chest radiographs if needed.

7. Repeat blood type and crossmatch if hemolysis is occurring. Consider Coombs testing.

8. If fever is persistent without signs of hemolysis, shock or bacterial contamination, restart the transfusion.

The best way to minimize transfusion reactions is to appropriately screen the donor and recipient (*e.g.*, blood typing, crossmatching, screening for infectious disease), following aseptic techniques for collection and administration of blood products, select the correct component and stringently monitor the patient during and after the transfusion.

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