JOURNAL OF Veterinary Emergency AND Critical Care

Retrospective Study

Journal of Veterinary Emergency and Critical Care **00**(0) 2015, pp 1–8
doi: 10.1111/vec.12338

Autologous blood transfusion in dogs with thoracic or abdominal hemorrhage: 25 cases (2007–2012)

Veronica A. Higgs, DVM; Elke Rudloff, DVM, DACVECC; Rebecca Kirby, DVM, DACVIM, DACVECC and Andrew K.J. Linklater, DVM, DACVECC

Abstract

Objective – To describe the use and outcome following autologous blood transfusion (ABT) in dogs.
Design – Retrospective study (January 2007–July 2012).
Setting – Private veterinary referral center.
Animals – Twenty-five dogs that underwent ABT secondary to thoracic or abdominal hemorrhage.
Interventions – None.
Measurements and Main Results – The hospital transaction database was searched using the keyword "autotransfusion" from January 2007 to July 2012. Data collected included signalment, body weight, etiology of hemorrhage, source and method of collection, volumes and method of ABT administration, use of anticoagulant, reported complications, and outcome. Twenty-five dogs were included for a total of 27 ABTs. Causes of hemorrhage included vascular trauma (14/25 dogs, 56%), ruptured tumor (8/25, 32%), and coagulopathy attributed to brodifacoum toxicosis (3/25, 12%). Autologous blood was collected from the abdominal (19/25, 76%), thoracic (5/25, 20%), or abdominal and thoracic cavities (1/25, 4%). Anticoagulant was added to the ABT blood in 13 of 25 (52%) cases. A median ABT volume of 29.3 mL/kg (range 2.9–406.9 mL/kg) was infused through either a 210 μm blood administration filter (21/27, 78%) or an 18 μm hemonate filter (6/27, 22%). Reported complications that may have been associated with ABT included hypocalcemia (4/17, 24%), hemolyzed serum (5/19, 26%), and prolonged coagulation times (4/5, 80%). These complications were considered of minimal clinical significance. Additional blood products were administered in 17 of 25 (68%) dogs. Seventeen (68%) dogs survived to discharge. Cause of death in the remaining cases was euthanasia or cardiac arrest secondary to uncontrollable hemorrhage.
Conclusions – ABT is an adjunct to volume replacement in dogs with thoracic or abdominal hemorrhage secondary to vascular trauma, ruptured tumor, or anticoagulant rodenticide toxicosis. ABT may be used as bridge to definitive hemorrhage control, particularly when other blood products are not available or affordable. Complications may include hypocalcemia, prolonged coagulation times, and hemolysis.

(J Vet Emerg Crit Care 2015; 00(0): 1–8) doi: 10.1111/vec.12338

Keywords: autotransfusion, canine, hemoabdomen, hemothorax

Abbreviations

ABT	autologous blood transfusion
ACT	activated clotting time
aPTT	activated partial thromboplastin time
DA	direct aspiration
PT	prothrombin time
SA	surgical aspiration

From the Lakeshore Veterinary Specialists, Glendale, WI (Higgs, Rudloff, Linklater) and Critical Care for Animals, Glendale, WI (Kirby).

The authors declare no conflicts of interest.

Presented in part as an abstract at the International Veterinary Emergency and Critical Care Symposium, San Antonio, TX, September 2012.

Address correspondence to Dr. Veronica Higgs, Lakeshore Veterinary Specialists, 2100 West Silver Spring Drive, Glendale, WI 53209, USA.
Email: veronica.higgs@gmail.com
Submitted May 27, 2013; Accepted May 12, 2015.

Introduction

Thoracic or abdominal hemorrhage in veterinary patients has been attributed to vascular injury caused by trauma, organ torsion, ruptured neoplasia, or coagulopathy.[1–3] In cases of closed cavitary hemorrhage, shed blood can be collected and reinfused intravenously as an autologous blood transfusion (ABT) to provide blood components and intravascular volume quickly.[1,4,5]

Blundell[6] first described ABT in dogs in 1818, when he removed and reinfused blood into a dog by syringe. Various ABT techniques have since been described in the veterinary literature[1,4,5] and are referred to as technically simple[1,7] and inexpensive to perform.[1,7–10] Complications reported in the human[7,10] and canine[4,5,11,12] medical literature include hemolysis, coagulation disorders, microembolism, air embolism, sepsis, and metastasis through reinfusion of neoplastic cells. Studies documenting the clinical use and outcome of ABT in dogs are limited to single or small case series.[5,11–14] The purpose of this retrospective study was to describe the use, technique employed, complications encountered, and outcome of ABT in dogs in a single institution.

Materials and Methods

The hospital computer financial transaction database from January 2007 to July 2012 was searched using the keyword "autotransfusion" to identify patients that received an ABT. The sole criterion for inclusion was having received an ABT during that time frame. Patient signalment, body weight, as well as location and etiology of internal hemorrhage were retrieved from the medical record. Recorded parameters included: collection technique and method of ABT administration, volume of ABT blood administered, use of anticoagulant, infusion of allogeneic blood products, recognized complications, survival to discharge, and 2-week survival. When available, serum color; serum ionized calcium concentration;[a] coagulation panels[b] (prothrombin time [PT], activated partial thromboplastin time [aPTT], activated clotting time [ACT]); and physical or biochemical evidence of sepsis, microemboli, or air emboli were recorded to identify complications. Patients were then divided into 1 of 3 groups based on etiology of hemorrhage: dogs with vascular trauma, dogs with ruptured neoplasia, or dogs with coagulopathy.

Statistical Methods

Descriptive statistics were calculated to determine mean and standard deviation for the continuous variables that met the assumptions of normality. To account for multiple measurements in 2 dogs, a linear regression analysis was performed to compare the continuous variables across categories. If the assumption was not met, medians were used to describe the variable and linear regression analysis was performed on the log converted outcome after checking for assumption again. Frequencies and percentages were reported for categorical variables. Chi-square analysis was used to determine whether addition of anticoagulant to ABT, blood filter pore size, body cavity from which blood was collected, hemolysis, or etiology of hemorrhage affected a categorical outcome. An alternative Fisher's exact test was used if any of the cells in the contingency tables contained fewer than 5 cases. All analyses were performed with statistical software[c] and $P < 0.05$ was considered significant for all comparisons.

Results

Records of 26 dogs that received ABT between January 2007 and July 2012 were identified. No cats were identified in the search. One case was excluded because there was no documentation of ABT administration in the medical record. Of the 25 dogs included in the analyses, the mean age was 5.8 ± 3.1 years. There were 2 intact males, 10 neutered males, 2 intact females, and 11 spayed females. Ten breeds were represented: 6 mixed breed dogs, 5 Labrador Retrievers, 3 Golden Retrievers, 3 German Shepherd Dogs, 2 Bernese Mountain Dogs, 2 Coonhounds, and 1 of each Pit Bull, Shih Tzu, Newfoundland, and Rottweiler. Specific case information is presented in tabular form in Appendix 1.

In the 25 dogs evaluated, hemorrhage was localized to and thus collected from the thoracic cavity (5/25, 20%), the abdominal cavity (19/25, 76%), or both cavities (1/25, 4%). A total of 27 ABTs were performed. Two dogs received 2 ABTs: 1 from both abdominal and thoracic hemorrhage, and the other from abdominal hemorrhage both pre- and intraoperatively. The method used for collection and administration of ABT varied, and appeared to be based on whether hemorrhage was identified in the thoracic or abdominal cavity and whether blood was collected by centesis (10/27, 37%) or intraoperatively by suction (17/27, 63%). There was no significant association between survival and the body cavity from which the blood was collected ($P = 1.00$).

The etiologies for hemorrhage included vascular trauma (14/25, 56%), ruptured neoplasia (8/25, 32%), and coagulopathy (3/25, 12%). Vascular trauma was caused by organ torsion due to gastric dilation and volvulus with hemorrhage from torn short gastric and splenic vessels in 6 of 14 (43%) dogs; postoperative ovariohysterectomy or neuter in 3 of 14 (21%) dogs; and blunt force trauma in 5 of 14 (36%) dogs. In the blunt force trauma group, 4 dogs were hit by a car and 1 had trauma of unknown cause. Three of the dogs with blunt force trauma had injury to the spleen and liver confirmed through surgical abdominal exploration.

Ruptured neoplasia was the cause of hemorrhage in 8 (32%) dogs: 6 (75%) had splenic masses, 1 (12.5%) had bilateral renal masses, and 1 (12.5%) had an intrathoracic mass. Gross or histopathologic metastasis was present at the time of ABT in 6 of 8 (75%) of the neoplastic cases.

Histopathology performed in 4 cases confirmed a diagnosis of hemangiosarcoma. Histopathology was not performed in the other 4 cases.

Coagulopathy due to brodifacoum toxicosis was the cause of hemorrhage in 3 (12%) dogs. One of 3 dogs had confirmation of ingestion through owner history and visual inspection of the package. Two dogs were not observed to ingest the compound but had positive qualitative blood tests for brodifacoum by mass spectrometry.[d] In addition to ABT, each of these dogs was treated with a single subcutaneous injection of vitamin K_1[e] in hospital (4.0 ± 1.0 mg/kg), oral vitamin K_1[f] for 30 days (3.5 ± 1.8 mg/kg/day), and allogeneic donor whole blood transfusion (24.7 mL/kg, range 19.8–25.3 mL/kg).

ABTs were administered either during initial resuscitation or during surgery. One of 2 techniques of ABT collection and administration was used. The collected blood cells were not washed or processed in either technique. The first technique was direct aspiration (DA), in which blood was collected from the body cavity via centesis, after aseptic preparation, by manual aspiration using a butterfly catheter[g] attached to a 60 mL syringe.[1,4] The DA technique was used in 10 of 27 (37%) ABTs. The ABT blood was then reinfused by 1 of 2 methods. In the first variation (DA_1; 6/27 [22%] ABTs), the blood was reinfused into a vein from the collection syringe using a 3-way stopcock, extension fluid tubing, and an in-line 18 μm hemonate filter.[h] The DA_1 technique was used to collect blood from the thoracic cavity. In the second variation (DA_2; 4/27 [15%] ABTs), the collected blood was transferred via syringe into a blood transfusion collection bag[i] or in a sterile, empty crystalloid fluid bag[j] for reinfusion through an in-line 210 μm blood administration filter.[k] The DA_2 technique was used to collect blood from the abdominal cavity.

The second technique[4] was surgical aspiration (SA), which involved the intraoperative collection of cavitary hemorrhage through a Poole suction tip and sterile tubing, and into a sterile canister using mechanical suction[l] at a collection pressure <100 mm Hg. The SA technique was used in 17 of 27 (63%) ABTs. Blood was then transferred from the canister into either a blood transfusion collection bag or a sterile, empty crystalloid fluid bag for reinfusion through an inline 210 μm blood administration filter into a vein. Transfer of the blood from the canister to the sterile fluid bag was accomplished aseptically via needle and syringe transfer or by pouring the blood into the bag after removing a corner with sterile scissors.

ABTs given by DA_1 (6/27, 22%) or DA_2 (4/27, 15%) were administered during initial resuscitation, while those given by SA (17/27, 63%) were administered during surgery. Seventeen of 25 (68%) patients had surgery for bleeding control and the majority of those (16/17, 94%) did not have ABT as part of the presurgical resuscitation.

Blood was administered through a 210 μm blood administration filter in 21 of 27 (78%) of ABTs: 4 using the DA_2 technique and 17 using the SA technique. In the remaining 6 of 27 (22%) ABTs, blood was infused through an 18 μm hemonate filter using the DA_1 technique. There was no significant association between survival and the filter pore size ($P = 1.00$) or ABT collection method used ($P = 0.86$) in any group of dogs.

The median infused ABT volume for all etiologies was 29.3 mL/kg (range 2.9–406.9 mL/kg). The median ABT volume in the dogs with vascular trauma was 34.8 mL/kg (range 2.9–406.9 mL/kg), in dogs with ruptured neoplasm was 36.0 mL/kg (range 7.3–122.2 mL/kg), and in dogs with anticoagulant rodenticide toxicosis was 18.0 mL/kg (range 11.0–22.0 mL/kg). ABT volume administered was significantly higher in cases with ruptured tumor ($P = 0.029$) or trauma ($P = 0.05$) compared to cases with brodifacoum toxicosis. Anticoagulant was added to collected blood in 13 of 25 (52%) dogs. No anticoagulant was used in any of the dogs with anticoagulant rodenticide intoxication. An average of 0.17 ± 0.05 mL of anticoagulant per milliliter of ABT blood was added. In 12 of 13 (92%), the blood was transferred directly into a blood collection bag containing citrate phosphate dextrose adenine. Acid citrate dextrose[m] was added to blood collected into a sterile suction canister and transferred into an empty crystalloid fluid bag in 1 of 13 (8%). There was no significant association between outcome and the addition of anticoagulant to blood used for ABT ($P = 1.00$).

Additional blood products were administered to 17 of 25 (68%) dogs. A median of 24.46 mL/kg (range 9.5–132.4 mL/kg) of allogeneic donor whole blood was administered to 17 of 25 (68%) dogs. Of the dogs receiving whole blood, 9 had vascular trauma and received whole blood at a median dose of 24.3 mL/kg (range 16.5–132.4 mL/kg), 5 had ruptured neoplasia and received a median dose of 21.4 mL/kg (range 9.5–28.3 mL/kg), and 3 had anticoagulant rodenticide toxicosis and received a median dose of 24.7 mL/kg (range 19.8–25.3 mL/kg). Other blood products administered included packed RBCs (5.5 mL/kg) administered to 1 dog with vascular trauma; frozen plasma (4.9 mL/kg) administered to 1 dog with a ruptured tumor; and bovine hemoglobin-based oxygen carrier (Hb-200, Oxyglobin[n]) administered to 3 dogs suffering vascular trauma (6.8 mL/kg, range 1.8–17.7 mL/kg).

There were no reports of increased rectal temperature, urticaria, erythema, vomiting, labored breathing, impaired blood flow, or other reactions associated with

Table 1: Five cases with post-ABT hemolyzed serum

Patient	Pre-ABT serum color	Immediately post-ABT serum color	Recheck post-ABT serum color
4	Clear	Hemolyzed	Clear (1.5 h after ABT)
5	Clear	Hemolyzed	Hemolyzed (48 h after ABT)
12	Straw	Hemolyzed	Hemolyzed (1 h after ABT)
14	Hemolyzed	Hemolyzed	None
17	Clear	Hemolyzed	Clear (3 h after ABT)

ABT, autologous blood transfusion; h, hour.

Table 2: Four cases with post-ABT hypocalcemia and treatment

Patient	Pre-ABT iCa (mmol/L)	Post-ABT iCa (mmol/L)	Treatment
5	2.16	1.45	Calcium gluconate 10% 0.27 mL/kg
7	2.29	1.81	None
14	1.75	1.65	None
19	2.4	1.58	None

ABT, autologous blood transfusion; iCa, serum ionized calcium concentration (reference interval 1.9-2.66 mmol/L).

Table 3: Five cases with prolonged post-ABT coagulation tests

Patient	Pre-ABT coagulation tests (s)	Post-ABT Coagulation tests (s)
10	None	PT/PTT 16/129
19	None	PT/PTT 21/154
23	None	PT/PTT 16/114
24	ACT out of range high	ACT 110
25	PT 100	PT 22

ABT, autologous blood transfusion; PT, prothrombin time (reference interval 12–17 seconds); aPTT, activated partial thromboplastin time (reference interval 71–102 seconds; ACT, activated clotting time (reference interval 70–180 seconds).

administration of ABT in any case. No clinical signs compatible with microemboli or air emboli were reported in the medical records.

Potential complications of ABT identified from medical records included hemolysis, hypocalcemia, and prolongation of coagulation times. Serum color was documented in 19 dogs. Hemolyzed serum color was observed post-ABT in 5 of 19 (26%) dogs (Table 1). Of these dogs, 1 had hemolyzed serum color prior to ABT and died of cardiac arrest secondary to uncontrolled hemorrhage. In 2 of these dogs, the hemolyzed serum color cleared within 3 hours of ABT; in 1 the hemolyzed serum color persisted through the time of hospital discharge 48 hours after ABT; and 1 dog was euthanized prior to the serum clearing. Neither clinical evidence of kidney dysfunction nor other complications attributable to hemolysis were reported in the records. There was no significant association between survival and hemolyzed serum color ($P = 0.63$). There was also no significant difference between the occurrence of hemolyzed serum and the method of ABT ($P = 0.60$). Of the 5 patients with hemolysis, 6 ABTs were performed with 5 of 6 utilizing the 210 micron filter and 1 of 6 with a hemonate.

Serum ionized calcium concentration was measured post-ABT in 17 dogs, all of which received stored donor whole blood in addition to ABT. Hypocalcemia was documented in 4 of 16 (25%) dogs tested (Table 2), all of which had anticoagulant added to their ABT. No clinical signs attributable to hypocalcemia (eg, muscle fasciculations, dysrhythmias) were reported in any of the dogs. Two of the 4 dogs with hypocalcemia survived, 1 of them having been treated with calcium gluconate.[o] One of the 4 dogs died of uncontrollable hemorrhage and 1 was euthanized, both without calcium replacement therapy.

Coagulation tests were performed in 5 patients post-ABT (Table 3). Two of these dogs had a rodenticide-induced coagulopathy, and thus pre- and post-ABT ACT or PT were obtained. Following therapy, ACT and PT improved to normal or near-normal range in both dogs. In the remaining 3 dogs (1 from each etiology category), post-ABT PT and aPTT were reported. All had slightly prolonged aPTT, and 1 had a slightly prolonged PT. No evidence of continued hemorrhage, bruising, or petechiation was reported.

Seventeen of 25 (68%) dogs survived to hospital discharge. The cause of death in the 8 dogs that did not survive to discharge was euthanasia in 5 dogs and cardiac arrest secondary to uncontrollable hemorrhage in 3. In the dogs that died from ongoing hemorrhage, cardiopulmonary arrest occurred in surgery or immediately postoperatively. Necropsies were not performed in any dogs. Survival to discharge was 71% (10/14) for dogs with vascular trauma, 50% (4/8) for dogs with ruptured neoplasia, and 100% (3/3) for dogs with a coagulopathy from anticoagulant rodenticide ingestion. There was no significant association between survival and the etiology of hemorrhage ($P = 0.22$).

Fifteen of the 17 dogs that were discharged were alive at 2 weeks. The 2 dogs that died during the 2-week post-ABT period had a confirmed diagnosis of hemangiosarcoma with evidence of metastatic disease. While undergoing doxorubicin chemotherapy, both dogs

developed recurrence of hemoperitoneum suspected to be from metastatic neoplasia. One dog presented deceased the day after ABT and no necropsy was permitted. The other dog had a recurrence of hemoperitoneum 2 days after ABT and was euthanized.

Discussion

ABT has been described extensively in the human literature with few complications reported.[7,10,15–19] Reported advantages of ABT when compared to allogeneic blood transfusion include immediate availability, blood compatibility, avoidance of transfusion reactions, normothermic transfusion, no transmission of infectious agents, higher levels of RBC 2,3-diphosphoglycerate, and decreased overall cost.[1,4,7,9,10,12,20] The procedure is not widely reported to be performed in veterinary medicine, possibly due to a lack of data on clinical outcome associated with ABT. This study is the largest retrospective investigation to date to describe the use of and techniques for performing ABT, and the outcome of dogs that have received it. To the authors' knowledge, this study is also the first to describe the successful use of ABT as an adjunct to volume replacement in dogs hemorrhaging from anticoagulant rodenticide toxicosis.

Eight of the dogs in this study received ABT using blood collected from a cavity with a ruptured neoplasm. It is unknown whether administering an ABT obtained from the hemorrhage of a ruptured tumor could contribute meaningfully to metastatic cancer spread in dogs. Some authors state that ABT is contraindicated in cases of neoplastic disease.[8,10,19] However, investigations in people have failed to demonstrate worse outcome or increased metastatic rate associated with administration of ABT to patients undergoing oncological surgery,[21–25] and no association has been found between the presence of circulating neoplastic cells and poorer prognosis.[21,22] Nonetheless, the use of leukocyte depletion filters has been recommended when performing ABT in human cancer patients to reduce the number of malignant cells infused.[26,27] Such filters were not used in these dogs. Since 6 of 8 (75%) of the dogs with neoplasia in this study had gross or histopathologic metastasis at the time of ABT, the risk of cancer dissemination from ABT could not be determined. Prospective, long-term studies regarding the use of ABT in cases of ruptured hemangiosarcoma and other neoplasms are needed.

The blood collected for ABT in this study was neither washed nor processed other than passage through a blood filter during administration. Well-described techniques for ABT in companion animals[1,4] were used in this study, and differed from the ABT technique described using a cell saver device.[13] Recommendations to minimize lysis of ABT RBCs during collection include minimizing aspiration of air or mixing of the collected blood with air;[1,4] keeping the vacuum suction tip below the surface of the blood pool to decrease the blood-air interface; and maintaining an ideal vacuum pressure between 40 and 60 mm Hg, and always below 100 mmHg.[1,5,10,19]

The filter pore size selected in the 25 dogs coincided with the site of blood collection. An 18 μm hemonate filter was used to reinfuse blood collected from the thoracic cavity, and a 210 μm blood administration filter was used to re-infuse blood collected from the abdominal cavity. This difference likely occurred because the DA technique was used for all thoracic blood collection, and as such, an insertable, in-line filter was more practical for blood administration. The manufacturer of hemonate filters[h] recommends they be changed every 50 mL of blood transfused, or sooner if they become clogged. The literature recommends a filter size between 20 and 270 μm to filter particles and minimize trauma to RBCs.[1,8,10] Four dogs in this study developed hemolytic serum color following ABT administration; it is unclear whether technique or filter pore size was associated with hemolysis in these dogs. There was no association between survival and filter pore size or technique used in this study.

Adding anticoagulant to ABT blood is controversial. Blood becomes defibrinated when in contact with the thoracic or abdominal serosal surfaces for more than 1 hour.[1,28] Therefore, blood that has been in contact with a peritoneal surface for more than 1 hour may not require anticoagulation prior to ABT.[28] When active hemorrhage is the source of ABT blood, the addition of anticoagulant may be warranted.[1,4,9] It has been recommended in the veterinary literature to add either 0.05–0.07 mL of anticoagulant per milliliter of collected blood[1,4,10] or 0.14 mL of anticoagulant per milliliter of collected blood.[9,26,29] In this study, 12 dogs had the collected blood transferred into commercial blood bags containing 63 mL citrate phosphate dextrose adenine. The bags are meant to be filled with 450 mL blood but in these cases were not always filled to capacity, and may have contained a higher ratio of anticoagulant to collected blood than intended. No association was found between survival and the addition of anticoagulant to ABT. Further studies are needed to determine the appropriate indications and dose for anticoagulant in these cases.

Additional blood products were administered in 68% of the dogs receiving ABT. Due to the administration of other blood products, it is impossible to determine if some of the complications were solely due to ABT. Timing of the administration of other blood products in relation to the ABT could not be determined from the record in most cases.

There are a number of nonhematologic and hematologic complications reported secondary to ABT. Nonhematologic complications reported in people

include microembolism, air embolism, dissemination of malignancy, and sepsis.[7,9,10] There was no evidence of microembolism, air embolism, increase of body temperature, urticaria, erythema, or vomiting in the records of the 25 dogs receiving ABT. Researchers have examined the occurrence of sepsis as a consequence of infusion of autologous blood with bile or fecal contamination.[10,15,30] No increase in mortality was found after infusion of contaminated blood in experimental dogs if there was <40% blood loss or when broad spectrum antimicrobials were administered in situations with >40% blood loss.[10,15,30] None of the 25 dogs in this study had gross evidence of contamination of the ABT blood at the time of collection, and none had post-ABT infections identified.

Reported hematologic consequences of ABT include hemolysis, hypocalcemia, and coagulopathies.[1,7,9,10,31,32] In our study, hemolyzed serum color was reported in 5 dogs, 1 of which had hemolyzed serum color prior to ABT. Hemolysis can occur due to prolonged exposure of blood to serosal surfaces, and during collection and reinfusion of RBCs associated with exposure to air, mechanical stress from vacuum pressures, or excessive air-fluid interface exposure.[1,9] The causes of hemolysis in the 5 dogs in this study were unknown, and no clinical signs or problems were attributed to hemolysis in any of the dogs. Human and veterinary literature report that hemolysis associated with ABT should resolve within 48–72 hours.[4,7] The serum had cleared in 2 of the dogs within 3 hours of testing, and 1 dog continued to have hemolytic serum when it was discharged 48 hours post-ABT. The final 2 dogs with hemolytic serum color died as a result of uncontrollable traumatic hemorrhage, with hemolysis not likely a contributing factor. Monitoring for hemolysis post-ABT is recommended.[1,5,10,19]

Citrate toxicosis has been suggested as a possible complication of autotransfusion due to the large total doses of anticoagulant administered.[33] Citrate binds divalent cations such as calcium[33] and inhibits coagulation during blood collection. Unbound citrate given in the ABT can bind to calcium in the recipient's blood and cause hypocalcemia.[31,33] There are numerous reports of citrate toxicosis in human medicine[32–35] secondary to allogeneic blood transfusion, but overall incidence is low and clinical signs are mild.[33,35] Four of 16 (25%) dogs in this study with pre- and post-ABT serum calcium concentrations reported developed new hypocalcemia post-ABT transfusion, all of which had anticoagulant added to their ABT blood. No clinical signs were attributed to hypocalcemia. To the authors' knowledge, this is the first study to report that hypocalcemia may have occurred as a result of the ABT in canine patients. However, all 4 of these patients also received allogeneic blood products containing anticoagulant that could have contributed to the hypocalcemia. It is recommended to monitor serum ionized calcium concentration in patients after massive transfusions in human[31,32] and canine[36] medicine. Based on the data from this series of ABT dogs, it may be beneficial to extend these recommendations to veterinary patients receiving ABT.

In this study, coagulation parameters including PT, PTT, or ACT were measured in 5 dogs post-ABT. Of the 5 tested dogs, coagulation profiles were normal or near-normal following ABT. Two of these dogs had prolonged coagulation parameters pre-ABT. However, the impact of ABT on coagulation test results in these 2 is unknown, because these dogs had brodifacoum toxicosis and were thus treated concomitantly with plasma-containing blood products. In previous reports, small increases in PT and PTT were noted but self-corrected within 72 hours of ABT.[1,37] Dilutional coagulopathy in people has been reported when transfusion volume exceeds 3,500 mL.[1,9,19] There are guidelines for plasma administration for people receiving ABT, with the recommendation that either 1 unit of fresh frozen plasma be given for every 2 units of ABT[1] administered, or that plasma be administered to effect when the ABT volume exceeds 3500 mL.[19] In an average person weighing 70 kg, 3,500 mL is 50 mL/kg. In our study, 9 of 25 dogs received an ABT blood volume ≥50 mL/kg but due to the fact that only 1 of 9 had post-ABT coagulation testing, we cannot accurately discuss dilutional coagulopathy in our patient population.

This study documents a 68% (17/25 dogs) survival to hospital discharge, and a 60% (15/25 dogs) survival rate after 2 weeks. Our dogs had a similar survival to discharge rate as that reported by Crowe[14] (67%) and higher than reported by Niebauer[5] (28%). Of the 8 dogs that did not survive to discharge, 5 were euthanized and 3 suffered cardiopulmonary arrest attributed to uncontrollable blood loss. The highest survival rate was in the coagulopathy category at 100%, followed by the vascular trauma category at 71%, and the ruptured tumor category at 50%. The 2 dogs that died during the 2-week period following discharge from the hospital were from the ruptured tumor category and received their ABT during a chemotherapy recheck. Fatalities secondary to ABT in people have been reported when intra-abdominal blood was collected and administered that had been allowed to remain within the peritoneal cavity for >72 hours.[16,38] Thus, the benefits of ABT should be weighed against possible complications in situations where blood may have dwelled in a body cavity for an extended period of time.

The retrospective nature of this study presents a major limitation. The lack of consistent clinicopathologic data, physical parameter monitoring, and reporting in the medical records prevents conclusions regarding many aspects of ABT. Unfortunately, physiologic parameters

such as blood pressure, heart rate, and pulse quality; PCV measurements; and the timing and types of other fluid therapies in relation to ABT were not consistently recorded. Due to the inconsistent presence of these data points, they were purposely omitted from this paper to avoid providing misleading information about the ability of ABT to restore perfusion or improve oxygen-carrying capacity. The authors believe that this information is best collected, evaluated, and presented through a controlled prospective clinical trial.

There are many factors that may have affected clinician choice to use ABT, such as availability of other products, cost, and patient selection. Our hospital maintains a whole and component blood bank intended to meet the needs of patients. However, patient transfusion requirements occasionally exceed the quantity of blood products available. A randomized trial that compares ABT with banked blood products and their associations with outcome is warranted.

Furthermore, due to the retrospective nature of the study, there is a possibility of unrecognized or unrecorded reactions to ABT. Lack of consistent data collection severely limits the statistical power of our study. Small sample size and large variations in the data set introduce the possibility of type 2 error. While no statistical differences were found between survival and etiology of hemorrhage, filter pore size, ABT retrieval or administration technique, addition of anticoagulant, and occurrence of hemolysis, these results should be interpreted cautiously due to the small sample size and group heterogeneity. A prospective study with more dogs treated by a standardized protocol is recommended for further evaluation.

Conclusion

ABT is a viable adjunct to volume resuscitation in dogs with abdominal or thoracic hemorrhage secondary to vascular trauma, ruptured tumor, or coagulopathy from anticoagulant rodenticide intoxication. ABT may provide a necessary bridge to definitive hemorrhage control for intracavitary hemorrhage from a variety of causes. Complications may include hypocalcemia, prolonged clotting times, and hemolysis.

Footnotes

[a] Blood Gas Analyzer, NOVA Biomedical, Waltham, MA.
[b] Veterinary coagulation analyzer SCA 2000, Synbiotics Corporation, San Diego, CA.
[c] SAS version 9.31, SAS Institute, Cary, NC.
[d] Antech Diagnostics, Rodenticide Screen, Oak Brook, IL.
[e] K-Ject 10 mg/kL, Butler Animal Health Supply, Dublin, OH.
[f] K-chew 50 mg Vitamin K1 supplement, Butler Schein Animal Health.
[g] Nipro Scalp Vein Set, Nipro Medical Corporation, Miami, FL.
[h] Hemo Nate Blood Filtration System, Jorgensen Laboratories Inc, Loveland, CO.
[i] Teruflex Blood Bag System, Terumo Corporation, Tokyo, Japan.
[j] Veterinary Plasma-lyte A Injection pH 7.4 (Multiple Electrolyte Injection Type 1 USP), Abbott Laboratories, North Chicago, IL.
[k] Blood Administration set, Terumo Corporation.
[l] Medela Fluid Management System, Medela International, Baar, Switzerland.
[m] Anticoagulant citrate dextrose solution USP (ACD) Formula A, Baxter Healthcare Corporation, Marion, NC.
[n] Oxyglobin, Biopure Company, Cambridge, MA.

References

1. Purvis D. Autotransfusion in the emergency patient. Trans Med 1995; 25(6):1291–1304.
2. Aronsohn MG, Dubiel B, Roberts B, et al. Prognosis for acute non-traumatic hemoperitoneum in the dog: a retrospective analysis of 60 cases (2003–2006). J Am Anim Hosp Assoc 2009; 45(2):72–77.
3. Hammond TN, Pesillo-Crosby SA. Prevalence of hemangiosarcoma in anemic dogs with a splenic mass and hemoperitoneum requiring a transfusion: 71 cases (2003–2005). J Am Vet Med Assoc 2008; 232(4):553–558.
4. Crowe DT. Autotransfusion in the trauma patient. Vet Clin North Am Small Anim Pract 1980; 10(3):581–597.
5. Niebauer GW. Autotransfusion for intraoperative blood salvage: a new technique. Compend Contin Educ Pract Vet 1991; 13(7):1105–1117.
6. Blundell J. Experiments on the transfusion of blood by the syringe. Med Chir Trans 1818; 9(Pt 1):56–92.
7. Saarela E. Autotransfusion: a review. Ann Clin Res 1981; 13(33):48–56.
8. Chiaramonte D. Blood-component therapy: selection, administration and monitoring. Clin Tech Small Anim Pract 2004; 19(2):63–67.
9. Jutkowitz LA. Blood transfusion in the perioperative period. Clin Tech Small Anim Pract 2004; 19(2):75–82.
10. Young GP, Purcell TB. Emergency autotransfusion. Ann Emerg Med 1983; 12(3):180–186.
11. Buckley GJ, Aktay SA, Rozanski EA. Massive transfusion and surgical management of iatrogenic aortic laceration associated with cystocentesis in a dog. J Am Vet Med Assoc 2009; 235(3):288–291.
12. Zenoble RD, Stone EA. Autotransfusion in the dog. J Am Vet Med Assoc 1978; 172(12):1411–1414.
13. Hirst C, Adamantos S. Autologous blood transfusion following red blood cell salvage for the management of blood loss in 3 dogs with hemoperitoneum. J Vet Emerg Crit Care 2012; 22(3):355–360.
14. Crowe DT. Simple autotransfusion in severe hemorrhage: success in 8 of 12 dogs. J Vet Emerg Crit Care 2004; 14:S9.
15. Klebanoff G, Phillips J, Evans W. Use of a disposable autotransfusion unit under varying conditions of contamination. Am J Surg 1970; 120(3):351–354.
16. Bennett SH, Gellhoed GW, Terrill RE, et al. Pulmonary effects of autotransfused blood: a comparison of fresh autologous and stored blood with blood retrieved from the pleural cavity in an in situ lung perfusion model. Am J Surg 1973; 125(6):696–702.
17. Reul GJ, Solis RT, Greenberg SD, et al. Experience with autotransfusion in the surgical management of trauma. Surgery 1974; 76(4):546–555.
18. Ubee S, Kumar M, Athmanathan N, et al. Intraoperative red blood cell salvage and autologous transfusion during open radical retropubic prostatectomy: a cost-benefit analysis. Ann R Coll Surg Engl 2011; 93(2):157–161.
19. Brewster DC, Ambrosino JJ, Darling R, et al. Intraoperative autotransfusion in major vascular surgery. Am J Surg 1979; 137(4):507–513.
20. Tawes RL. Autotransfusion in vascular surgery: an overview. Semin Vascul Surg 1994;7(2):67–71.
21. Fisher ER, Fisher B. Circulating cancer cells and metastasis. Intern J Radiat Oncol Biol Phys 1975; 1(1–2):87–91.
22. Salsbury AJ. The significance of the circulating cancer cell. Cancer Treat Rev 1975; 2(1):55–72.
23. Liang TB, Li DL, Lang L, et al. Intraoperative blood salvage during liver transplantation in patients with hepatocellular carcinoma:

efficiency of leukocyte depletion filters in the removal of tumor cells. Transplantation 2008; 85(6):863–869.
24. Heiss MM, Mempel W, Delanoff C, et al. Blood transfusion-modulated tumor recurrence: first results of a randomized study of autologous versus allogeneic blood transfusion in colorectal cancer surgery. J Clin Oncol 1994; 12(9):1859–67.
25. Hansen E, Knuechel R, Altmeppen J, et al. Blood irradiation for intraoperative autotransfusion in cancer surgery: demonstration of efficient elimination of contaminating tumor cells. Transfusion 1999; 39(6):608–615.
26. Herold LV, Devey JJ, Kirby R, et al. Clinical evaluation and management of hemoperitoneum in dogs. J Vet Emerg Crit Care 2008; 18(1):40–53.
27. Edelman MJ, Potter P, Mahaffey KG, et al. The potential for reintroduction of tumor cells during intraoperative blood salvage: reduction of risk with use of the RC-400 leukocyte depletion filter. Urology 1996; 47(2):179–181.
28. Broadie TA, Glover JL, Bang N, et al. Clotting competence of intracavitary blood in trauma victims. Ann Emerg Med 1981; 10(3):127–130.
29. Crowe DT. The steps to arresting abdominal hemorrhage. Vet Med 1988; 83:676–681.
30. Smith RN, Yaw PB, Glover JL. Autotransfusion of contaminated intraperitoneal blood: an experimental study. J Trauma 1978; 18(5):341–344.
31. Dzik WH, Kirkley SA. Citrate toxicity during massive blood transfusion. Trans Med Rev 1988; 2(2):76–94.
32. Ho KM, Leonard AD. Concentration-dependent effect of hypocalcaemia on mortality of patients with critical bleeding requiring massive transfusion: a cohort study. Anaes Intensive Care 2011; 39(1):46–54.
33. Uhl L, Maillet S, King S, et al. Unexpected citrate toxicity and severe hypocalcemia during apheresis. Transfusion 1997; 37(10):1063–1065.
34. Bell AM, Nolen JD, Knudson CM, et al. Severe citrate toxicity complicating volunteer apheresis platelet donation. J Clin Apher 2007; 22(1):15–16.
35. Makar YF, Butler MO, Cockersole GM, et al. National adult of citrate toxicity in plateletpheresis donors. Trans Med 2002; 12(3):187–191.
36. Jutkowitz LA, Rozanski EA, Moreau JA, et al. Massive transfusion in dogs: 15 cases (1997–2001). J Am Vet Med Assoc 2002; 220(11):1664–1669.
37. Moore KL, Bendick PJ, Broadie TA, et al. Systemic effects of intraoperative autotransfusion. Med Instrum 1983; 17(1):85–87.
38. Ewer EN, Oakland MD, Doyle JC, et al. Ruptured ectopic pregnancy. Cal West Med 1934; 41(1):16–20.
39. Munoz M, Garcia-Vallejo JJ, Ruiz MD, et al. Transfusion of postoperative shed blood: laboratory characteristics and clinical utility. Eur Spine J 2004; 13(Suppl 1):S107–S113.