Original Article

jfms Journal of Feline Medicine and Surgery

Journal of Feline Medicine and Surgery
2019, Vol. 21(6) 481–487

DOI: 10.1177/1098612X18785742
journals.sagepub.com/home/jfm

This paper was handled and processed by the European Editorial Office (ISFM) for publication in *JFMS*

SAGE

Twelve autologous blood transfusions in eight cats with haemoperitoneum

Laura P Cole and Karen Humm

Abstract

Objectives The objectives of this study were to describe the clinical use and outcome of autologous transfusions in cats with intracavitary haemorrhage.

Methods A retrospective descriptive study was performed. Computerised medical records of a single referral centre were searched for cats receiving an autotransfusion. Medical records were evaluated for underlying disease process, autotransfusion technique, autotransfusion volume, time period over which the autotransfusion was given, packed cell volume (PCV) pre- and post-autotransfusion, percentage rise in PCV, use of other blood products and any complications of the procedure. Survival to discharge and survival at 2 months was documented.

Results Between July 2012 and March 2018 a total of 12 autotransfusions were performed in eight cats. All patients were diagnosed with haemoperitoneum. Four of the eight cats were diagnosed with abdominal neoplasia, three had postoperative haemorrhage and one had a traumatic haemoperitoneum. Three cats received more than one autotransfusion. Blood was collected using a 23 G butterfly catheter and 20 ml syringe in 7/12 collections, a 23 G needle and 20 ml syringe in 2/12 collections and directly into syringes from the open abdomen at the time of surgery in 3/12 collections. A median volume of 50 ml (range 25–80 ml) was collected and administered, meaning a median volume of 16.5 ml/kg (range 9–26 ml/kg) was administered. The autologous transfusions were given over a median of 3 h (0.25–6 h). Five cats were given another blood product alongside the autotransfusion. Median percentage PCV increase was 5% (range 1–7%). Anticoagulant was used in 5/12 autotransfusions. No clinically relevant adverse effects were reported. Six of the eight cats survived to discharge. Two month survival was 60% (3/5).

Conclusions and relevance Autologous transfusion appears to be a safe and effective technique for stabilising cats with haemoperitoneum. This technique allows rapid and cheap provision of blood and avoids the need for an allogenic blood donor.

Keywords: Autotransfusion; haemoperitoneum; blood products; neoplasia

Accepted: 18 May 2018

Introduction

The transfusion of blood products to anaemic patients is an important part of critical care. However, access to feline blood products can be limited owing to technical difficulties in collecting and storing feline blood products and difficulties in recruiting feline blood donors.[1] Both haemoglobin-based oxygen carriers (HBOCs) and xenotranfusion with canine blood products have been used as alternative strategies for the anaemic cat.[2–4] However, HBOCs have well-documented adverse effects and transfused canine red blood cells have a short lifespan as a result of intravascular haemolysis.[2,5]

An alternative method to allogenic transfusion, which is well described in the human literature, is autotransfusion.[6] Autotransfusion has been reported in dogs with intracavitary haemorrhage in the veterinary literature, but there are no clinical reports in cats.[7–12] In these canine studies minor, non-clinically significant adverse effects were reported, and autotransfusion

Department of Clinical Science and Services, The Royal Veterinary College, Hatfield, UK

Corresponding author:
Laura P Cole MA, VetMB, PgCert VPS, CertAVP (ECC), MRCVS, Royal Veterinary College, Hawkshead Lane, Hatfield AL9 7TA, UK
Email: lcole3@rvc.ac.uk

appeared to be a successful management option. This study aimed to investigate the frequency and efficacy of feline autotransfusion in a referral hospital setting, as well as describing the reasons for performance of autotranfusion and the methods used.

Materials and methods

Inclusion criteria

The electronic clinical and surgical records from the Queen Mother Hospital for Animals (Hatfield, UK). were searched for cats that were administered an autotransfusion between July 2012 and March 2018.

Retrieved data

The following data were extracted from the clinical records: signalment, underlying disease, blood collection technique, volume of blood collected, use of anticoagulant, volume of autologous blood transfused, transfusion time period, pre- and post-transfusion packed cell volume (PCV), serum calcium, prothrombin time (PT) and partial thromboplastin time post-transfusion, and administration of other blood products. Survival to discharge and 2 month survival were also documented.

Results

A total of eight cats had at least one autotransfusion during the time period. Six were female (five neutered) and two were male (one neutered). Five were domestic shorthairs and three were pure breeds (British Shorthair, Ragdoll and Bengal). The median weight of the cats was 3.67 kg (range 1.38–5.5 kg). All cats were blood typed. Six cats were blood type A and two were blood type B.

Four of the eight cats had spontaneous haemoperitoneum secondary to abdominal neoplasia (two cats had splenic haemangiosarcoma, one cat had both splenic and liver haemangiosarcoma and one cat had liver and splenic lesions consistent with neoplasia on ultrasound, but histological diagnosis was not made). Three of the eight cats required an autotransfusion for management of postoperative haemorrhage (the surgical procedures were routine ovariohysterectomy performed at the primary care veterinarian in two cats, and extrahepatic shunt ligation and liver biopsy in the other cat). One cat presented with a traumatic haemoperitoneum. Six of eight cats required surgery for management of their condition.

A total of 12 autotransfusions were performed over the study period. Three cats had an autologous transfusion performed on more than one occasion. Case 1, a cat with a traumatic haemoperitoneum, required autotransfusion on presentation and 12 h later owing to continuing haemorrhage. Surgical exploration revealed a splenic fracture with bleeding splenic artery. An autotransfusion was performed on case 3 prior to surgery for removal of a poorly differentiating splenic haemangiosarcoma and it required repeat autotransfusion 10 days post-discharge owing to recurrence of the haemoperitoneum. Case 5 received an autotransfusion during cardiopulmonary arrest suspected to be due to haemorrhage post-surgery for extrahepatic portosystemic shunt ligation and liver biopsy. Autotransfusion was performed again at the time of revision surgery (0.5 h later) and also in the postoperative period (2 h later).

Autotransfusion was performed in all cats to treat their anaemia and hypovolaemia. Three of the 12 autotransfusions were performed intraoperatively, 1/12 was performed postoperatively and 2/12 were performed peri-cardiopulmonary arrest.

Out of the total 12 autotransfusions performed, blood was collected using: a 23 G butterfly catheter and 20 ml syringe in seven collections; a 23 G needle, three-way tap and 20 ml syringe in two collections; and directly into syringes from the open abdomen at the time of surgery in three collections. Ultrasound-guided sampling was performed in all cases except collection at the time of surgery.

Anticoagulant acid citrate dextrose (ACD-A; Citra Labs) was used in 5/12 of the autotransfusions performed with 0.14 ml of ACD used per 1 ml blood collected, as described in previous studies.[13] In all cases the collected blood was transfused through an 18 μm blood filter (Utah Medical Products). A median volume of 50 ml (range 25–80 ml) was collected and administered, equivalent to median volume of 16.5 ml/kg (range 9–26 ml/kg) over a median of 3 h (range 0.25–6 h, the time over which the autotransfusion was administered was not recorded in one case). Three autotransfusions were given in 1 h or less at a rate of 0.28–1.2 ml/kg/min.

The median PCV pre-autotransfusion was 12% (range 7–20%; n = 11). Post-autotransfusion, the median PCV was 18% (range 9.5–23%; n = 11) with the median percentage PCV increase being 5% (range 1–7%; n =10).

During the administration of the autotransfusions there were no documented reports of urticaria, erythema, increased rectal temperature or other signs consistent with transfusion reaction. Post-transfusion ionised calcium levels were available after 7/12 autotransfusions. The median ionised calcium value was 1.22 mmol/l (range 0.92–1.3 mmol/l). Total calcium was measured in one patient and this was 2.03 mmol/l (reference interval 2.07–2.8 mmol/l). Out of these eight patients, two were documented as having a mild hypocalcaemia, one of which received anticoagulant. No patient showed clinical signs of hypocalcaemia.

Five of the eight cats received other blood products. Cases 2 and 8, which presented with haemoperitoneum post-routine ovariohysterectomy, received both packed red blood cells and type-specific fresh frozen plasma. Case 8 received type-specific feline packed red blood cells and case 2 received canine packed red blood cells owing to the lack of availability of feline blood at the

time of admission. Case 5 received feline whole blood and oxyglobin and cases 4 and 7 received feline packed red blood cells (Table 1).

Coagulation tests were assessed in three cats prior to the first autotransfusion and were found to be within normal limits. Two cats had PT and activated partial thromboplastin time (aPTT) measured post-autotransfusion; one had had mild prolongation of aPTT and one had moderately prolonged PT and aPTT, as well as a severe thrombocytopenia of 40×10^9/l (reference interval 200–800×10^9/l). This cat (case 2) had received canine packed red blood cells and autologous transfusion in less than 2 h. A total of 10 ml/kg fresh frozen plasma transfusion was given for management of the coagulopathy. Four hours after all transfusions the patient was found to have an increased respiratory effort and documented pleural effusion, suspected to be the result of fluid overload. The patient was treated with oxygen and 2 mg/kg frusemide (Diamzon; MSD Animal Health).

Gross haemolysis was detected in one cat (case 3) post-autotransfusion on examination of serum, but this had also been present prior to autotransfusion. This patient's PCV increased by 2% and 2.5% after each autotransfusion.

Three cats had cytology performed on the abdominal fluid and two cats had culture of the abdominal fluid used for autotransfusion. None of these cases had cytological evidence of bacteria. One cat out of the two (case 6) that had culture of the abdominal fluid cultured positive for *Enterococcus faecalis.* This case was given an autologous transfusion after respiratory arresting and was euthanased owing to progressive neurological deterioration.

Outcome

Six of the eight cats survived to discharge. No delayed adverse reactions to the autotransfusions were reported in any patient. Both of the patients that died in hospital were given an autotransfusion peri-cardiopulmonary arrest. Case 5 arrested postoperatively after extrahepatic portosystemic shunt ligation and hepatic biopsy. This patient regained spontaneous circulation and had repeat surgery performed to isolate the bleeding vessel. The patient was euthanased on recovery from general anaesthesia owing to severe hypoxaemia, despite further autotransfusion, whole blood, crystalloid and colloid and vasopressor therapy. Case 6 neurologically deteriorated and was euthanased post-respiratory arrest.

Two month survival was 60% (3/5). Two patients (cases 3 and 4) were diagnosed with splenic and liver haemangiosarcoma and were euthanased 4 and 6 weeks post-discharge, respectively. Both patients re-presented collapsed and pale, one with a recorded PCV of 9%. This latter patient was presumed to have had a repeat abdominal haemorrhage. The other case (case 7) diagnosed with splenic haemangiosarcoma was lost to follow-up. Case 1 with traumatic haemoperitoneum and cases 2 and 8 with haemoperitoneum post-ovariohysterectomy are reported to be well on follow-up.

Discussion

The aim of this case series was to examine the use of autotransfusion in feline patients in a referral hospital setting. We report eight cats that had an autotransfusion to aid treatment of their anaemia. Given the high caseload of the hospital, this is not a frequently performed procedure, probably helping to explain the lack of literature on the use of autotransfusion in cats. A recent survey of canine and feline transfusion practice found that autotransfusion is performed in 36% of both primary care and tertiary referral centres in the USA.[13]

Three main autotransfusion techniques have been described in humans: preoperative autologous donation (PAD), whereby blood is collected in advance of an elective procedure, stored in the blood bank and transfused back to the patient when required; acute normovolaemic haemodilution, where blood is collected immediately prior to surgery and blood volume restored by crystalloid or colloid; and cell salvage, in which blood is collected from suction, surgical drains or both, and re-transfused back to the patient after filtration or washing.[6] There is one experimental report of autologous transfusion in cats and one clinical report of PAD in cats performed prior to planned craniotomy surgery.[14-16] There are various reports of canine cell salvage in the veterinary literature.[8–12]

Autotransfusion can be considered an underused method in cats as it has several advantages over the use of allogenic blood products. The blood is readily available and is cheaper than allogenic blood products as there is no need for blood typing or cross matching. This is particularly useful outside large referral hospitals in the UK as there is no commercial feline blood bank and access to blood donors, particularly type B and AB cats, can be limited. Autotransfusion has the proposed advantage of reducing the risk of transmission of disease or isoimmunisation associated with allogenic blood transfusion. A meta-analysis in humans found that red cell salvage reduced exposure to allogenic blood by 40%.[16] In this case series 40% of cats did not require allogenic blood products vs 30% dogs undergoing autotransfusion.[10]

Cell salvage in humans has been predominantly used intraoperatively in cardiothoracic, vascular, orthopaedic, neurological and transplantation surgery, and there are rare reports of its use in the emergency department.[6,17] In dogs, autotransfusion has been used primarily for resuscitation in emergencies, the management of intraoperative haemorrhage and coagulopathy, postoperative haemorrhage and bleeding secondary to neoplasia where surgical intervention may or may not be

Table 1 Summary of cats receiving autotransfusions during the study period

Case	Signalment	Underlying disease	Volume of blood transfused (ml/kg)	Transfusion time period (h)	ml/kg/h	Other blood products received	% Change in PCV	Transfusion complications	Outcome
1	9-month-old F BSH	Traumatic haemoperitoneum (splenic fracture)	20	6	3	No	6	None	Discharged
			26	3	9		6	None	
2	9-month-old FN DSH	Intra-abdominal haemorrhage post-ovariohysterectomy	16	1	16	Canine PRBCs, feline FFP	7	Consumptive coagulopathy, fluid overload, mild total hypocalcaemia	Discharged
3	14-year-old MN DSH	Splenic and liver haemangiosarcoma	14	6	2	No	2.50	None	Re-presented 10 days later with recurrent haemoperitoneum
			16	6	3		2	None	Four weeks post-discharge re-presented collapsed and euthanased
4	15-year-old FN DSH	Splenic haemangiosarcoma	12	6	2	Feline PRBCs	5	None	In hospital developed partial blindness suspected thiamine deficiency. Started on chemotherapy (doxorubicin and cyclophosphamide). Developed azotaemia. Six weeks post-discharge re-presented collapsed with PCV 9%. Euthanased
5	5-month-old M Ragdoll	Postoperative haemoperitoneum post-extrahepatic portosystemic shunt ligation	18	0.25	72	Oxyglobin, feline whole blood	6	Mild hypocalcaemia	ROSC. Revision surgery with intraoperative autotransfusion. Persistent hypotension and severe obtundation, despite additional blood products and vasopressor therapy. Owner elected euthanasia
			18	0.25	72		2	None	
			26	1.5	17.3		1	None	
6	12-year-old FN DSH	Splenic and liver uncharacterised neoplasm	Unknown			No	NA	None	Respiratory arrest and neurological deterioration – euthanased
7	7-year-old FN Bengal	Splenic haemangiosarcoma	9	4	2	Feline PRBCs	NA	None	Discharged, lost to follow-up
8	6-month-old FN DSH	Intra-abdominal haemorrhage post-ovariohysterectomy	12	1.5	8	Feline PRBCs, FFP	5	None	Discharged

PCV = packed cell volume; F = female; BSH = British Shorthair; FN = female neutered; DSH = domestic shorthair; PRBCs = packed red blood cells; FFP = fresh frozen plasma; MN = male neutered; M = male; ROSC = return of spontaneous circulation; NA = not applicable

required.[8,10,12] In this case series, autotransfusion was a key part of stabilisation in all eight of the cats, as well as providing intraoperative support, and included similar causes as the aforementioned studies. Surgery was performed, as well as autotransfusion, in 66.7% (8/12) of autotransfusion events, which is similar to the number requiring surgery in dogs undergoing an autotransfusion.[10]

Techniques for red cell salvage in humans and dogs include direct collection from the abdomen using a syringe or suction device, and the use of a cell-saver device whereby shed blood is collected, anticoagulated and washed or filtered prior to re-transfusion via a filter.[6,8,9,11] A cell-salvage device has the advantage of washing and filtering the blood and thus removing potentially antigenic cells such as leukocytes and neoplastic cells.[18] However, most cell-salvage systems require a predetermined volume of erythrocytes prior to washing, making it less suitable for most cats, where collected blood volumes are usually small. The techniques described for autotransfusion in the cats of this case series were percutaneous collection by ultrasound guidance using a butterfly catheter connected to a 20 ml syringe or direct collection via a 20 ml syringe at the time of surgery, which is similar to that reported in the case series of 25 dogs.[10]

In 5/12 autotransfusion cases blood was collected into acid citrate (ACD-A). The use of anticoagulant in autotransfusion is controversial. Some literature suggests that blood in contact with the peritoneal surface after more than 1 h becomes defribinated and thus systemic anticoagulant is unnecessary and the citrate itself may lead to hypocalcaemia.[18] In 2/8 autotransfusion events where ionised or total calcium was available post-transfusion there was a documented mild non-clinically significant hypocalcaemia. Acid citrate was used only in one of these cases. Hypocalcaemia has been reported in dogs undergoing autotransfusion via cell-saver device and direct collection.[10,11] In one study of autotransfusion in dogs, 50% of the cases were administered blood with anticoagulant and 50% without, and there was no association seen between the use of anticoagulant and survival.[10] Further studies are required to investigate the clinical relevance of anticoagulant use in autotransfusion in cats.

The use of a blood filter is recommended for re-delivery of blood in an attempt to remove micro-aggregates that could promote an inflammatory reaction. Platelets and platelet products have been found to incite an inflammatory reaction, which can lead to the development of cutaneous oedema and acute respiratory distress syndrome.[19] The filter size of 18 μm used in the cats in this case series has a high micro-aggregatory retention, preventing platelet and leukocyte passage. However, this size filter will not filter serotonin, histamine or catecholamine, which are reported to lead to an increased risk of system inflammatory response.[20] No patient in this case series showed any clinical signs consistent with an inflammatory response post-transfusion.

Each patient, where recorded, received between 9 and 26 ml/kg of autologous blood during each transfusion. Two cats received in excess of 30 ml/kg total blood product in 4–6 h and thus by definition underwent a massive transfusion.[20] The one patient that received a massive transfusion, and survived, was found to have prolonged PT and aPTT and severe thrombocytopenia post-transfusion, requiring fresh frozen plasma therapy. Autotransfusions have been previously documented to cause consumptive coagulopathy; PT and aPTT were prolonged post-transfusion in 80% of cases of canine autotransfusions where post-transfusion PT and aPTT were measured in one study.[10] This hypocoagulability is thought to occur as a result of widespread activation of the coagulation system and secondary fibrinolysis when the blood is re-infused.[21] The cat in this case series that had prolonged PT and aPTT post-transfusion received a large volume of crystalloid, massive transfusion of canine packed red blood cells and autologous blood. It is therefore difficult to determine the contribution of the autotransfusion to this coagulopathy. Only one other patient, diagnosed with a traumatic haemoperitoneum, had coagulation values measured after the transfusion, which revealed a mild coagulopathy and could be the result of continual bleeding or the effect of the autotransfusion, or a combination of both. Ideally, a post-transfusion platelet count and clotting times should be assessed to monitor for development of a consumptive coagulopathy.

Other reported complications of autotransfusion include haemolysis secondary to prolonged exposure to serosal membrane and mechanical injury during collection and re-infusion.[10,22,23] Haemolysis results in the release of free haemoglobin, which can lead to acute kidney injury. To minimise the risk of mechanical injury to the red blood cells, aspiration was performed gently using low-suction pressure to minimise cell damage during the retrieval. One cat, diagnosed with a haemangiosarcoma, was reported to have haemolysed serum post-autotransfusion vs 5/19 (26%) of dogs in a previous study.[10] This patient was also shown to have haemolysed serum pre-transfusion and no evidence of worsening post-transfusion, suggesting it was likely part of the patient's disease state. This patient's PCV showed a mild increase (PCV increase 2–2.5%) after the transfusions, which could have been the result of ongoing haemolysis. Larger studies of feline autotransfusions are required to assess the true prevalence and consequence of haemolysis in these cases.

One patient suffered from suspected transfusion-associated circulatory overload. This patient had received a massive transfusion of canine packed red

blood cells and autologous blood products alongside crystalloid therapy and fresh frozen plasma. It is therefore likely that it was due to the volume of product vs the type of transfusion. This patient responded well to therapy and went on to make a complete recovery.

Reported contraindications for autotransfusion in humans are surgeries for malignancy, bacterial contamination and contamination of the blood with products that can cause haemolysis, such as hypotonic fluids.[6] The use of autotransfusion for management of haemorrhage secondary to neoplasia is controversial. It is unclear how well malignant cells are removed by filtration and it has been suggested that autotransfusion can contribute to metastatic spread of the tumour.[24] However, autotransfusion has been described in dogs with haemoperitoneum secondary to neoplasia with no reported complications, and studies in humans have not shown an increased metastatic rate when autotransfusions have been performed in patients with neoplasia.[8,10,25] In this study, 50% of patients (4/8) had an autotransfusion due to a ruptured neoplasm, of which 3/4 died within 6 weeks of the autotransfusion. These patients likely already had metastatic disease so we cannot elucidate if the transfusion contributed to disease progression. In this case transfusion itself was a lifesaving treatment and prevented the use of feline blood products, a scare resource, in a terminal patient.

In one cat the autotransfusion may have involved infusion of blood contaminated with bacteria. Microbiological culture was performed on the abdominal fluid of two cats and in one case this led to a positive culture for *E faecalis*. Bacterial growth of salvaged blood has not previously been reported in the veterinary literature, but has been reported in up to 12.7% of blood salvaged in humans.[26] Patients in this study were followed up for 2 months post-autotransfusion and no statistically significant correlation between bacteriological results of autotransfused blood and infectious complications could be found. The cat with the positive culture in this case series was euthanased shortly after its autotransfusion and therefore it was not possible to determine its clinical significance.

Two month survival was 75% for cats available for follow-up in this study. In the cats that died, the cause of death was euthanasia due to underlying disease and continued haemorrhage, similar to that reported in dogs.[10] This case series supports other studies in humans and veterinary species that autotransfusion does not appear to adversely affect mortality or lead to significant complications.[10,16]

This case series describes the successful use of a simple, cost-effective autotransfusion technique using a 23 G needle or butterfly catheter, 20 ml syringe and a blood filter to manage life-threatening abdominal haemorrhage and to provide intravascular support under general anaesthesia. This technique is cheap and requires minimal equipment with no clinically significant adverse effects and should be considered in unstable cats with a confirmed non-septic haemoperitoneum. Monitoring for post-transfusion haemolysis, coagulopathy and hypocalcaemia are recommended post-transfusion.

Conclusions

Autologous transfusion appears to be a safe and effective technique for stabilising cats with haemoperitoneum. This technique allowed rapid and cheap provision of blood and avoids the need for an allogenic donor.

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding The authors received no financial support for the research, authorship, and/or publication of this article.

ORCID iD Laura Cole https://orcid.org/0000-0001-5865-2181

References

1 Doolin K, Chan D, Adamantos S, et al. **Retrospective evaluation of unexpected events during collection of blood donations performed with and without sedation in cats (2010–2013)**. *J Vet Emerg Crit Care* 2017; 27: 555–560.
2 Weingart C and Kohn B. **Clinical use of haemoglobin-based oxygen carrying solution (Oxyglobin) in 48 cats (2002–2006)**. *J Feline Med Surg* 2008; 10: 431–438.
3 Oron L, Bruchim L, Klainbart S, et al. **Ultrasound-guided intracardial xenotransfusion of canine packed red blood cells and epinephrine to the left ventricular of a severely anaemic cat during cardiopulmonary resuscitation**. *J Vet Emerg Med Crit Care* 2017; 27: 218–223.
4 Bovens C and Gruffydd-Jones T. **Xenotransfusion with canine blood in the feline species: review of the literature**. *J Feline Med Surg* 2012; 15: 62–67.
5 Euler CC. **Xenotransfusion of anemic cats with blood compatibility issues: pre- and post transfusion laboratory diagnostic and crossmatching studies**. *Vet Clin Pathol* 2016; 45: 244–253.
6 Walunj A, Babb A and Sharpe R. **Autologous blood transfusion**. *Contin Educ Anaesth Crit Care Pain* 2006; 6:1 92–196.
7 Zenoble RD and Stone EA. **Autotransfusion in the dog**. *J Am Vet Med Assoc* 1978; 172: 1411–1414.
8 Hirst C and Adamantos S. **Autologous blood transfusion following red blood cell salvage for the management of blood loss in 3 dogs with hemoperitoneum**. *J Vet Emerg Crit Care* 2012; 22: 355–360.
9 Kellet-Gregory L, Seth M, Adamantos S, et al. **Autologous canine red blood cell transfusion using cell salvage devices**. *J Vet Emerg Crit Care* 2013; 23: 82–86.
10 Higgs VA, Rudloff E, Kirby R, et al. **Autologous blood transfusion in dogs with thoracic or abdominal haemorrhage: 25 cases (2007–2012)**. *J Vet Emerg Med Crit Care* 2015; 25: 731–738.
11 Lamb JL, Thieman Mankin KM, Levine GJ, et al. **Electrolyte and acid/base changes in dogs undergoing autologous**

blood transfusion via a cell salvage device. *Can Vet J* 2015; 56: 947–952.
12 Robinson DA, Kiefer K, Bassett R, et al. **Autotransfusion using a 2-syringe technique**. *J Vet Emerg Crit Care* 2016; 26: 766–744.
13 Jagodich TA and Holowaychuk MK. **Transfusion practices in dogs and cats: an internet based survey**. *J Vet Emerg Crit Care* 2016; 26: 360–272.
14 Heikes BW and Ruax CG. **Effect of syringe and aggregate filter administration on survival of transfused autologous fresh feline red blood cells**. *J Vet Emerg Crit Care* 2013; 24: 162–167.
15 Fusco JV, Hohenhaus AE, Aiken SW, et al. **Autologous blood collection and transfusion in cats undergoing partial craniectomy**. *J Am Vet Med Assoc* 2000; 216: 1584–1588.
16 Carless PA, Henry DA, Moxey AJ, et al. **Cell salvage for minimising perioperative allogeneic blood transfusion**. *Cochrane Database Syst Rev* 2006; 18: CD001888.
17 Kenneth MD and Mattox L. **Autotransfusion in the emergency department**. *J Am Coll Emerg Physicians* 1975; 4: 218–222.
18 Niebauer GW. **Autotransfusion for intra-operative blood salvage: a new technique**. *Compend Contin Educ* 1991; 13: 1105–1121.
19 Bull BS and Bull MH. **The salvaged blood syndrome: a sequel to mechanochemical activation of platelets and leukocytes?** *Blood Cells* 1990; 16: 5–20.
20 Rozanski E and de LaFrocade AM. **Transfusion medicine in veterinary emergency and critical care medicine**. *Clin Techn Small Anim Pract* 2004; 19: 83–87.
21 Purviss D. **Autotransfusion in the emergency patient**. *Vet Clin North Am Small Anim Pract* 1995; 25: 1291–1304.
22 Ari Jutkowitz L. **Blood transfusion in the perioperative period**. *Clin Tech Small Anim Pract* 2004; 19: 75–82.
23 Hofbauer N, Windberger U, Schwendenwein I, et al. **Evaluation of canine red blood cell quality after processing with an automated cell salvage device**. *J Vet Emerg Med Crit Care* 2016; 26: 376–383.
24 Karczewski D, Lerna M and Glaves D. **The efficiency of an autotransfusion system for tumour cell removal from blood salvaged during cancer surgery**. *Anaesth Analg* 1994; 78: 1131–1135.
25 Waters JH, Yazer M, Chen YF, et al. **Blood salvage and cancer surgery: a meta-analysis of available studies**. *Transfusion* 2012; 52: 2167–2173.
26 Ezzedine H, Baele P and Robert A. **Bacteriologic quality of intraoperative autotransfusion**. *Surgery* 1991; 109: 259–264.