State of the Art Review

Platelet transfusions: treatment options for hemorrhage secondary to thrombocytopenia

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Abstract

Objective – To review current human and veterinary protocols for platelet transfusion triggers, available platelet transfusion products to support veterinary thrombocytopenic patients, and the advantages and disadvantages of each product.

Data Sources – Data from human and veterinary literature.

Human Data Synthesis – Prophylactic and therapeutic platelet transfusions are instrumental in managing human patients with thrombocytopenia. The platelet transfusion products used in human medicine consist of platelet concentrates, derived from pooled random donor platelets, or single-donor apheresis platelets. Historically, platelet transfusions in human medicine have been prophylactic in nature; however, recent research suggests changing from a prophylactic transfusion strategy to a therapeutic transfusion strategy may be safe for most patients. The optimal platelet transfusion trigger and the use of prophylactic verses therapeutic platelet transfusions are ever changing in human medicine.

Veterinary Data Synthesis – There have been many advances in platelet transfusion products, but fresh whole blood remains the most commonly used platelet transfusion product in veterinary medicine. New products such as lyophilized platelets and cryopreserved platelets offer the benefits of long shelf life, immediate availability, and higher concentration of platelets at smaller doses. Veterinary platelet transfusion guidelines are mostly extrapolated from human literature because data on veterinary platelet transfusions are lacking.

Conclusions – In veterinary medicine the most commonly available product for platelet transfusions is fresh whole blood, because of availability of blood donors and lack of a cost effective easily obtainable alternative. Cryopreserved and lyophilized platelets are promising new products being used in the treatment of hemorrhaging patients with thrombocytopenia. These products offer increased platelet concentrations at decreased volumes, longer storage shelf life, and decreased exposure to whole blood products. With the development of newer readily available products, platelet transfusion parameters, to include dose, platelet count trigger, presence of disease, and clinical signs, should be further evaluated in veterinary medicine.

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Introduction

Thrombocytopenia is a common clinical syndrome seen in emergency veterinary patients and is the most common acquired hemostatic defect of dogs and cats.[1] There are many causes of thrombocytopenia, including accelerated removal, decreased production, increased consumption, increased sequestration in the spleen, and sample dilution. The most common cause of severe thrombocytopenia in dogs is idiopathic (or primary) immune-mediated thrombocytopenia and is mainly a diagnosis of exclusion.[2] Other secondary causes of thrombocytopenia include drug induced thrombocytopenia, infectious causes (*Ehrlichia* species and viral induced),

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Abbreviations

aPLT:PRBC	apheresed platelet: packed RBC ratio
CPDA1	citrate-phosphate-dextrose-adenine
CPD	citrate-phosphate-dextrose
FWB	fresh whole blood
LYO	lyophilized platelets
MT	massive transfusion
PC	platelet concentrate
PRBC	packed red blood cells
PRP	platelet-rich plasma

incompatible transfusions, parasites (*Dirofilaria* species), disseminated intravascular coagulation, and vasculitis. In the absence of identifiable causes of thrombocytopenia, immune mediated antibodies directed towards the platelet surface are suspected. A detailed description of each etiology is beyond the scope of this review.

Despite advances in blood component products, platelet transfusion in hemorrhaging thrombocytopenic veterinary patients can be difficult. Dogs with thrombocytopenia often present with superficial hemorrhage, but it is usually nonlife-threatening. Examples of superficial bleeding in thrombocytopenic patients include petechia, bleeding from mucous membranes, epistaxis, and periocular bleeding. However, when thrombocytopenic dogs are hemorrhaging into vital organs (eg, brain, lungs, gastrointestinal tract) or into body compartments (eg, cranium, thorax) rapid therapeutic measures are required. Anemia and hypovolemia should be treated appropriately with crystalloids, colloids, packed red blood cells, and whole blood as indicated.[3] Specific treatment of thrombocytopenia with platelet therapy is indicated in patients that are actively bleeding or about to undergo invasive procedures; however, it has many challenges. Some of the specific challenges associated with platelet therapy are the lack of readily available blood donors for obtaining fresh whole blood (FWB), high cost and difficult logistics involved in producing and storing many platelet products, and the need for large numbers of platelets to meet the dog's transfusion needs.[4] The purpose of this article is to review the current human and veterinary protocols for platelet transfusion triggers, available platelet transfusion products to support veterinary thrombocytopenic patients, and the advantages and disadvantages of each product.

Platelet Physiology

Platelets are nonnucleated cytoplasmic fragments that originate from megakaryocytes. The primary location of platelet production is the bone marrow, with minimal production in the liver, spleen, kidney, and lung. Although platelets are cytoplasmic fragments, their structure is complex. Platelet membranes are composed of a bilayer of phospholipids that form a hydrophobic core that contain proteins and glycoproteins that serve as specialized receptors.[5] An example of these specific receptors is the GP Ib-IX-V complex that functions as the receptor for von Willebrand factor (vWF).[5] Microtubules forming a circumferential band located just beneath the membrane surface maintain the disc-shaped form of nonactivated platelets. Also located in the cytoplasm are storage granules (eg, alpha, dense, and lysosomal), scattered mitochondria, and small accumulations of glycogen.[5] Platelets function to form a temporary hemostatic plug at the site of vascular injury through shape change, adhesion, aggregation, and secretion. Platelets also play an important role in the maintenance of normal hemostasis by plugging gaps in the endothelium of intact blood vessels.[6] For example, thrombocytopenia is associated with a gradual thinning of vessel walls, and over time the space between endothelial cells widens producing gaps between the cells.[7,8] This thinning of the vessel walls and increased endothelial gaps results in increased use of circulating platelets.[9] To illustrate this point, human patients undergoing chemotherapy with total platelet counts $<100 \times 10^9$/L ($<100,000/\mu$L) often require platelet transfusions every 3 days due to this phenomenon.[10] It is estimated in people that 10–15% of all platelets are removed from circulation daily and a fixed platelet count of 7.1×10^9/L/d is required to maintain normal hemostasis.[11] In order to prevent spontaneous bleeding in healthy people, there appears to be a basal physiologic requirement for platelets; however, in times of illness such as sepsis, fever, and inflammation this requirement increases.[6]

Indications for Platelet Transfusions

The primary indications for a platelet transfusion is the management of uncontrolled or life-threatening bleeding from severe thrombocytopenia or thrombocytopathia.[4] Specific situations of concern are internal bleeding into the lungs, brain, and myocardium. Patients with thrombocytopenia or thrombocytopathia that need invasive life saving procedures, including surgery, may need preemptive treatment with platelet transfusions. Platelet transfusion guidelines, or platelet transfusion triggers, are a subject of much debate in human literature. In human medicine, the traditional platelet trigger, or platelet threshold, is a platelet count $< 20 \times 10^9$/L.[12] However, researchers have performed a number of studies to determine if lower platelet counts plus the presence of clinical abnormalities should be used as a more appropriate transfusion trigger than just platelet count alone. Slichter[12] evaluated prophylactic platelet transfusions in thrombocytopenic patients at platelet counts of 5, 10, and 20×10^9/L and demonstrated no difference in blood loss in stool samples. This study suggested that lowering the platelet transfusion threshold from 20×10^9/L to 5×10^9/L may be safe in patients that are not actively bleeding. In human medicine, the vast majority of platelet transfusions are prophylactic, not therapeutic, in nature. For example, Greeno et al[13] prospectively collected data from platelet transfusions in an academic hospital for a period of 6 months to determine platelet transfusion numbers when the transfusion threshold was lowered from 20×10^9/L to 10×10^9/L.[13] During the 6-month study period, 503 patients

received 7401 platelet transfusions with 74% being prophylactic in nature, 18% therapeutic, and 8% administered prior to surgery or invasive procedures in patients with coagulopathies or at a high risk of bleeding.[13] The following platelet thresholds are derived from human literature. A platelet count $>10 \times 10^9$/L (10,000/µL) is considered adequate to prevent spontaneous bleeding, while spontaneous bleeding rarely occurs with platelet counts $>20 \times 10^9$/L (20,000/µL).[14] The platelet transfusion threshold for bleeding, septic, or hemodynamically unstable patients should be increased from 10×10^9/L (10,000/µL) to $15–20 \times 10^9$/L (15,000–20,000/µL).[14] A further increase in the transfusion threshold to $30–50 \times 10^9$/L (30,000–50,000/µL) is recommended for patients with life-threatening bleeding into the thoracic cavity or cranium.[14] Many surgeons require platelet counts of 25×10^9/L (25,000/µL) for multilumen catheter placement and 50×10^9/L (50,000/µL) for invasive procedures to include surgery and biopsies.[14] However, there is little supporting evidence for these practices and they may or may not be unnecessary or counterproductive.[14]

Massive transfusions (MTs) are another indication for platelet transfusions.[4] The definition of MT is extrapolated from human literature as receiving a volume of whole blood, or blood components, greater than the patient's estimated blood volume within a 24-hour period or half of the estimated blood volume in 3 hours.[4] New data from deployed military health care professionals are causing medical professionals to reevaluate the role of platelet transfusions in MT. Multiple studies have demonstrated that increasing the apheresed platelet: packed RBC ratio (aPLT:PRBC) improves survival at 24 hours and 30 days when the aPLT:PRBC ratios exceeded 1:8.[15,16] Perkins et al[15] performed a retrospective review of trauma patients admitted to a combat support hospital between January 2004 and December 2006, concluding that a transfusion ratio of ≥1:8 (platelet:PRBC) is associated with improved 24-hour and 30-day survival in massively transfused military patients when the MT was performed within 24 hours of injury.[15] Gunter et al[16] performed a retrospective study on all trauma exsanguination protocol activations (ie, a system in which a predetermined ratio of plasma, platelets, and PRBCs are provided for resuscitation of patients presented to trauma centers) in an academic Level I trauma center, and concluded that increased platelet:PRBC ratios during MT improved survival after major trauma.[16] As an example, Gunter et al implemented a trauma exsanguination protocol where the attending trauma physician would determine, through analysis of the patient, physiology, and complexity of the injury, that the patient would require blood components beyond routine use. For the initial blood products the blood bank would prepare 10 units of PRBC, 4 units of plasma, and 2 units of platelets.[16] Subsequent blood components would be prepared as 6 units of PRBC, 4 units of plasma, and 2 units of platelets.[16] In another study by Inada et al,[17] patients at a Level I trauma center receiving an aPLT:PRBC ratio approaching 1:6 showed an improvement in overall survival.[17] Holcomb et al[18] performed a retrospective multicenter study involving 16 Level I trauma centers concluding that high plasma and high aPLT:PRBC ratios were associated with increased 6-hour, 24-hour, and 30-day survival and decreased ICU, ventilator, and hospital days with no change in multiple organ failure deaths in humans receiving MTs.[18] The previous study suggested that conventional MT guidelines may underestimate the most advantageous plasma/platelet/RBC ratios and that MT guidelines should target the 1:1:1 ratio of plasma/platelets/RBCs.[18]

Veterinary studies examining MT are limited and currently only 1 study exists. Jutkowitz et al[19] performed a retrospective study on dogs receiving MT in a university teaching hospital that suggested that MT is possible and potentially successful in dogs.[19] The etiologies necessitating the need of MT included abdominal neoplasia, trauma, gastric dilatation-volvulus, gastrointestinal hemorrhage secondary to ulceration and thrombocytopenia, and septic peritonitis.[19] Patients requiring MT inevitably have high mortality rates, and the mortality rate for this study approached 74% that limited the author's ability to make conclusions as to the relative risk factors.[19] However, this study did suggest that dogs needing MT can be successfully managed with aggressive monitoring for electrolyte changes (eg, hypocalcemia and hypomagnesemia), coagulation abnormalities (eg, prolongation of the prothrombin time and activated partial thromboplastin time), and thrombocytopenia.[19]

Platelet Dosing

The standard dosing protocol for human platelet transfusions is 6 units of whole-blood derived platelets (in the form of platelet concentrate [PC]) or a single unit of apheresis platelets.[6] However, there is no clearly defined optimal dose in human literature. The standard of practice in human medicine is prophylactic platelet transfusions are not needed when the platelet count is $>10 \times 10^9$/L (>10,000/µL) or prior to invasive procedures if the platelet count is $> 25 \times 10^9$/L (25,000/µL).[14] Therapeutic platelet transfusions are considered effective if the platelet count is raised $>20–30 \times 10^9$/L (20,000–30,000/µL); however, many experts advocate a threshold of $50–100 \times 10^9$/L (50,000–100,000/µL) for major surgeries.[14]

A number of studies investigating large/infrequent versus small/frequent platelet dosing strategies have been performed in human medicine.[20–22] The theories supporting each dosing strategy are that large/infrequent transfusions would decrease the number of individual transfusion episodes and small/frequent platelet transfusions would decrease the number of platelets needed in a large patient population and decrease the number of exposures to blood products for individual patients. Hersh et al developed a differential mathematical equation for platelet loss in humans and compared their results with data derived from platelet survival data in normal, thrombocytopenic, and thrombocythemic patients after high-dose chemotherapy, concluding that larger doses of platelets would increase the time between transfusion but smaller more frequent doses of platelets would decrease the total number of platelets transfused.[22] Norol et al[21] conducted a prospective study involving 69 adults and 33 children that required platelet transfusions after induction of chemotherapy or conditioning for allogenic bone marrow transplantation, concluding that high doses of platelets in thrombocytopenic patients can significantly reduce the need for further transfusion support and reduce donor exposure.[21] These studies illustrate that the optimal dose of platelets has not been clearly defined and individual preferences tailored to the requirements of the patient, costs, and supply, heavily influence decisions.[23]

Platelet Products

Fresh whole blood

FWB is the product most often used in veterinary medicine to provide platelets to thrombocytopenic animals, in contrast to human medicine where FWB transfusions has typically not been used for decades.[24] In the private practice setting, this is the product that is most readily available via blood donors, negating the cost of storing other blood and platelet products, which can be expensive if products are not used in a timely manner. It is important to always use aseptic techniques when collecting and administering blood to reduce the risk of bacterial contamination. All blood donors should weigh >27 kg, be tested for potential infectious diseases, blood type identified, have a hematocrit >40%, and should not have been previously pregnant, to reduce exposure to foreign red blood cells and antibody formation.[25,26] Donor dogs, weighing over 27 kg, can donate 450 mL (or 16 mL/kg) every 3 weeks without experiencing adverse effects.[25,26] Collection and storage of FWB has improved over the years, from glass collection bottles to plastic collection bags with multiple satellite bags that aid in separating FWB into its components.[25] The 2 important components that all blood collection systems contain regardless of manufacturer are an anticoagulant and preservative for red blood cells. Heparin can be used as an anticoagulant at a dose of 5–10 units/mL of blood; however, heparin has no preservatives and should be administered shortly after collection.[27] Anticoagulant preservatives that are commonly used include citrate-phosphate-dextrose (CPD), and citrate-phosphate-dextrose-adenine (CPDA1). CPD and CPDA1 can be used to store blood for up to 35 days.[27,28] There are other preservatives, Adsol and Nutricel, for example, that can extend the storage of packed red blood cells for approximately 5 weeks, but the viability of platelets stored in whole blood for this extended amount of time has not been proven. One prospective study involving 18 dogs used FWB collected in CPDA1 to assess platelet aggregation with storage time and temperature, suggesting that canine platelets maintain viability when stored at room temperature for up to 8 hours in CPDA1 treated FWB.[29] Once FWB is collected it should be stored at room temperature for a maximum of 8 hours and continuously rotated.[17,29] However, Hughes et al[30] performed a prospective study in which 10-CPD whole blood units from human volunteers were collected and divided into 2 equal volumes, one-half of each unit was then stored at 19°C (66.2°F) and the other half was stored at 25°C (77°F). At 6, 24, 48, and 72 hours post collection, aliquots of platelet-rich plasma were assessed via aggregometry.[30] Their findings indicated that storage of whole blood at room temperature for 72 hours only modestly reduced platelet function and coagulation factor activity as compared to published literature values.[30] The authors did note some disadvantages of storing FWB at room temperature for this time period, among others they included the potential for bacterial contamination and overgrowth and that cytokines produced by white blood cells, which may cause immunomodulatory effects, will persist even if the white blood cells are removed.[30] Clearly, long-term storage of FWB is limited because of the risk of bacterial contamination and loss of platelet function. It is recommended to never chill or refrigerate FWB as platelets will become dysfunctional and will be quickly cleared from circulation. Advantages of administering FWB to treat hemorrhage secondary to thrombocytopenia are that platelets are not lost during processing, plasma from FWB contains liable clotting factors, and FWB should be used to treat microvascular bleeding refractory to treatment with blood components.[31–33] Limitations of using FWB are the need for multiple donors for repeated dosing, the need for cross-matching, the need to use the blood within 4–8 hours after collection, and if the patient is not anemic FWB is not indicated as part of the treatment protocol. It is important to remember that transfusions reactions can occur with any type of blood product. A detailed description of transfusion

related reactions is beyond the scope of this article but can include: acute immunologic transfusion reactions (eg, immune-mediated hemolysis, febrile nonhemolytic reactions, allergic reactions, and transfusion-related acute lung injury) acute nonimmunologic transfusion reactions (eg, transfusion-associated sepsis, transfusion-associated circulatory overload, nonimmune-mediated hemolysis, and air embolism), and delayed transfusion reactions (eg, immune-mediated hemolysis).[34] The average platelet count from a 500 mL unit of canine blood contains approximately 70×10^9/L and the dose of 10 mL/kg of whole blood is expected to raise the platelet count by about 10×10^9/L (10,000/μL).[21] Adding 10,000/μL of platelets to an actively bleeding patient may not be sufficient to stop active bleeding, depending on the underlying disease process; therefore, continued monitoring of the patient is recommended. FWB is the appropriate treatment for acute anemic thrombocytopenic patients that are bleeding; however, in nonanemic patients the amount of transfused red blood cells may lead to development of polycythemia, and volume overload.[35]

Fresh Platelet Products

Platelet rich plasma (PRP) is produced from FWB that is held at 22°C for up to 8 hours and then centrifuged at $1,000 \times g$ for 4 minutes as a "soft spin."[36] The supernatant is removed and stored as PRP or processed further by centrifuging at $2,000 \times g$ for 10 minutes, known as a "hard spin" to produce PC.[36–38] One unit of FWB will yield 1 unit (approximately 200 mL) of PRP.[35] PC, approximately 40–70 mL, is stored at room temperature and gently rocked for approximately 30 minutes prior to use.[36] Platelet yields for both products range from $80–100 \times 10^9$/L (80,000–100,000/μL) to $> 100 \times 10^9$/L (1,000,000/L) with greater than 80% of units having $>5.5 \times 10^{10}$/L.[36] Platelet recovery after processing is approximately 80% as compared to FWB.[39] Platelet yields for PC in veterinary medicine are similar to human medicine, 1.0×10^{11} platelets/100-mL bag.[40] Both products should not be frozen or chilled because platelets will be activated and clumping may occur. PCs, either PRP or PC, should be stored at room temperature for a maximum of 5 days.[35] It should be noted that if clumping is detected, by visibly observing clumps within the bag, the product should not be used. The recommended dose of PRP or PC is approximately 1 platelet unit per 10 kg of body weight that should raise the platelet count by a maximum of 40,000/μL.[35] The advantage to using PC or PRP is the large number of platelets for the small volume of administration; thereby, reducing the occurrence of volume overload in small breed dogs. Some of the disadvantages, besides the requirement for specialized equipment and staff training, are there is only approximately 80% recovery of platelets because of processing, each unit of PRP and PC contain WBCs and RBCs in minute quantities that can cause transfusion related reactions, potential for bacterial contamination, short shelf life, and the product must be constantly agitated.[39] Plateletpheresis is another process used in producing PC, in which blood is taken from the donor, anticoagulated, split into components using an apheresis machine where platelets are removed from the blood, and the remaining blood components are then returned to the donor. This process produces 4–6 times the amount of platelets in each unit than centrifuging FWB.[35] The benefits from plateletpheresis are increased platelet concentration per unit of PC, decreased WBC and RBC contamination, decreased risk of bacterial contamination, and storage time of up to 5 days at room temperature.[35] Disadvantages include the need for specialized and costly equipment, the cost of supporting and training large numbers of donor dogs, and highly trained personnel.

Cryopreserved Platelets

Because of the limitations of fresh platelet products, including short-term storage restrictions, platelet cryopreservation has been investigated as a means to provide long-term storage of platelets with immediate availability for transfusion. Cryopreserved platelets are PCs that can be stored in either 6% DMSO or 2% DMSO plus Thrombosol. Thrombosol is a mixture of 12.5 mM amiloride, 2.5 mM sodium nitroprusside, and 5mM adenosine and is used to reversibly inhibit premature platelet activation.[41] Thrombosol has demonstrated a higher percentage of platelets retaining discoid morphology, lower expression of platelet P-selectin, and improved posttransfusion platelet recovery and survival time.[41,42] Appleman et al[39] demonstrated in a prospective study using 33 research dogs that there was no significant improvement in detectable platelet survival between PC stored in 6% DMSO when compared to PC stored in 2% DMSO/Thrombosol.[39] Valeri et al[43] verified that platelets stored in 6% DMSO can be stored at −80°C for 1 year with an in vitro recovery rate of 70% and an in vivo survival time of 1–2 hours post transfusion.[43] While preserving platelets with DMSO greatly improves storage time, previous studies have proven a reduced clinical efficiency through altered platelet morphology and a decreased response to agonists when compared to fresh platelets.[40,44,45] To assess the function of platelets after processing and storage with DMSO, Guillaumin et al[40] performed a prospective study using 11 units of frozen PC stored in 6% DMSO and fresh PRP from 6 healthy control dogs.[40] The results of this in vitro study indicated a post thaw platelet recovery of 68%

at the time of transfusion, which decreased to 51%, 2 hours later, at the end of the transfusion time, with a median platelet count of 59×10^9/L platelets per 100-mL bag which corresponded to a 59% recovery rate.[40] Appleman et al[39] in a prospective study using 13 healthy research dogs demonstrated that the most significant increase in posttransfusion platelet count was with fresh PC as compared with cryopreserved products.[39] In human medicine, the American Association of Blood Banks requires a postthaw/pretransfusion wash step to remove the 6% DMSO from cryopreserved platelets; however, because specialized equipment and technical proficiency is required, the wash step is currently not done in veterinary medicine.[39,41] The current human dosing protocol is to use 2.5 units of cryopreserved PC to achieve a comparable increase in platelet count as seen with a single unit of fresh PC.[41] When using doses of ≤10 mL/kg in dogs, transfusions were well tolerated and washing did not appear to be necessary.[39] Advantages of using cryopreserved PCs to treat hemorrhaging thrombocytopenic animals are the longer storage shelf life, increased platelet count per unit of volume, low risk of side effects when used in moderate doses, and availability for on demand use. Disadvantages include a reduced platelet recovery when compared with fresh platelet products, variability in platelet counts between units, decreased platelet yield after collection and processing, decreased platelet function after thawing,[40,44,45] limited availability, and short posttransfusion platelet lifespan.

Lyophilized Platelets

Lyophilized (LYO) platelets, or "freeze-dried" platelets, are produced by vacuum lyophilization of previously frozen material to remove water by sublimation. The lyophilization process started over 50 years ago and has been perfected by investigators at East Carolina University and the University of North Carolina at Chapel Hill.[46] The process includes washing PRP with a 0.1% bovine serum albumin solution containing a phosphate buffer that resuspends the platelets in solution, the solution is incubated for 1 hour in a 0.68% paraformaldehyde solution, the platelets are washed again with a phosphate washing buffer to remove the paraformaldehyde, resuspended in a 5% bovine serum albumin washing buffer, frozen at –70°C, and dried over 1–3 days in a lyophilizer.[47–49] Lyophilized platelets have been shown to bind to collagen, vWF, damaged endothelium, fibrinogen, factor VIIa, and express procoagulant activity.[46,47,50–53] Fischer et al[51] demonstrated that LYO platelets retain the ability to respond to thrombin stimulation, degranulate, and increase their surface membrane thrombogenicity.[51] In vivo studies have demonstrated

that LYO platelets actively participative in hemostasis by detecting fluorolabeled LYO platelets as part of a hemostatic plug and improvement in venous bleeding times after infusion during a canine cardiac bypass procedure.[47,49] Bode et al[49] performed a prospective in vivo study using splenectomized dogs on cardiopulmonary bypass, creating a defect in the jugular vein, and measuring venous bleeding time after infusion of LYO platelets.[49] The findings of the study included that after inducing a platelet defect with the cardiopulmonary bypass machine nearly every patient's venous bleeding time improved after infusion of LYO platelets, the full effect of the LYO platelet infusion was not seen until 30 minutes after infusion, the effect of the LYO platelets appeared to be dose dependent, the peripheral platelet count increase post LYO platelet infusion was of short duration, there were no signs of toxic side effects of LYO platelet administration, and LYO platelets appeared to be a safe and effective therapy for treating patients with platelet dysfunctions.[49] Lyophilized platelets can be stored by refrigeration for up to 24 months and are reconstituted with normal saline just prior to use. Advantages include long storage shelf life, ease of use, and decreased probability of bacterial contamination.[54] Disadvantages include limited supply or inability to obtain as they are still in research and development, transfusion reactions, and lifespan of minutes to hours after transfusion.[4,49] It should be emphasized that LYO platelets are used to arrest active hemorrhage and are not used to prevent future hemorrhage.[49] The author used LYO platelets in a case of Basset Hound thrombocytopathia. The patient was treated with FWB but continued to bleed and bruise; however, after administration of 2 units of LYO platelets bleeding subsided and the patient was discharged 3 days later. Currently LYO platelets are not commercially available.

Conclusion

In the emergency and critical care setting platelet transfusions can be essential for the management of life-threatening hemorrhage as a result of thrombocytopenia. The most commonly available product for the treatment of hemorrhage secondary to thrombocytopenia is FWB because of availability of blood donors and lack of a cost effective easily obtainable alternative. While FWB provides the greatest percentage of usable platelets, the disadvantages of using it as a sole source of platelet therapy are that some patients are thrombocytopenic and not anemic. Potential transfusion reactions from repeated exposure to blood products, large volumes are needed for adequate platelet transfusions and the inability to use the same donor multiple times in a short-time period are major disadvantages to using FWB. Fresh PC can also be

used for the treatment of thrombocytopenia, but several limiting factors include the need for specialized equipment and technical training, short shelf life, and have limited its use in veterinary medicine. Cryopreserved and lyophilized platelets are promising new products being used in the treatment of hemorrhaging patients with thrombocytopenia. These products offer increased platelet concentrations at a decreased volume, longer storage shelf life, higher degree of sterility, decreased exposure to whole blood products, and improved response to therapy when used in MTs. With the development of newer readily available products, platelet transfusion parameters, to include dose, platelet count trigger, presence of disease, and clinical signs, should be further evaluated in veterinary medicine.

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