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Whole blood transfusions in 91 cats: a clinical evaluation

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Summary This survey assessed the feline transfusion practices at the University of Berlin from 1998 to 2001 in regard to patient population, indications, efficacy, and transfusion reactions. Blood was obtained from seven healthy in-house donors and 127 mostly indoor client-owned pet cats. Over a 3-year period 91 cats were transfused with blood type compatible blood. The blood was fresh (within 8 h of collection) or stored no longer than 15 days. Transfusions were required because of blood loss anaemia (*n*=40), haemolytic anaemia (*n*=13), ineffective erythropoiesis (*n*=35), hypoproteinaemia (*n*=2) or coagulopathy (*n*=2). The anaemic cats had a pretransfusion haematocrit of 5–20% (*m* [median]=13), and received one to six transfusions (*m*=1). The survival rates of the anaemic cats at 1 and 10 days after transfusion were 84 and 64%, respectively. None of the deaths appeared to be related to transfusion reactions. The major crossmatch, undertaken before 117 transfusions, was incompatible for eight cats. All except for one had previously been transfused. Lysis of transfused cells in six cases resulted in a less than expected haematocrit rise and an increase in serum bilirubin. Transient mild transfusion reactions were only noted in two cats during the second or third transfusion. In conclusion, with proper donor selection and appropriate compatibility screening, blood transfusions are well tolerated, appear effective, and may increase chances of survival.

Introduction

There has been a notable increase in the willingness of pet owners to seek out veterinary care and more intensively treat their cats' illnesses (Kraft and Danckert, 1999). Hence, blood transfusions have become an important component of intensive medical and surgical care. Furthermore, blood collection techniques have been improved, and the characterisation of the feline blood group system and the simplification of blood typing procedures with the application of test cards, have greatly improved the safety of blood transfusions in cats (Andrews et al., 1992; Auer and Bell, 1981; Bücheler and Giger, 1992; Giger, 2000; Griot-Wenk and Giger, 1995; Griot-Wenk et al., 1996; Knottenbelt, 2002; Kohn et al., 1997).

Transfusions are typically administered to animals experiencing severe anaemias due to life-threatening blood loss, haemolysis or bone marrow failure. In cats, fresh whole blood is the most common form of transfusion. In canine transfusion medicine, therapy with blood components has become standard, whereas in cats, due to small blood donation volumes, separation into its components has only rarely been described (Henson et al., 1994; Springer et al., 1998). Storage of feline

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blood is seldom practised as preservation of blood acquired by an open system increases the risk of bacterial contamination (Council of Europe, 2000).

There are very few surveys concerning methods, indications and efficacy of transfusion in cats (Griot-Wenk and Giger, 1995; Henson et al., 1994; Sommer, 1993). The goal of this study was to evaluate all feline blood transfusions at the Clinic for Small Animals at the Free University of Berlin over a 3-year period (September 1998 until August 2001). The study included the indications for blood transfusions, haematocrit (Hct) values before and after transfusion, transfusion frequency and volume, survival rate, and evidence of transfusion reactions. Moreover, the practicability of a hospital and volunteer-donor based feline transfusion programme was evaluated. Additionally, in some cases pre- and post transfusion blood crossmatches as well as Coombs' tests were performed to determine whether alloantibodies were produced against transfused erythrocytes.

Materials and methods

Blood donors

Seven clinic-owned cats as well as 127 client-owned cats served as blood donors. Donor assessment included a normal physical examination, normal complete blood count and clinical chemistry as well as negative serology for feline leukaemia virus (FeLV) and feline immunodeficiency virus (FIV). All donors had had regular deworming and vaccination programmes and indoor cats were preferred. All screening test results were evaluated before blood collection and transfusion. The cats were sedated using 5–6 mg/kg ketamine (Ketamin 10%; Essex Tierarznei, München, Germany) and 0.1 mg/kg midazolam (Midazolam; Ratiopharm, Ulm, Germany) or in some cases 0.1 mg/kg acepromazine (Vetranquil; Sanofi-Cefa, Düsseldorf, Germany) intramuscularly, respectively. After clipping and scrubbing the neck area over the jugular vein, a butterfly catheter (Vasoflo Perfusionsbesteck, 19 G, Dispomed Witt, Gelnhausen, Germany) was used to aspirate blood into one or more 10 ml syringes containing anticoagulants by gently mixing the content back and forth. The blood was immediately transferred from the syringes into a transfer bag (Baxter Healthcare Corporation, Unterschleissheim) and only whole blood was administered.

If the blood was transfused immediately (within 8 h), sodium citrate (3.13%, Braun, Melsungen, Germany) was used as an anticoagulant (1 part sodium citrate to 9 parts blood). Citrate–phosphate–dextrose–acetate-1 (1.2 parts CPDA-1 to 8.8 parts blood), taken from a single human blood bag system (Baxter Fenwal; Unterschleissheim, Germany), was used as an erythrocyte preservative and anticoagulant to store the units at 4–6 °C for a maximum of 20 days. Blood donation volume did not exceed 10% of the total blood volume calculated at 6–7 ml/kg. After the blood collection, donor cats were observed for 1–2 h and were given subcutaneously, or in rare cases intravenously, lactated Ringer's solution (Sterofundin; Braun, Melsungen, Germany) (approximately 20 ml/kg).

Blood typing

Both donor and recipient were blood typed using the whole blood slide method or DMS typing cards (RapidVet H Feline; dms laboratories, Flemington, NJ, USA). The presence of alloantibodies in type B cats was determined by 'back-typing'. In the case of autoagglutination and to confirm blood type AB, a haemagglutination test tube method on a washed red cell suspension was employed (modified from Giger et al., 1989; Griot-Wenk and Giger, 1995; Kohn et al., 1997).

Blood transfusions

Transfusions were administered into the saphenous, cephalic antebrachial or jugular vein using 150 cm long transfusion sets with 200 μm filters (Sangofix Air; Braun Melsungen, Germany). The volume of whole blood to be administered can be determined using the following formula (Griot-Wenk and Giger, 1995):

$$\text{transfusion volume (ml)} = \text{Hct rise desired (\%)} \times \text{body weight (kg)} \times 2$$

However, the transfusion volume was often limited by the amount of blood available and thus smaller than desired. The transfusion rate for normovolaemic cats was approximately 10 ml/kg/h, cats with cardiovascular dysfunction received 4 ml/kg/h, whereas animals with hypovolaemic shock were transfused more quickly at a rate of up to 60 ml/kg/h. The Hct was measured before as well as 16–24 h after the transfusion. During and up to 1 h after the transfusion, the recipient was observed for any signs of a transfusion reaction.

The evaluation of blood transfusions included the following parameters: signalment and blood type of donors and recipients, blood donation

volume, indications for blood transfusions, number of transfusions and blood volume administered per cat, Hct change, and expected Hct rise as

expected Hct increase (%)
= transfusion volume administered (ml)
÷ body weight (kg) × 2

After several transfusions (n=34) an evaluation of the Hct change was not performed. Causes were death or euthanasia of the cats (11), no Hct measurement 16–24 h after transfusion (11), 11 cats had surgery with incalculable blood loss performed between measurements, and one cat lost blood from an accidentally disconnected catheter. The occurrence of transfusion reactions and the survival rate up to 10 days after the last transfusion were also evaluated.

Blood crossmatching test/direct Coombs' test

In some cases blood crossmatching (BCM) tests were performed before and between 1–3 weeks after transfusion. Plasma was separated from EDTA blood of donor and recipient and a 3–5% erythrocyte suspension was prepared. Plasma and erythrocyte suspensions were mixed according to the following scheme and then incubated at 37 °C for 15 min (Giger, 1992):

Major BCM:	50 µl recipient plasma+25 µl donor erythrocytes
Minor BCM:	50 µl donor plasma+25 µl recipient erythrocytes
Recipient control:	50 µl recipient plasma+25 µl recipient erythrocytes

(25 µl represents approximately one drop)

After centrifugation (15 s at 1000 g), the supernatant was examined for signs of haemolysis. Then the pellet was resuspended by gently tapping the tube and examining for macroscopic agglutination followed by microscopic evaluation. Any evidence of haemolysis and agglutination in the absence of autolysis or autoagglutination was deemed incompatible. The level of agglutination was scored from (+) to +++ (3+).

In some cases, a direct Coombs' test was performed (Immunology, School of Veterinary Medicine, Hannover, Germany) using monospecific antisera (goat anti-cat IgM [Bethyl, Montgomery, Texas, USA], goat anti-cat IgG H+L [Dianova, Hamburg, Germany], sheep anti-cat C3 [The Binding Site GmbH, Heidelberg, Germany]) in order to test for anti-erythrocytic antibodies or complement on the erythrocyte surface.

Statistical analyses

Descriptive statistics were used to report the results of age and weight of the donors and recipients, the Hct before donation or transfusion, the Hct post transfusion, the transfusion volume, and the difference between the calculated and the actual post transfusion Hct. A paired Student's t-test was used to compare the pre- and post transfusion Hct and the difference between the calculated and the actual post transfusion Hct. One-way ANOVA was performed to compare the anaemia groups in regard to pre- and post transfusion Hct changes. Statistical analyses were performed with computer software (SPSS 10, SPSS GmbH Software, Munich, Germany), and values of P<0.05 were considered significant.

Results

Donor cats

Within the 36-month study period, a total of 134 cats donated blood. Of those animals, 129 had blood type A and five had blood type B (three Turkish Angora, one British Shorthair, and one Chartreux). Seven clinic-owned domestic shorthair cats, age 1.5–9 years (m=4.2), donated blood a total of 41 times or 28% of all transfusions. Blood was collected one to four times per year from each clinic-owned cat with an average interval of 113 days (26–249 days). The remaining 127 cats were client-owned and generally donated only once. Most of the patient cats' owners had other cats in the household, or blood was donated from animals belonging to their friends. The ages of all donor cats ranged between 0.5–15 years (m=4), they weighed between 2.7–9 kg (m=5), and their Hct ranged from 27–51% (m=38, reference range 30–44). The cats donated between 1.8–9.5 ml blood/kg body weight (m=5.9). Cats having a Hct <35% (n=14), or those older than 8 years (n=13) had less blood taken than heavier and younger cats.

All cats tolerated the sedation and blood collection. One client-owned cat died unexpectedly 2 days after the donation as a result of an occult dilated cardiomyopathy confirmed at necropsy.

Feline patients

Within the 3-year study period, 91 cats received 163 blood transfusions (Table 1). The patients' age and weight ranged from 0.8–20 years (m=7) and

Table 1 Indications for transfusions, number of blood transfusions, transfusion volumes, haematocrit (Hct) before and after transfusions, and Hct change 16–24 h post transfusion

Indications	No. of cats	Transfusion			Hct (%)		Hct change (no. of transfusions)		
		Total no.	No./cat	Volume /cat (ml/kg)	Pre transfusion	Post transfusion	Rise	No change	Decrease
Anaemias									
Blood loss	40	62	1–4	1.7–16.3 (6.0)	8–20 (14)	11–28 (18)[a]	43	2	4
Haemolysis	13	21	1–4	3.5–12.5 (7.0)	6–17 (13)	8–22 (16)[a]	15	2	–
Ineffective erythropoiesis	35	76	1–6	3.3–16 (6.7)	5–20 (12)	9–27 (14)[a]	46	8	8
Others									
Coagulopathy	2	2	1	6.6/8	27/28	died/31	1	–	–
Hypoproteinaemia	2	2	1	6.3/6.3	> 20	died/died	–	–	–

[a] The pre- and post transfusion Hct differed significantly ($P<0.05$). The differences between groups (blood loss, haemolysis, ineffective erythropoiesis) in regard to any parameter were not significant. Values in parentheses represent medians.

0.7–7.8 kg (*m*=4.5), respectively. Fifty-one cats received one blood transfusion, 21 received two, 10 received three, seven received four, and two cats received six transfusions. One cat with disseminated intravascular coagulation required a second transfusion at a later date due to ineffective erythropoiesis and was, therefore, recorded twice.

Eighty-six patients had blood type A and four cats (two Chartreux, one Turkish Angora, and one British Shorthair) had blood type B. Furthermore, one Chartreux cat had blood type AB. Only A–B compatible transfusions were administered, with the exception of the one cat having type AB, which received blood from a type A cat.

Indications, transfusion volumes, efficacy

In 88 cats, the main reason for the transfusion was severe anaemia; an additional four cats were transfused for other reasons (Table 1). (One cat was mentioned twice, see above.)

Blood loss anaemia

Forty animals, which suffered from acute or chronic blood loss anaemia received a total of 62 blood transfusions (Table 1). Of the 37 cats with acute blood loss anaemia, 22 needed just one transfusion, 10 required two, four required three and one cat required four transfusions. The cats suffered from multiple trauma (12), rodenticide intoxication (three), ruptured haemangiosarcoma (three), and feline lower urinary tract disease with haematuria (three), and two cats lost blood from accidentally disconnected intravenous catheters. Severe thrombocytopenia due to Evans' syndrome, immune-mediated thrombocytopenia, FIV infection, and leukaemia was determined to be the cause of blood loss in four cats. Furthermore, there were isolated cases of haemoperitoneum due to lymphoma, renal neoplasia with disseminated intravascular coagulation, hepatolipidosis with bleeding after a biopsy, bleeding tongue laceration, postoperative bleeding from a castration and a mesenterial abscess wound-site, epistaxis with a chronic feline respiratory disease complex, haemometra, haemorrhage after urinary bladder rupture and haemoperitoneum/haemothorax of unknown aetiology.

Before transfusion, the Hct values ranged between 8–20%. With a transfusion volume of 1.7–16.3 ml/kg body weight, the observed Hct change was ranging from −5 to +12% (*m*=4) ($P<0.05$). A rise in Hct was noted after 39 transfusions, a decline seen after four, and in two cases there was no change. The difference between the calculated and the actual post transfusion Hct was significant ($P<0.05$) and ranged between −10.1 and +8.5% (*m*=+2.4).

In addition, three cats suffered from chronic blood loss anaemia due to multiple diagnostic blood collections (diabetes mellitus), stomach ulcers, or unexplained melaena, respectively. The Hct rise 16–24 h after transfusion was 5–9% (*m*=6.5). In these cats the difference between the calculated and actual Hct values ranged from +2 to +6.2% (*m*=2.4), thus the calculation was underestimating the observed rise.

Haemolytic anaemia

Thirteen cats with haemolytic anaemia received a total of 21 blood transfusions (Table 1). Of those, eight cats were transfused once, three had been transfused twice, and one cat each three and four times. These cats suffered from immune-mediated haemolytic anaemia (*n*=6), haemolysis due to Heinz-body anaemia (one), hypophosphataemia (two), or lymphoma (one). In three cases the cause of the haemolysis was unknown. With a transfusion volume of 3.5–12.5 ml/kg body weight, a +1 to +9% (*m*=3) increase in Hct was achieved ($P<0.05$); in two cases the Hct did not change. The difference between the actual and calculated Hct values was not significant and ranged between −5.9 and +6% (*m*=−0.2).

Ineffective erythropoiesis

Thirty-five cats, which experienced ineffective erythropoiesis, received a total of 76 blood transfusions (Table 1). Of those cats, 15 were transfused once, seven were transfused twice, five transfused three times, five transfused four times, and two cats received six transfusions. These cats' illnesses included: panniculitis (*n*=6), inflammatory diseases (gastrointestinal, abscesses, endometritis) (six), renal failure (five), pure red cell aplasia (three), erythrocytic and megakaryocytic hypoplasia (three), leukaemia (two), FIP (two), and intestinal lymphoma (two). In addition one cat each had the following: FIV- or FeLV-infection, renal fibrosarcoma, hypereosinophilic syndrome, intestinal adenocarcinoma, and urinary bladder malformation. After transfusion the Hct values were between 9–27%, and the Hct changes were ranging from −4 to +19% (*m*=4; $P<0.05$). Eight transfusions were associated with a drop in Hct, eight other transfusions led to no Hct change, while 46 transfusions resulted in the expected Hct increase between +1 to +19%. The difference between the calculated

Table 2 Survival rate of 88 anaemic cats at 24 h, 5 days, and 10 days post transfusion

Indications	*n*	24 h cats (%)	5 days cats (%)	10 days cats (%)	Dead/euthanased
Blood loss anaemia	40	36 (90)	31 (80)	30 (75)	5/5
Haemolytic anaemia	13	10 (76.9)	10 (76.9)	10 (76.9)	2/1
Ineffective erythropoiesis	35	28 (80)	21 (60)	17 (48.6)	3/15

and the actual Hct was not significant, ranging between −7.8 and +12.4% (*m*=0).

Transfusions given for other reasons than anaemia

Four cats, which were mildly anaemic, received transfusions for other reasons (Table 1). Two littermate kittens (Hct 21 and 23%) had severe hypoproteinaemia (total protein 32 and 35 g/l) due to parvovirosis and both received 6.3 ml blood/kg body weight. Two other cats with Hct values of 27 and 28% were transfused due to a severe coagulopathy and life-threatening haemorrhage (rodenticide intoxication, disseminated intravascular coagulation).

Plasma bilirubin

The plasma bilirubin concentrations were determined before and 1–5 days after 29 transfusions. In 18 of 29 cases, the pre- and post transfusion bilirubin concentrations were similar. A mild rise in bilirubin (range 0.2–2.5 mg/dl, 3.4–42.5 μmol/l, *m*=0.5, 8.5) was observed after the other 11 transfusions, which in six of them could be attributed to the underlying disease process (hepatopathy, haemolysis, resorbing large haematoma), while in the other cases it may be related to lysis of the transfused erythrocytes (plasma bilirubin increase of 0.3–0.7 mg/dl, 5.1–12 μmol/l [*n*=6]). In four of the six cases, the observed rise in Hct was much lower than the calculated value. One of these cats was also showing a clinical transfusion reaction during the second transfusion (see transfusion reactions).

Transfusion of stored blood

Seven cats with acute blood loss anaemia and two cats with ineffective erythropoiesis received 11 transfusions of stored blood. The storage period ranged from 2–15 days (*m*=9). Before transfusion, while the pre transfusion Hct values ranged between 12 and 18% (*m*=13.5), the post transfusion Hct were between 13–24 (*m*=18) ($P<0.05$). The change in Hct varied from 0 to +11% (*m*=3), and the difference between the actual and calculated Hct was between −4.6 to +5.0% (*m*=0.2). Microbiological examination of three blood units performed after 4, 5, and 10 days of storage revealed no evidence of bacterial contamination.

Survival rate

During the first 24-h post transfusion period, 14 of 88 anaemic cats died or were euthanased (Table 2). There were no specific signs of blood incompatibility encountered in any of these cases, thus, their deaths were not directly attributed to the received transfusion. During the following 9 days, 17 additional cats died or were euthanased. These animals suffered from blood loss anaemia (six), or ineffective erythropoiesis (11), and again their deaths could not directly be attributed to receiving blood. The 1- and 10-day post transfusion survival rates of the anaemic cats were 84.1 and 63.7%, respectively. However, none of the cats which were transfused because of hypoproteinaemia or coagulopathy survived.

Transfusion reactions

Apart from the above described lack of a Hct rise and increase in serum bilirubin, transfusion reactions were only noted after two of 163 transfusions (1.2%). In both cases the blood type and crossmatch results were compatible. One cat with pure red cell aplasia experienced an increase in body temperature from 38.8 to 40 °C within the first 5 min of the second transfusion. After withdrawal of the transfusion, compatibility reassessment, treatment with metamizol (Novaminsulfon; Ratiopharm, 20 mg/kg), and an infusion with lactated Ringer's solution (50 ml), the temperature fell to 39.6 °C within 20 min and the transfusion was resumed without any further temperature rise or other reaction. However, no post transfusion Hct rise was achieved and a slight increase in serum bilirubin of 0.6 mg/dl was observed. A second anaemic cat with ineffective erythropoiesis due to chronic endometritis experienced retching, tachypnoea, and a temperature increase from 38.8 to

39.2 °C after the third transfusion. The transfusion was discontinued and blood from another blood type and crossmatch compatible donor was given later without incidence. The Hct rise was 7% as predicted by calculation.

Blood crossmatching (BCM) test results

A total of 117 BCM tests were performed on blood from 60 cats before transfusion and 57 BCM tests were also performed on 32 of these cats between 3 and 21 days post transfusion. Haemolysis was not observed in any of the BCM tests. Before transfusion, agglutination reactions occurred in seven major as well as seven minor BCM test reactions; all except one cat had already been transfused once before. In five cases the major incompatibility reaction was observed macroscopically (graded ++ to +++), and in two cases agglutination (graded + to ++) was only microscopically present. In three cases the minor BCM test showed macroscopic (grade + to ++) and in four cases a microscopic agglutination (graded + to ++). Three of the positive minor and two of the major incompatible crossmatch reaction results occurred in the cat with blood type AB after receiving three transfusions from three different type A blood donor cats. Because BCM tests were generally performed in this study when the transfusion was already given, blood had been administered despite incompatible crossmatch results. No obvious clinical transfusion reactions occurred in any of these cats. An increase in Hct was observed after five blood transfusions despite having positive major BCM results, while in two cases the Hct remained unchanged. Three to 21 days post transfusion eight of 57 major BCM tests (two macroscopic, six microscopic) were incompatible (graded + to ++).

Coombs' tests

A direct Coombs' test was performed on blood from 13 cats, and of these, 12 had negative results both pre- and post transfusion (6–18 days after transfusion). One cat with a negative pre transfusion Coombs' test result had a positive result for IgG 3 weeks post transfusion. This cat suffered from erythrocytic aplasia and had received six blood transfusions from different donors over a period of 17 days.

Discussion

Over a 3-year period from 1998 to 2001, 163 whole blood transfusions were administered to 91 cats at the Free University of Berlin. Both in-house clinic-owned as well as client-owned cats served as blood donors. Seventy-two percent of the transfusions were covered by voluntary donors which allowed clinic-owned cats to be available for emergency situations. Volunteer donors require more labour-intense procedures that include the physical examination and blood collection for diagnostic tests and serology. All this must be done before transfusion and makes it more difficult to use these animals in emergency situations. Many of the proposed donors were not acceptable because of positive FeLV- or FIV-serology results or physical abnormalities such as cardiac murmurs.

The range and median blood donation volume of 2–9.5 ml/kg and 5.9 ml/kg body weight, respectively, are lower than those reported in the literature which range up to 10–15 ml/kg body weight (Callan and Giger, 1994; Griot-Wenk and Giger, 1995; Wardrop, 2001). In order to reduce the risks associated with donation, less than 10% of the total blood volume was withdrawn from the volunteer donors. Despite the small volumes collected, and the careful screening of the donors, one cat died 2 days after collection as the result of an occult cardiomyopathy. Cardiomyopathy may go unrecognised in many cats and in a recent survey conducted in Munich represented the third most common illness group (Kraft and Danckert, 1999). Thus, blood collection is not without potentially serious risks to the donor and informed-client consent should to be obtained.

The blood type distribution in this study was similar to those of other surveys (Austria, Germany, Switzerland, United States): 92.6–99.6% of those cats had blood type A, 0.4–6.7% blood type B, and 0–0.7% had blood type AB (Giger et al., 1989, 1991; Giger, 2000; Haarer and Grünbaum, 1993; Hubler et al., 1993). Blood type A, seen in 95.6% of the 225 donor and recipient cats, was the most common blood type. Blood type B (4%) was only seen in pure bred cats. The Turkish Angora, Chartreux, and British Shorthair breeds are commonly reported to have type B blood reaching 50% (Arikan et al., 2003; Giger et al., 1991; Giger, 2000; Knottenbelt, 2002).

Few reports exist regarding indications for feline blood transfusions (Griot-Wenk and Giger, 1995; Hohenhaus, 2000; Sommer, 1993). Severe anaemia (Hct <15%) was the leading indication for blood transfusion in this (67.3% of all blood transfusions) and other surveys. Of these 110 blood transfusions 33.9% were given because of a blood loss anaemia, and in 13.8% and in 52.3% haemolysis and ineffective erythropoiesis, respectively, were the reason for severe anaemia and the need for a transfusion.

Forty-nine blood transfusions (30.2%) were performed due to moderate anaemia (Hct 15–20%) (acute bleeding 49%, chronic bleeding 2%, haemolysis 10.2%, and ineffective erythropoiesis 38.8%). In the remaining four transfusions (2.5%) the Hct values were above 20%. In a study done by Griot-Wenk and Giger (1995), 74% of the transfusions were performed because of anaemia, and of those, 26.9% suffered from a regenerative anaemia, 43% from anaemia due to ineffective erythropoiesis, and in 4.1% the cause of anaemia was unknown. Compared to other studies, the number of patients receiving transfusions due to hypoproteinaemia (two) or coagulopathy (two) was low. In the survey by Griot-Wenk and Giger (1995), 38 of the 103 patients were transfused with whole blood for non-anaemia reasons. Hohenhaus (2000) reported on 19 cats suffering from hepatopathy (six), lymphoma (six), or other illnesses (seven), which received fresh frozen plasma. The most common indication in that study (10 of 19 cats) was disseminated intravascular coagulation.

Anaemic dogs at the Small Animal Clinic in Berlin primarily received packed red cells and other blood components (Kohn et al., 2000). The small blood volume collected, the difficulties in separation of blood elements coupled with the lack of documentation on the need for plasma transfusions make whole blood transfusions the norm in feline patients.

While most cats of this study were transfused with fresh citrated blood, 11 cats received stored CPDA-1-blood. The observed Hct rise and the difference between the expected and the determined Hct of the stored versus fresh whole blood were similar. The advantage of preserving blood relates to its immediate availability for transfusion in an emergency situation as well as the fact that it reduces the burden of blood donor recruitment and collection for the on-call veterinary clinician and technician. A compromise was made storing blood units drawn with an open collection system, since no commercially available closed systems for cats currently exist. Bacterial testing of three blood units resulted in no growth. At the University of Pennsylvania, a closed small bag system was recently developed for cats, consisting of two pediatric blood bags sealed to a 19 G butterfly or apheresis catheter allowing for closed blood collection, plasma and packed cell component separation, and storage (Springer et al., 1998).

In this study, the median Hct before transfusion was similar among the different forms of anaemia. In the survey by Griot-Wenk and Giger (1995) cats with an acute blood loss were transfused with a higher Hct (mean 18.1%) than cats with ineffective erythropoiesis (mean 12.1%).

Over half of all cats in this study (56%) received only one transfusion, while the rest were given between two and six transfusions. Particularly in the group of ineffective erythropoiesis, 12 of 35 cats (34.3%) were transfused more than twice, which may be related to the chronicity, severity, and underlying illness (e.g., anaemia of inflammatory disease, chronic renal insufficiency, bone marrow hypoplasia). The percentage of cats receiving multiple transfusions was similar among the groups having blood loss (13%) and haemolytic anaemia (15.4%). In the study by Griot-Wenk and Giger (1995) similar number of transfusions per cat was administered; in the group of ineffective erythropoiesis the number of blood transfusions per cat was, however, lower in comparison to the present study.

The calculation of the expected Hct rise 16 to 24 h post transfusion seems to be useful, since the difference between actual and calculated Hct may help judge whether loss of blood or haemolysis continued. Moreover, any pre-existing hypovolaemia, the concomitant infusion of large volumes of crystalloids or lysis of the transfused erythrocytes may cause a lower than expected rise in Hct. Of 127 transfusions included in this evaluation (where pre- and post transfusion Hct-values were available) 24.4% showed a lower increase in Hct (having a difference in Hct between −10 and −2%) than calculated. Of these, 22.6% suffered from acute bleeding, 12.9% had haemolysis, and 64.5% had ineffective erythropoiesis. In 43.3% of the cats, the actual Hct was close to the expected value (±2%). In 32.3% of the transfusions, the post transfusion Hct was higher than that calculated (difference in Hct 2–12.4%). Of these, 53.7% had acute bleeding, 9.8% chronic bleeding, 12.1% haemolysis, and 24.4% had ineffective erythropoiesis. Possible causes for these differences in Hct include resorptive mechanisms from cavity bleedings, splenic contraction, dehydration, and regenerative bone marrow response.

After six fresh whole blood transfusions, five cats showed a mild increase in plasma bilirubin concentration, which could not be explained by their underlying illnesses such as a haemolytic anaemia. In four of these cases, a lower than expected rise in Hct was also seen; post transfusion haemolysis might have caused the plasma bilirubin rise. A transfusion reaction was observed in only one cat with a mild rise in plasma bilirubin concentration of 0.6 mg/dl. In four of these six cases, a BCM test was performed, which showed no evidence of an agglutination or haemolytic reaction.

In only two of 163 cases (1.2%) a transient transfusion reaction occurred despite blood type and crossmatch compatibility. In an analysis of 348 transfusions in dogs at the Small Animal Clinic Berlin, transfusion reactions were seen after administration of packed red blood cells (n=4) or plasma (two) at a similarly low rate of 1.7% (Reitemeyer et al., 2000). In five of these six dogs, this happened after the first transfusion; however, transfusion reactions seem to occur especially in cats which have been previously transfused (Henson et al., 1994; Stokol and Blue, 1999), as was seen in this study. The low incidence of transfusion reactions underlines the safety of feline transfusions, if the guidelines of transfusion medicine are followed.

The presence of blood type B or AB in 10 cats illustrates the necessity of blood type determination of donor and patient, or, if this is not possible, BCM test should be performed before every transfusion. Blood type or crossmatching compatibility, however, does not rule out transfusion reactions, as demonstrated in the two cases of this study. Possible causes of these reactions include the presence of antibodies against leukocytes, thrombocytes, or plasma proteins in donor blood (Snyder, 1995). Because these reactions cannot be avoided by blood typing or crossmatching, the recipients must be monitored closely during and shortly after transfusion, particularly in multiply transfused cats. When a type B cat required a transfusion, it was difficult to find a donor animal. A clinic-owned type B cat or a breeder with type B cats, who is willing to provide cats for donations, would be advantageous. If no type B or compatible blood is immediately available, the administration of an ultrapurified bovine haemoglobin solution (Oxyglobin; Biopure, Cambridge, UK) may offer an alternative in an emergency situation, as shown in a large retrospective study in cats (Gibson et al., 2002), although this solution is not yet approved for use in cats.

The survival rate of the transfused cats with anaemia over the first 24-h period for 88 anaemic cats was 84%. However, three of the four cats which were transfused for reasons other than anaemia died or were euthanased. The high survival rate affirmed the effectiveness of feline blood transfusions, especially since many of these cats were transfused because of severe anaemia. In a canine study, a 24-h survival rate of 100% could be achieved in the group with haemolysis, whereas 93% with ineffective erythropoiesis and 79% with blood loss anaemia survived (Reitemeyer et al., 2000). Both the 24-h survival rate and the 10-day rate (64%) are considered high in the light of the bad prognosis often given prematurely to cats with severe anaemia.

BCM tests were performed before (60 cats) and between 1 to 3 weeks after transfusion (32 cats) in order to check whether cats had or formed alloantibodies post transfusion outside the AB blood group system. In the BCM before transfusion, 14 agglutination reactions occurred in the major and minor tests. Three positive minor and two positive major BCM results were observed in a cat with blood type AB which had previously received transfusions from three different type A cats. The minor tests might have been positive due to anti-B antibodies in the donor blood reacting with the B-antigen on the recipient's erythrocytes. The other positive BCM tests occurred with A–B compatible transfusions. Interestingly, positive BCM test results were common in cats that had received previous transfusions. In four of five cases with agglutination in the major BCM test, a post transfusion rise in Hct was still observed. In eight cases, agglutination of the major test occurred in the second BCM test, which possibly may be related to antibody developed to the previous transfused red blood cells. Moreover protein is present in transfused whole blood products in the form of platelets, leukocytes and soluble plasma proteins. Based upon these results and as previously suggested, a BCM test is recommended before transfusing a previously transfused cat, since it is possible that antibodies could form against antigens other than those associated with the AB system (Giger, 2000; Griot-Wenk and Giger, 1995).

In conclusion, besides the various risks for infectious disease transmission, occult cardiomyopathy may limit the use of feline client-owned donors. Transfusions are well tolerated when initial blood typing and crossmatching procedures are performed and may increase survival even though the expected rise in Hct is not achieved.

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