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Transfusion practice in dogs and cats: an Internet-based survey

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Abstract

Objective – To characterize and compare current canine and feline transfusion practices at private referral hospitals (PRH) and veterinary teaching hospitals (VTH), including information regarding blood donor screening; blood product collection, storage, and administration; recipient screening; and monitoring during transfusions.
Design – Internet-based survey.
Subjects – Sixty-five board-certified specialist veterinarians, 3 veterinarians, and 5 veterinary technicians from 53 PRH and 20 VTH.
Methods – A survey was disseminated via email LIST-SERVs; 1 survey response per hospital was included.
Main Results – Survey results revealed that PRH more commonly obtained canine and feline blood products solely from blood banks ($P < 0.05$) and VTH more commonly used hospital-run donor programs ($P < 0.05$). Canine cryo-poor plasma was more likely to be stored by VTH compared to PRH ($P = 0.018$) and VTH were more likely to store canine fresh platelet products for >72 hours ($P = 0.046$). The use of client-owned canine donors ($P = 0.043$), administration of precollection 1-deamino-8-D-arginine vasopressin to canine donors ($P = 0.041$), and storage of blood products in a dedicated refrigerator ($P = 0.003$) and −20°C or −80°C freezer ($P = 0.044$) were more common in VTH than PRH. However, the use of a refrigerator freezer ($P = 0.001$), single bag canine collection systems ($P = 0.021$), and agglutination cards for feline blood typing ($P = 0.032$), as well as warming of blood products prior to administration ($P = 0.021$) were more commonly reported by PRH compared to VTH.
Conclusions – Although some transfusion practices including the method and length of storage of blood products, use and screening of blood donors, and administration methods varied between VTH and PRH, most transfusion practices were similar. The information reported from this survey could aid the development of future veterinary transfusion consensus statements.

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Keywords: blood bank, blood donor, blood product, cross-match, fresh frozen plasma, packed red blood cells

Abbreviations

ACVECC	American College of Veterinary Emergency and Critical Care
ACVIM	American College of Veterinary Internal Medicine
CPP	cryoprecipitate-poor plasma
DDAVP	1-deamino-8-D-arginine vasopressin
DEA	dog erythrocyte antigen
FFP	fresh frozen plasma
FWB	fresh whole blood
pRBC	packed red blood cell
PRH	private referral hospitals
SEV	sevoflurane
VTH	veterinary teaching hospitals

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The authors declare no conflicts of interest.

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Introduction

Blood transfusions are routinely performed in small animal veterinary hospitals; however, current transfusion practices are insufficiently reported in the literature and few consensus statements exist to guide transfusion protocols. Additionally, there is controversy within human and veterinary medicine regarding blood donor screening, blood product storage, methods of blood product

administration, and appropriate protocols to monitor for and treat transfusion reactions.[1] Recent veterinary studies have identified new erythrocyte antigens in dogs and cats, suggesting that traditionally accepted methods of blood typing might not be sufficient to detect donor-recipient incompatibilities.[2,3] Unfortunately, investigation of these newly discovered antigens as risk factors for transfusion reactions and recommendations for prescreening transfusion recipients are unreported. Likewise, leukoreduction has been shown to minimize the inflammatory response to packed red blood cell (pRBC) transfusions in dogs,[4] but it is unclear how many hospitals have adopted leukoreduction as part of their routine blood collection protocol. Recent studies in human transfusion medicine have also investigated the association between the age of blood product transfused and morbidity and mortality; however, results have been inconsistent among human studies.[5,6] In the meantime, it is unknown whether veterinary hospitals are adjusting their blood product storage and administration protocols in the face of information discovered in human transfusion studies.

In the veterinary literature, there is 1 consensus statement published by the American College of Veterinary Internal Medicine (ACVIM) recommending infectious disease screening in canine and feline blood donors in order to enhance recipient safety.[7] Review articles have also been published outlining recommended pretransfusion screening of recipients, particularly blood typing and cross-matching cats, whose alloantibodies can lead to a fatal reaction if an unmatched product is administered.[8–10] Likewise, veterinary researchers have studied the impact of mechanical administration of pRBCs on in vivo cell survival[11,12] in order to provide information for blood product administration guidelines. But while the number of studies investigating transfusion-related questions has increased, there are no reports of current veterinary transfusion practice to integrate this new knowledge into hospital protocols. Although a survey of 25 small animal practices reported transfusion practices and costs in dogs over 20 years ago,[13] to the authors' knowledge, no more recent survey has been published since.

The objective of the present study was to characterize current canine and feline transfusion practices at private referral hospitals (PRH) and veterinary teaching hospitals (VTH) in Canada, the United States, Europe, and Australia including information related to blood donor screening; blood product collection, storage, and administration; recipient screening; and monitoring during blood transfusions. The authors hypothesized that transfusion practices would differ between PRH and VTH due to differences in the availability of resources for in-hospital blood banking, and that knowledge of current transfusion practice could provide a foundation for future transfusion studies and veterinary consensus statements.

Methods

Survey composition

After examining the current veterinary literature related to blood donor selection and screening, blood collection, blood product storage, and blood product administration, survey questions were composed. Blood bank product and laboratory service lists were also consulted for available blood products, blood collection, and administration supplies, as well as blood type and cross-match kits. Two blood donor program coordinators at 2 VTH completed a preliminary survey and additional questions were added or altered as per their feedback.

Data collection

The survey questions were added to and disseminated by an online professional surveying program.[a] An invitation to participate in the Internet-based survey was emailed to the American College of Veterinary Emergency and Critical Care (ACVECC) and ACVIM LISTSERVs and to the board of directors of the Association of Veterinary Hematology and Transfusion Medicine. The invitation included an outline of the study objectives and assurance of confidentiality, as well as a link to the survey, which was also posted on the ACVECC online discussion board. Although the invitation was sent to Diplomates and veterinarians, a board-certified specialist, nonboard-certified veterinarian, or veterinary technician could complete the survey. Email dissemination of the invitation began on May 24, 2012, with a deadline for completion of the survey by June 29, 2012. An extension to July 2, 2012, was allowed for hospitals that had only 1 representative submission that was incomplete, to allow time for completion of the survey. Only 1 response per individual was recorded and only the authors viewed the respondent names to find duplicate submissions. One respondent represented each hospital and if greater than 1 response per hospital was received, the authors reviewed the submissions and 1 submission was chosen. Preferential selection between 2 respondents from the same hospital was given to the blood donor program coordinator and if neither individual held that position, the individual with the highest credentials was selected.

Survey population and characteristics

The survey contained 86 questions, including 1 for consent and 1 for permission for follow-up. Survey completion time was approximately 15 minutes based on trial survey submissions. Questions were organized

according to respondent contact information, blood product storage and collection, blood donor program and selection, recipient screening, and blood product administration. A combination of multiple choice (only 1 answer possible), multiple selection (>1 answer could be selected), Likert-type or frequency scales (ie, never, rarely, occasionally, routinely), and yes/no questions were included. The first 4 questions characterized the respondent and hospital represented by the submission, and were used only for categorization of respondents and hospitals (PRH or VTH). There were 13 questions pertaining to blood product storage, including 3 questions related to platelet product use and storage. Sections were separated into canine and feline blood donor program characteristics including: 31 canine questions (6 regarding blood typing and cross-matching, 25 regarding blood banking) and 24 feline questions (5 regarding blood typing and cross-matching, 17 regarding blood banking). There were 15 questions regarding blood product administration and 1 follow-up question. Some questions were stratified based on a preceding question after which the surveying program directed respondents who answered "Yes" to a set of applicable questions, or if "No" was selected, the subsequent set of questions would not apply to that respondent and the program omitted that section and continued to the remainder of the survey.

Survey results were included in the study if the respondent fully completed the survey and was the sole representative from the hospital. Incomplete surveys or duplicate responses from the same hospital were excluded. Submissions from emergency or general practices that were not affiliated with a VTH or PRH were also excluded given the relatively decreased frequency of blood product storage and blood banking performed at these hospitals. Respondents from commercial blood banks were also excluded given that questions regarding recipient screening and blood product administration did not apply to them.

Statistical methods

As submissions were completed, answers were transcribed to a commercial spreadsheet[b] to facilitate statistical analyses. Descriptive statistics were performed to determine the frequency (percentage) of hospital responses to each survey question. Fisher's exact test was used for comparison of 2 variables at PRH and VTH. If >2 variables were compared between PRH and VTH, a chi-square test and Tukey adjustment pair-wise test were performed. All statistical analyses were completed using commercial statistical software[c] and all figures were generated using commercial graphing software.[d] Statistical significance for all comparisons was considered $P < 0.05$.

Results

Respondent characteristics

A total of 120 survey responses were received, 32 of which were incomplete and excluded. Of the remaining 88 complete responses, 4 duplicates from the same hospital, 2 from commercial blood banks, 1 from general practice, and 8 from emergency practice were excluded. The remaining 73 responses were categorized based on the type of hospital and included 53 PRH and 20 VTH. The majority of hospitals were located in the United States (85%; $N = 62/73$) with 10% in Canada ($N = 7/73$), 3% in the United Kingdom ($N = 2/73$), 1% in Switzerland ($N = 1/73$), and 1% from Australia ($N = 1/73$). Of the included respondents, 42 were board certified in emergency and critical care (9 VTH, 33 PRH), 19 were board certified in internal medicine (4 VTH, 15 PRH), 5 were veterinary technicians (4 VTH, 1 PRH), 3 were board certified in both emergency and critical care and internal medicine (1 VTH, 2 PRH), 3 were nonboard-certified veterinarians (1 VTH, 2 PRH), and 1 was board certified in clinical pathology (1 VTH).

Blood product storage

Blood products commonly stored by respondent hospitals were similar for PRH and VTH for canine (Figure 1A) and feline (Figure 1B) patients, except for canine cryoprecipitate-poor plasma (CPP), which was stored at 20% of VTH ($N = 4/20$) compared to 2% of PRH ($N = 1/53$, $P = 0.018$). Storage of platelet products was reported by 21% of all hospitals ($N = 15/73$) including 25% of VTH ($N = 5/20$) and 19% of PRH ($N = 10/53$, $P = 0.537$). Of these hospitals, 70% of PRH ($N = 7/10$) reported storing fresh platelet products for <24 hours versus 60% of VTH ($N = 3/5$) reported storing fresh platelet products for >72 hours. Therefore, VTH were more likely than PRH to store platelet products for >72 hours compared to PRH ($P = 0.046$). Of all hospitals, 17% stored cryopreserved platelet concentrate ($N = 10/73$), whereas 4% stored fresh platelet-rich plasma ($N = 3/73$), 3% stored fresh platelet concentrate ($N = 2/73$), 2% stored lyophilized and chilled platelet concentrate ($N = 2/73$), and 1% stored frozen platelet-rich plasma ($N = 1/73$).

Frozen blood products were stored in −80°C freezers by 20% of VTH ($N = 4/20$) compared to 4% of PRH ($N = 2/53$; $P = 0.089$), and 75% of VTH ($N = 15/20$) reported storing frozen blood products in −20°C freezers compared to 32% of PRH ($N = 17/53$; $P = 0.044$). Conversely, refrigerator freezers were more commonly used by PRH (64%, $N = 34/53$) compared to VTH (5%, $N = 1/20$; $P = 0.001$). Fresh frozen plasma (FFP) was considered frozen plasma by 75% of all hospitals ($N = 55/73$) if stored for >1 year at −20°C.

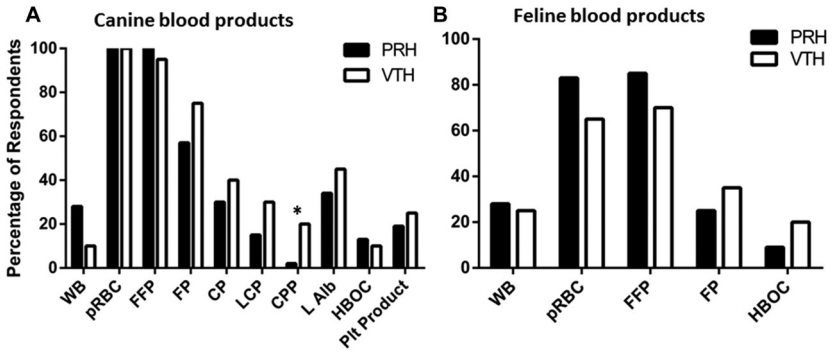

Figure 1: Percentage of respondents storing (A) canine and (B) feline blood products in private referral hospitals (PRH) and veterinary teaching hospitals (VTH). Data are reported as a percentage of total respondents. CP, cryoprecipitate; CPP, cryoprecipitate-poor plasma; FFP, fresh frozen plasma; FP, frozen plasma; HBOC, hemoglobin-based oxygen carrier; L Alb, lyophilized albumin; LCP, lyophilized cryoprecipitate; Plt product, any type of platelet product; pRBC, packed red blood cells; WB, whole blood. *Significant differences ($P < 0.05$) between PRH and VTH.

Refrigerators dedicated only to the storage of blood products were used more commonly by VTH (90%, $N = 18/20$) compared to PRH (51%, $N = 27/53$; $P = 0.003$). Eighty-one percent ($N = 59/73$) of hospitals stored blood bags in a vertical position with space to allow for air movement between bags. Additionally, 92% ($N = 67/73$) of all hospitals labeled and stored blood according to age with 75% ($N = 55/73$) of hospitals storing the most recently collected blood at the back of the refrigerator. Likewise, 56% ($N = 41/73$) of all hospitals reported always using the oldest blood products first, 32% ($N = 23/73$) of all hospitals reported using blood products stored for different lengths of time based on the patient's condition, 11% of all hospitals ($N = 8/73$) reported using blood products in random order depending on unit size and availability, and 1 hospital reported using the newest blood products first. Canine pRBCs were stored for ≤30 days by 73% ($N = 46/63$) of all hospitals, whereas 16% ($N = 10/63$) of hospitals reported storage of canine pRBCs for 42 days. Feline pRBCs were stored for ≤30 days by 76% ($N = 47/62$) of all hospitals, whereas 11% ($N = 7/62$) of hospitals reported storage of feline pRBCs for 42 days. Leukocyte reduction filters were reportedly used by 4% ($N = 2/53$) of all hospitals, including 1 VTH and 1 PRH.

Blood banking

According to all respondents, the person responsible for management of the blood donor program was a veterinary technician in 45% ($N = 24/53$) of hospitals, a board-certified veterinarian in 45% ($N = 24/53$) of hospitals, and a nonboard-certified veterinarian in 10% ($N = 5/53$) of hospitals.

Canine blood banking

Of the respondents, approximately half (53%, $N = 39/73$) reported using a combination of purchased blood products and hospital-run blood donor programs for canine blood product storage including 51% ($N = 27/53$) of PRH and 60% ($N = 12/20$) of VTH ($P = 1.000$). Nineteen percent ($N = 14/73$) of hospitals reported obtaining canine blood products only using hospital-run blood donor programs, which was more common at VTH (35%, $N = 7/20$) compared to PRH (13%, $N = 7/53$; $P = 0.047$). Most hospitals (85%, $N = 45/53$) used staff-owned dogs as canine blood donors including 91% ($N = 31/34$) of PRH and 74% ($N = 14/19$) of VTH ($P = 0.118$). Conversely, 53% ($N = 28/53$) of hospitals used client-owned dogs as canine donors, and this practice occurred more commonly at VTH (74%, $N = 14/19$) than at PRH (41%, $N = 14/34$; $P = 0.043$). Few hospitals (11%, $N = 6/53$) reported owning a colony of canine donors, including 6% of PRH ($N = 2/34$) and 21% of VTH ($N = 4/19$; $P = 0.172$). Likewise, 27% ($N = 20/73$) of hospitals reported only purchasing canine blood products from blood banks, which occurred more commonly at PRH (36%, $N = 19/53$) compared to VTH (5%, $N = 1/20$; $P = 0.040$). Packed RBCs and FFP were the most frequently reported canine blood products routinely purchased or collected by hospitals (Table 1).

The minimum accepted body weight for a canine blood donor was reported as 25 kg by 68% ($N = 34/50$) of respondents. Only 11% ($N = 4/36$) of hospitals including 10% ($N = 2/20$) of VTH and 4% ($N = 2/53$) of PRH reported excluding certain breeds as blood donors because of predilection for certain transmissible bloodborne diseases ($P = 0.712$). Infectious disease screening of blood donors was routinely performed at 94% ($N = 50/53$) of hospitals with a hospital-run blood donation program (Figure 2A), including 89% ($N = 17/19$) of VTH and 97% ($N = 33/34$) of PRH ($P = 0.598$). Approximately half (53%, $N = 28/53$) of respondents reported blood typing canine donors for dog erythrocyte antigen (DEA) 1.1. Additionally, 79% ($N = 41/52$) of hospitals reported

Table 1: Results from a question to determine the frequency that specific blood products were purchased or collected by all surveyed hospitals

Purchased	**Canine ($N = 20$)**				**Feline ($N = 17$)**			
Blood product	**Never**	**Rarely**	**Occasionally**	**Routinely**	**Never**	**Rarely**	**Occasionally**	**Routinely**
FWB	9 (45)	11 (55)	0 (0)	0 (0)	10 (59)	5 (29)	1 (6)	1 (6)
SWB	17 (90)	1 (5)	1 (5)	0 (0)	11 (65)	3 (18)	3 (18)	0 (0)
pRBC	0 (0)	0 (0)	0 (0)	20 (100)	1 (6)	0 (0)	3 (18)	14 (82)
FFP	0 (0)	0 (0)	0 (0)	20 (100)	1 (6)	0 (0)	5 (29)	12 (71)
CP	5 (25)	9 (45)	5 (25)	1 (5)	–	–	–	–
PC	8 (40)	9 (45)	1 (5)	2 (10)	–	–	–	–
PRP	9 (45)	7 (35)	3 (15)	1 (5)	–	–	–	–
LCP	12 (60)	5 (25)	2 (10)	1 (5)	–	–	–	–
Lalb	11 (55)	5 (25)	4 (20)	0 (0)	–	–	–	–
HBOC	14 (70)	5 (25)	0 (0)	1 (5)	14 (82)	3 (18)	0 (0)	0 (0)
Collected	**Canine ($N = 53$)**				**Feline ($N = 54$)**			
Blood Product	**Never**	**Rarely**	**Occasionally**	**Routinely**	**Never**	**Rarely**	**Occasionally**	**Routinely**
FWB	3 (6)	13 (25)	22 (42)	15 (28)	0 (0)	12 (24)	11 (20)	30 (55)
SWB	25 (47)	11 (21)	11 (21)	6 (11)	34 (63)	5 (9)	5 (9)	10 (19)
pRBC	21 (40)	1 (2)	3 (6)	28 (53)	36 (67)	3 (6)	3 (6)	12 (22)
FFP	22 (42)	1 (2)	3 (6)	27 (51)	36 (67)	3 (6)	3 (6)	12 (22)
CP	41 (77)	6 (11)	3 (6)	3 (6)	–	–	–	–
CPP	41 (77)	7 (13)	2 (4)	3 (6)				
PC	8 (40)	9 (45)	1 (5)	2 (10)	–	–	–	–
PRP	37 (70)	7 (13)	8 (15)	1 (2)	–	–	–	–

Note (Question: How often are the following blood products purchased or collected from your canine/feline donors?).
Data are reported as the *N* (%) of respondents. CP, cryoprecipitate; CPP, cryo-poor plasma; FFP, fresh frozen plasma; FWB, fresh whole blood; HBOC, hemoglobin-based oxygen carrier; Lalb, lyophilized albumin; LCP, lyophilized cryoprecipitate; PC, platelet concentrate; pRBC, packed red blood cells; PRP, platelet rich plasma; SWB, stored whole blood.

storing both "universal" and "nonuniversal" canine blood products and about one-third of respondents (32%, $N = 15/47$) considered a DEA 1.1 negative dog a universal donor. Dal antigen testing was never performed by 87% ($N = 46/53$) of respondents, but 9% ($N = 5/53$) did test for the Dal antigen if all cross-matches were incompatible including 3% of PRH ($N = 1/34$) and 21% of VTH ($N = 4/19$; $P = 0.099$).

Monthly parasite prevention was required for canine donors at 81% ($N = 43/53$) of hospitals including 88% ($N = 30/34$) of PRH and 68% ($N = 13/19$) of VTH ($P = 0.140$). None of the respondents reported supplementation of canine donors with oral ferrous sulfate. No PRH reported routine administration of 1-deamino-8-D-arginine-vasopressin (DDAVP) to canine donors, whereas 16% ($N = 3/19$) of VTH did ($P = 0.041$). Precollection sedative administration was routinely performed at 75% ($N = 40/53$) of all hospitals (Figure 3A) and the majority (83%, $N = 43/52$) reported collecting blood from canine donors less often than every 3 months.

Respondents that had a hospital-run collection program reported using various types of canine blood collection systems. Single bag collection systems were used at 54% ($N = 28/52$) of hospitals and more commonly by PRH (67%, $N = 22/33$) compared to VTH (32%, $N = 6/19$; $P = 0.021$). Conversely, double bag collection systems were used in 38% ($N = 20/52$) of hospitals including 53% ($N = 10/19$) of VTH and 33% ($N = 11/33$) of PRH ($P = 0.242$), and triple or quadruple bag collection systems were used in 33% ($N = 17/52$) of hospitals including 47% ($N = 9/19$) of VTH and 24% ($N = 8/33$) of PRH ($P = 0.126$). Over three-quarters (77%, $N = 41/53$) of respondents reported using RBC preservatives, with 26% ($N = 14/53$) using saline-adenine-glucose-mannitol[e] and 26% ($N = 14/53$) using phosphate-adenine-dextrose-mannitol.[f]

Feline blood banking

Feline blood banking programs were reported as a combination of purchased blood products and hospital-run blood donor programs at half (49%, $N = 36/73$) of all hospitals including 49% ($N = 26/53$) of PRH and 50% ($N = 10/20$) of VTH ($P = 1.000$). Conversely, 26% ($N = 19/73$) of all hospitals reported obtaining feline blood products using only a hospital-run blood donor programs, which was more common at VTH (45%, $N = 9/20$) compared to PRH (19%, $N = 10/53$; $P = 0.042$). Staff-owned cats were used most commonly as feline blood donors in 73% ($N = 40/55$) of hospitals including

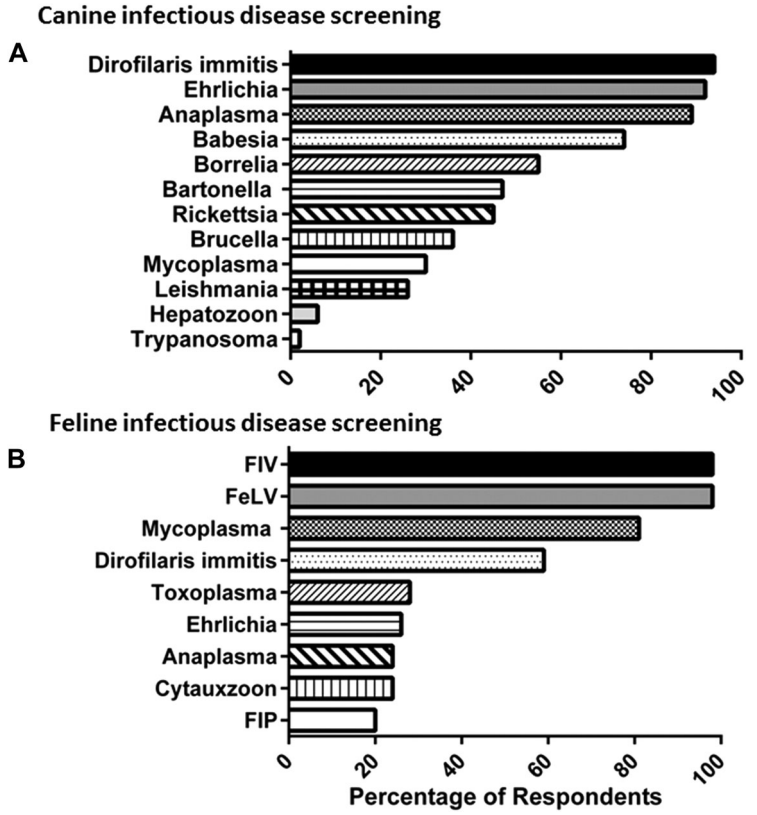

Figure 2: Percentage of respondents screening for different infectious diseases in (A) canine and (B) feline donors. Data are shown as a percentage of respondents that reported collecting blood at their hospital. FeLV, feline leukemia virus; FIP, feline infectious peritonitis; FIV, feline immunodeficiency virus.

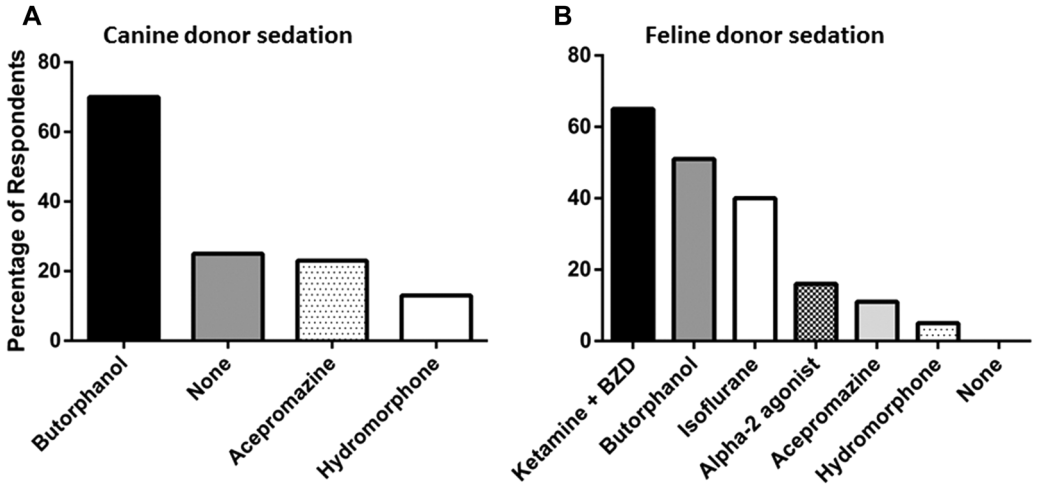

Figure 3: Percentage of respondents administering sedation routinely to (A) canine and (B) feline donors prior to blood collection. Data are shown as a percentage of respondents that reported collecting blood at their hospital. BZD, benzodiazepine.

72% ($N = 26/36$) of PRH and 74% ($N = 14/19$) of VTH ($P = 1.000$), whereas 40% ($N = 22/55$) of hospitals reported having a colony of feline donors including 33% ($N = 12/36$) of PRH and 53% ($N = 10/19$) of VTH ($P = 0.247$). Similarly, 36% ($N = 20/55$) of hospitals reported using client-owned cats as feline donors including 28% of PRH ($N = 10/36$) and 53% of VTH ($N = 10/19$; $P = 0.084$). Just 22% ($N = 16/73$) of all hospitals reported only purchasing feline blood products from commercial blood banks, which was more common at PRH (30%,

$N = 16/53$) compared to VTH (5%, $N = 1/20$; $P = 0.031$). Packed RBCs and FFP were the most frequently purchased feline blood products reported by those hospitals only purchasing feline blood products from commercial blood banks (Table 1). More than half (55%, $N = 30/55$) of respondents with a hospital-run feline blood banking program reported routine collection of fresh whole blood (FWB), including 58% (21/36) of PRH and 47% (9/19) of VTH ($P = 0.427$).

The minimum accepted body weight for a feline blood donor was reported as 5 kg by 47% ($N = 26/55$) of all respondents. Routine screening of feline blood donors for infectious diseases was reported by 98% ($N = 54/55$) of respondents (Figure 2B). The feline donor pool included both type A and B cats in 69% ($N = 38/55$) of hospitals including 67% of PRH ($N = 24/36$) and 74% of VTH ($N = 14/19$; $P = 0.946$). Feline donors were screened for the Mik antigen in 15% ($N = 8/55$) of hospitals including 14% ($N = 5/36$) of PRH and 16% ($N = 3/19$) of VTH ($P = 1.000$).

Monthly parasite prevention was required for feline donors in 44% ($N = 24/55$) of hospitals including 42% ($N = 15/36$) of PRH and 47% ($N = 9/19$) of VTH ($P = 0.778$). Supplementation with oral ferrous sulfate was only reported by 5% ($N = 3/55$) of hospitals including 3% ($N = 1/35$) of PRH and 10% ($N = 2/20$) of VTH ($P = 0.272$). All hospitals reported administration of sedation and/or general anesthesia prior to feline blood product collections (Figure 3B). Respondents reported collecting blood from feline donors less often than every 2 months at 45% of hospitals ($N = 25/56$) including 38% ($N = 14/37$) of PRH and 58% ($N = 11/19$) of VTH ($P = 0.252$). Of the hospitals that reported performing collections, 56% ($N = 31/55$) collected blood products using a commercially available closed system, whereas an open system was reportedly used by 44% ($N = 24/55$) of hospitals. Anticoagulant use varied amongst all respondents with 65% ($N = 33/51$) using citrate-phosphate-dextrose-adenine, 29% ($N = 15/51$) using acid-citrate-dextrose, and 6% ($N = 3/51$) using citrate-phosphate-dextrose. The use of RBC preservatives was reported by 36% ($N = 20/55$) of hospitals, with 50% ($N = 10/20$) using saline-adenine-glucose-mannitol and 50% ($N = 10/20$) using phosphate-adenine-dextrose-mannitol.

Recipient screening

Prior to blood product administration, 96% ($N = 70/73$) of hospitals reported blood typing or cross-matching canine and feline recipients. When blood typing canine recipients, 51% of hospitals ($N = 25/51$) reported using a cartridge-type test including 60% ($N = 9/15$) of VTH and 44% ($N = 16/36$) of PRH ($P = 0.513$). Likewise, 45% ($N = 23/51$) of hospitals reported using an agglutination card test to type dogs, including 27% ($N = 4/15$) of VTH and 53% ($N = 19/36$) of PRH ($P = 0.160$). Only 6% ($N = 3/51$) of hospitals reported using stored gel tests for canine blood typing. When blood typing feline recipients, 25% of hospitals ($N = 16/64$) reported using a cartridge-type test, including 44% ($N = 8/18$) of VTH and 17% ($N = 8/46$) of PRH ($P = 0.054$). Conversely, 67% ($N = 43/64$) of hospitals reported using an agglutination card test to type cats, which was more commonly performed by PRH (76%, $N = 35/46$) compared to VTH (44%, $N = 8/18$; $P = 0.032$). Only 8% ($N = 5/64$) of hospitals reported using stored gel tests for feline blood typing. Before blood typing, just 6% of hospitals ($N = 3/54$) reported removing plasma in order to complete the test within the manufacturer's recommended hematocrit range.[g] Almost all hospitals reported performing cross-match procedures only in certain situations (eg, if the animal was previously transfused) at the discretion of the clinician for dogs (99%, 72/73) and cats (95%, $N = 69/73$). However, some hospitals reported always performing major cross-matches for all dogs (15%, $N = 11/73$) and cats (22%, $N = 16/73$), regardless of the situation. Most hospitals (67%, $N = 45/67$) reported cross-matching dogs $\geq$5 days after the first transfusion, compared to 33% ($N = 22/67$) that reported cross-matching dogs $\leq$3 days after the first transfusion. Likewise, most hospitals (59%, $N = 38/64$) reported cross-matching cats $\geq$5 days after the first transfusion, compared to 41% ($N = 26/64$) that reported cross-matching cats $\leq$3 days after the first transfusion.

Blood product administration

Approximately half (49%, $N = 36/73$) of hospitals reported routine warming of blood products prior to administration, which was more commonly reported by PRH (57%, $N = 30/53$) compared to VTH (25%, $N = 5/20$; $P = 0.020$). Warming was performed most commonly at 71% ($N = 25/35$) of hospitals by placing the blood product bag in a warm water bath. During blood product administration, 74% ($N = 54/73$) of hospitals including 57% of PRH ($N = 30/53$) and 70% of VTH ($N = 14/20$) reported using a dedicated IV catheter ($P = 0.555$). Conversely, 25% ($N = 18/72$) of hospitals reported administration of blood products in an IV catheter concurrently with IV fluids such as 0.9% NaCl (89%, $N = 16/18$), Normosol-R (56%, $N = 10/18$), or Plasmalyte-A (50%, $N = 9/18$). The reported mode of delivery of blood products varied between canine and feline recipients. During canine transfusions, 32% of hospitals ($N = 23/73$) reported using syringe pumps, compared to 60% ($N = 44/73$) that reported using volumetric pumps and 47% ($N = 34/73$) that reported using gravity flow. Conversely, during feline transfusions, 82% ($N = 60/73$) of hospitals reported using syringe pumps, compared to

15% ($N = 11/73$) that reported using volumetric pumps and 18% ($N = 13/73$) that reported using gravity flow.

Administration of a "test dose" of the blood product at the beginning of the transfusion was reported by 84% ($N = 52/62$) of respondents, but the protocol varied greatly among hospitals (Figure 4). During blood transfusion, temperature, pulse, and respiratory rate were monitored at 99% ($N = 72/73$) of hospitals, whereas blood pressure was measured at 40% ($N = 29/73$) of hospitals including 38% ($N = 20/53$) of PRH and 45% ($N = 9/20$) of VTH ($P = 0.601$). Patient monitoring was completed at least every 5–15 minutes for the first hour at 92% ($N = 67/73$) of hospitals and a specific monitoring sheet was used at 93% ($N = 68/73$) of hospitals. A hematocrit tube containing the recipient's blood was spun to investigate for evidence of hemolysis during or immediately after the transfusion at 8% of hospitals ($N = 6/73$). Diphenhydramine was administered routinely pretransfusion at 11% of PRH ($N = 6/53$), but no VTH ($P = 0.179$).

Autologous transfusions that involved collection and storage of a patient's own blood for transfusion within the next 4 weeks were never performed at 68% ($N = 50/73$) of hospitals. Likewise, autotransfusions that involved transfusion of a patient's own body cavity hemorrhage were occasionally performed at 36% ($N = 19/53$) of hospitals, including 23% ($N = 12/53$) of PRH and 35% ($N = 7/20$) of VTH ($P = 0.540$).

Discussion

The data collected from this survey indicate that blood banking protocols and blood donor programs at the included VTH and PRH are mostly similar. Differences may depend on clinician preference and the feasibility of what can be performed in certain hospital settings. Almost every hospital (99%) reported routine storage of canine and feline pRBCs and FFP, which demonstrates that component therapy is commonly practiced in veterinary hospitals. Administration of blood products as components rather than whole blood began in the 1990s to conserve blood product usage and enable 1 donor collection to provide products for 2–3 recipients.[14] Depending on the hospital caseload and demand for blood products, collecting FWB only when the need arises might limit discarding unused products while saving technician time, supplies, and availability of feline donors. VTH were more likely than PRH to store canine blood components other than pRBCs and FFP, including CPP. This is likely because VTH were more likely to perform in-hospital blood collections and were thus able to make these products (eg, cryoprecipitate) on-site. VTH were also less likely to use single bag canine blood collection systems, which preclude making additional blood components. While the survey question regarding the use of canine blood collection systems was not linked or in reference to the blood components collected, it is likely that increased use of single bag collection systems at PRH reduced the collection and storage of blood components other than FWB.

Half of the hospitals reported using a combination of hospital-run donor program blood collections and purchased blood products for their canine blood bank program; however, PRH were more likely to purchase blood products compared to VTH. Additionally, blood donor dogs used for in-hospital blood collections were more likely to be client-owned at VTH, compared to staff-owned at PRH. These differences are likely attributable to the availability of hospital staff and time required to recruit, screen, and maintain a blood donor program and to collect and prepare blood products. Additionally, depending on the number of blood products used at the hospital, the economic justification for running a blood bank, including the costs required for it to function (eg, purchase of blood product centrifuge, dedicated staff) might not be justifiable at some PRH. Therefore, if PRH have more modest blood product usage, the technician time and equipment costs associated with running a blood bank might be unwarranted.

Twenty-one percent of hospitals reported storing canine platelet products, the majority (78%) of which stored cryopreserved platelet concentrate. This is likely due to the short shelf-life of fresh platelet products, which must be stored at 22°C (room temperature) under continuous, gentle agitation for a maximum storage time of 5 days in order to prevent bacterial contamination.[15,16] Fresh platelet products were stored more frequently for >72 hours at VTH, whereas PRH more frequently stored fresh platelet products for <24 hours; overall, 54% hospitals reported storing fresh platelet products for a maximum of 24 hours. A review of platelet product usage in veterinary patients concluded that fresh platelet concentrate was the product of choice given that stored products have decreased in vivo platelet recovery and survival.[17] However, the more recent availability of cryopreserved or lyophilized platelet products offers increased platelet concentrations at decreased volumes, which results in decreased exposure to blood products.[16] Recently, a prospective randomized clinical trial compared fresh platelet concentrate and lyophilized platelet transfusions in thrombocytopenic dogs with clinical signs of hemorrhage.[17] There was no difference in reaction rates, bleeding scores, or survival rates between the dogs; therefore, the authors concluded that lyophilized platelets were comparable to fresh platelets, in addition to being more user-friendly and providing storage (shelf-life) advantages over fresh platelets.[17]

The various methods and appliances used to store blood products also differed between hospitals. The use

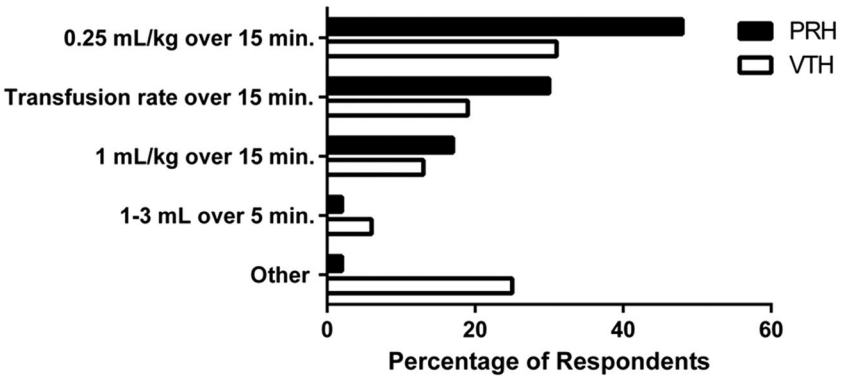

Figure 4: Percentage of respondents using different test doses at the beginning of blood transfusions at private referral hospitals (PRH) and veterinary teaching hospitals (VTH). Data are shown as a percentage of the total respondents. min., minutes.

of a −20°C or −80°C freezer to store frozen blood products was significantly more common in VTH than in PRH. This is likely due to the increased availability of funds to purchase and maintain such an appliance, given researchers at VTH might also have a need for this device to store research samples. VTH were also more likely than PRH to have a refrigerator dedicated to blood product storage. Dedicated storage devices opened infrequently are necessary to minimize the temperature fluctuations that occur when the appliance is opened multiple times per day, which can contribute to RBC storage lesions.[18] However, the purchase of a dedicated refrigerator might be cost prohibitive for certain hospitals, depending on the frequency of transfusions administered or the number of blood products stored.

Although the use of pRBC preservatives was reported by 57% of respondents for canine pRBCs and 65% of respondents for feline pRBCs, the majority of hospitals reported only storing canine (73%) or feline (76%) RBCs for ≤30 days. This is likely due to concerns regarding the development of storage lesions 21–42 days postcollection.[5,6,19] Likewise, 92% of hospitals reported storing blood products according to age as determined by the length of time stored following collection. Over half (56%) of respondents also reported using the oldest blood products first, followed by 32% of respondents that selected the blood product age according to the patient's underlying condition. Given that blood products are often in short supply, using the oldest stored products first to ensure that they are used before expiration seems the most logical. However, recent studies demonstrate an association between the length of pRBC storage and higher morbidity and mortality in people, suggesting that administration of blood products stored >21 days should possibly be avoided.[5,6] Unfortunately, the economic and logistic ramifications of allocating fresh stored blood to certain patients or discarding blood that is stored for >21 days would likely be impractical at most veterinary and human hospitals. A recent retrospective canine study revealed that administration of pRBCs stored >14 days was not associated with reduced survival to 30 days posttransfusion; however, an increased duration of storage was associated with a higher likelihood of developing multiple organ dysfunction and coagulopathy.[h]

The present survey revealed that 94% of hospitals screen canine donors for blood-borne infectious diseases; however, the pathogens tested varied among hospitals. The ACVIM published a consensus statement in 2005 outlining recommendations for infectious disease screening of canine and feline blood donors, which advocates testing for certain vector-borne and nonvector-borne diseases depending on the severity of clinical disease induced by the pathogen.[7] However, testing is only recommended for specific regions or breeds when specific pathogens are endemic to restricted geographical regions or certain breeds are typically affected.[7] These recommendations might account for the variation in canine donor infectious disease testing in the present study. Few hospitals excluded certain breeds as blood donors that more commonly carry certain infectious diseases, likely due to their vigilant screening process. Additionally, although DEA 1.1 is responsible for the majority of canine donor-recipient incompatibilities,[20] approximately one-thirds of the respondents considered a DEA 1.1 negative dog a universal canine donor. Currently, there is no consensus on what constitutes a universal donor, but some consider an ideal canine blood donor as negative for DEA 1.1 and 1.2, but positive for antigens of high frequency (ie, DEA 4).[10] Interestingly, only 9% of hospitals screened canine donors for the Dal antigen, and did so only when cross-matches were incompatible. Given that Dal is not considered a high frequency antigen, more studies are needed to determine the breed prevalence and clinical significance before firm recommendations are made with regards to Dal screening.[2]

Another difference between hospitals was that DDAVP was only routinely administered to canine blood donors at VTH, whereas no PRH reported routine administration of DDAVP. The higher frequency of DDAVP administration at VTH is likely due to the more frequent collection of cryoprecipitate, which probably explains the more frequent storage of cryo-poor plasma at VTH that was found in the present study. According to a study of greyhounds, administration of precollection DDAVP to blood donors significantly increased von Willebrand factor and factor VIII for a 2-hour period allowing for higher concentrations in collected components.[21] Therefore, it is common practice at many commercial veterinary blood banks to routinely administer DDAVP to canine donors, especially prior to the collection of blood for separation into cryoprecipitate, in order to enhance the yield of von Willebrand factor. Although the present survey indicates that routine precollection administration of DDAVP to canine donors is not commonly practiced at most hospitals, it might be considered during the collection of blood for cryoprecipitate units.

The most frequently (47%) reported minimum acceptable feline donor body weight in the present study was 5 kg. Different recommendations for feline blood donor body weights range from 4 kg[22] to >5 kg.[23] The present survey also revealed that all hospitals screened donor cats for feline immunodeficiency virus and feline leukemia virus, while 85% also screened for *Mycoplasma* sp. The ACVIM consensus statement on infectious disease screening recommends that all feline blood donors should be screened for feline immunodeficiency virus and feline leukemia virus prior to inclusion in a blood donor program, regardless of previous history, and that cats that are permitted outside should be excluded as donors given ongoing potential exposure to these viruses.[7] As well, it is recommended that all feline donors be tested using a commercially available polymerase chain reaction test to determine *Mycoplasma* status; if positive, these cats should be excluded as donors.[7]

All respondents reported using sedation or anesthesia for collection of blood from feline donors; the most commonly reported protocols included ketamine with a benzodiazepine, butorphanol, and isoflurane. Given that cats predictably struggle in response to physical restraint, as well as the time required to collect approximately 50 mL of blood, feline donor sedation is necessary to ensure everyone's safety and is typically well tolerated. Additionally, since bacterial contaminants are most likely to be normal epidermal flora, all donors must have surgical skin preparation, which underscores the need for anesthesia. One study using sevoflurane (SEV) anesthesia investigated the effect of blood collection on vital signs and oscillometric blood pressure in feline blood donors, and determined that 50 mL of blood could safely be collected from healthy cats weighing more than 5 kg, but with a noticeable decrease in heart rate, blood pressure, and PCV.[23] Another study compared 2 anesthetic protocols for feline blood collection including intramuscular ketamine-midazolam-butorphanol and inhalant SEV, and determined that cats anesthetized with SEV had a faster return to normal behavior.[24] Importantly, hypotension was experienced by nearly all cats; therefore, IV access and blood pressure monitoring was recommended by the authors for all anesthetized feline blood donors.[24] None of the respondents surveyed in the present study reported using SEV during feline blood collections, but 40% reported using isoflurane, possibly because more hospitals have isoflurane vaporizers.

Recipient pretransfusion screening is a pivotal part of transfusion practice given that transfusion reactions are seen in 3%–28% of transfused canine patients.[25,26] Most (62%) hospitals reported blood typing all canine recipients; respondents that did not report performing routine blood typing might not consider it necessary, given that dogs not previously transfused have alloantibodies of limited clinical significance.[27] Likewise, it is possible that some hospitals only transfuse blood from DEA 1.1 negative dogs. While commercial immunochromatographic cartridges were used more commonly by VTH compared to PRH when blood typing cats, both VTH and PRH reported using agglutination cards and immunochromatographic cartridges for blood typing dogs. Studies reveal that agglutination cards can be more subjective in dogs, whereas the cartridge test is more specific.[20,28] The cartridge test also removes the effect of autoagglutination, which makes proper interpretation of an agglutination card test impossible. Cartridge tests can be made more sensitive when the PCV of the patient is adjusted to within the manufacturer's specifications, such that a higher PCV will produce a more pronounced DEA 1.1 positive indicator; however, only 6% of all hospitals reported removing plasma from the recipient's blood sample prior to performing the test.

Almost all (96%) hospitals blood type feline recipients prior to transfusions; it is possible that the hospitals not blood typing are using cross-matching as a measure of compatibility. Either blood typing or cross-matching is mandatory given that type A-B incompatibilities in cats result in a potentially fatal acute hemolytic reaction.[22] Two-thirds (67%) of hospitals reported cross-matching feline recipients with an unknown transfusion history or previous transfusion reaction, whereas 22% of hospitals reported performing cross-matches in all cats. While the incidence of reactions in feline donors administered A-B compatible blood is only 1.2%,[29] routine cross-matching of cats is ideal because the novel Mik antigen might lead to incompatibilities that are not identified by commercial blood typing tests.[3] Only 15% of hospitals

that have a feline blood donor program reported testing for Mik in their donors. Interestingly, the majority (67%) of hospitals reported waiting ≥3 days after the first transfusion to perform a cross-match procedure in both cats and dogs, compared to 33% of hospitals that wait ≥5 days. While previous studies indicate that induced alloantibodies to DEA 1.1 are present 9 days after transfusion in dogs,[30,31] the majority of hospitals indicated preferring to perform cross-match testing sooner.

Respondents from PRH reported warming blood products prior to administration more frequently than those at VTH. Warm water baths were the primary reported method of warming, with few reportedly using commercial heating devices. Hypothermia can impair coagulation, produce myocardial ischemia, and induce thermal stress; therefore, warming of blood products using either a commercial device or other means to increase the unit temperature 1–6°C to a more normothermic range is recommended for human trauma patients receiving rapid transfusions.[32] With regard to the method of administration, blood products were reportedly administered more often using syringe pumps for cats and volumetric pumps for dogs, rather than gravity flow. This finding is likely attributable to the ability to more accurately deliver the desired volume and rate of administration given the size difference between most dogs and cats. However, 1 canine study identified that mechanical delivery compared to gravity flow caused RBC loss posttransfusion, presumably due to pump-induced RBC damage.[11] Conversely, a recent study revealed that the use of syringe pumps and aggregate filters to perform autologous transfusion in cats did not significantly affect the short- or long-term survival of RBCs.[12]

The majority (84%) of hospitals reported administering test doses of blood products and a 0.25 mL/kg volume administered over 15 minutes was the protocol reported most often. Test doses are recommended because pretransfusion recipient screening and compatibility procedures do not completely eliminate the risk of reaction, and specifically because major cross-matching does not predict reaction to donor plasma proteins or WBCs.[10] Measures to avoid transfusion reactions were demonstrated by nearly all hospitals, in that 93% reported using a monitoring form during each transfusion to record recipient temperature, pulse, respiration, and sometimes blood pressure, at least every 15 minutes for the first hour of the transfusion. Although collection of recipient blood for spinning of hematocrit tubes has been recommended to evaluate for evidence of hemolysis during or following transfusion,[8] this practice was only reported by 8% of respondents. Routine use of diphenhydramine as a premedication prior to transfusion administration was reported by 11% of PRH, whereas no VTH reported prophylactic use of diphenhydramine. A review of 3 randomized controlled trials comparing premedication with diphenhydramine and either acetaminophen or hydrocortisone versus placebo in people revealed that premedication did not reduce the likelihood of febrile or nonhemolytic transfusion reactions.[33]

Survey respondents reported performing autologous transfusions or autotransfusions very infrequently. Autologous transfusions involve the collection and storage of a patient's own blood for administration within 4 weeks, whereas an autotransfusion refers to transfusion of a patient's own body cavity hemorrhage immediately.[34] The risks associated with these procedures include bacterial contamination or bacteremia, coagulopathy, hemolysis, and embolism.[34] Although many hospitals are equipped with the supplies necessary to perform these procedures, preference is likely given to stored blood products, given their ready accessibility and the relative assurance that they are not contaminated. In a study including 15 cats diagnosed with meningioma requiring resection by partial craniectomy, 60 mL of blood was collected and stored for 1–2 weeks and administered at the time of surgery in 11 of the 15 patients.[35] No cats received allogenic blood and no transfusion reactions occurred, with all 15 cats being discharged and doing well >6 months later.[35] An important benefit of autologous transfusion is sparing valuable blood resources while eliminating the risk of severe transfusion reactions, when it is safe and feasible.[36,37] In a report of autologous transfusion following intra-abdominal vessel damage and hemoperitoneum, blood removed from the abdominal cavity using cell-salvage devices was effectively readministered to replace circulating volume with no detrimental effects related to RBC salvage.[38] Therefore, salvaging the patient's blood in cases of severe hemorrhage might in fact reduce complications, given the risks associated with allogenic transfusion.

The present study has some limitations. While internet-based surveys can sample a large number of individuals, response rates are often low, which biases the sampled population. The present study included only 1 survey response per hospital; given that board-certified veterinarians from both ACVIM and ACVECC were given access to the survey link, duplicate submissions from different individuals at the same hospital were received. Each response was reviewed and results were sometimes different among respondents from the same hospital, suggesting that many responses could be based on clinician preference. Because one of the objectives was to compare responses from VTH and PRH, only 1 response per hospital was permitted. As such, variations in clinician preferences within hospitals

were not investigated. Perhaps a future survey could include the responses of each individual clinician, to determine variability amongst clinicians. Unfortunately, incomplete survey submissions were excluded, which decreased the number of hospitals included in the study. Although the number of surveys from PRH was almost 3 times greater than the number of surveys from VTH, the number of VTH respondents encompassed approximately half of VTH in North America, which is considered an excellent response rate for most surveys.[39] However, few survey respondents were from hospitals outside of North America; therefore, the results of the survey cannot necessarily be applied to veterinary hospitals worldwide. Likewise, emergency hospitals not affiliated with PRH or VTH were excluded, thus preventing the inclusion of information from nonreferral veterinary hospital settings.

Additionally, the development of the survey was not performed by experts in the field of online research. As such, questions were created after reviewing the current literature in the field of small animal transfusion medicine to determine topics pertaining to current practices and controversies related to blood donor programs and blood product administration. Thereafter, 2 experienced veterinary technicians in charge of blood donor programs were given access to the survey to provide their feedback, but no formal assessment of the survey was provided by experts in the field. As such, survey questions might not have been ideal and survey programming restrictions might not have provided respondents with the ability to select a desired response, although open text-boxes were provided throughout the survey for additional notation, and comments were included whenever possible.

Conclusions

Differences existed between surveyed VTH and PRH in some transfusion and blood banking practices. PRH more frequently purchased blood products, whereas VTH were more likely to have an in-hospital blood donor program and use client-owned dogs in their canine donor program. Also, CPP was more frequently stored at VTH, which were also more likely to store blood products in a dedicated refrigerator and −20°C or −80°C freezer. PRH more frequently used a refrigerator freezer and were more likely to discard platelet products after 24 hours of storage. Precollection DDAVP was more commonly administered to dogs at VTH, whereas collection of canine blood products using a single bag system was more likely at PRH. Before administering blood to feline recipients, PRH more commonly used agglutination cards to perform blood types, and PRH were also more likely to warm blood products. Although differences exist between VTH and PRH, the results demonstrate an overall similarity in the practice of transfusion medicine at the surveyed hospitals. The results of this survey provide an understanding of current veterinary transfusion practice, which might serve as an aid when developing future veterinary transfusion consensus statements.

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Footnotes

[a] SurveyMonkey Professional Online Surveying Program [www.surveymonkey.com].
[b] Microsoft Office 2010. Microsoft Excel (version 14). Microsoft Corporation, 2010. Redmond, WA.
[c] SAS Institute Inc 2004. SAS OnlineDoc 9.1.3. Cary, NC.
[d] GraphPad Prism version 5.00 for Windows, GraphPad Software, San Diego, CA [www.graphpad.com].
[e] Adsol, Fenwall Laboratories, Lake Zurich, IL.
[f] Optisol, Terumo Medical Corp., Somerset, NJ.
[g] RapidVet-H Canine DEA 1.1, DMS Laboratories, Flemington, NJ.
[h] Hann L, Brown DC, King LG, et al. Effect of duration of packed red blood cell storage on morbidity and mortality in dogs following transfusion. J Vet Intern Med 2013;27(3):713–714.

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