

Evaluation of the effects of bovine hemoglobin glutamer-200 on systolic arterial blood pressure in hypotensive cats: 44 cases (1997–2008)

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Objective—To determine effects of bovine hemoglobin glutamer-200 (Hb-200) solution on systolic arterial blood pressure (SAP) in hypotensive cats and describe potential adverse effects associated with this treatment.

Design—Retrospective case series.

Animals—44 cats.

Procedures—Medical records of hypotensive (Doppler SAP \leq 80 mm Hg) cats that received Hb-200 treatment were reviewed. Volume and rate of Hb-200 administration, treatments for hypotension given prior to Hb-200 administration, changes in SAP, potential adverse effects, and short-term outcome were evaluated.

Results—44 cats were included in the study. Mean \pm SD SAP prior to Hb-200 administration was 52 ± 11 mm Hg, despite other treatments. Forty-three cats received Hb-200 via IV bolus administration (mean \pm SD volume, 3.1 ± 2.2 mL/kg [1.41 ± 1.0 mL/lb] over 25.17 ± 17.51 minutes); 1 cat received a continuous rate infusion (CRI) only. The SAP increased to > 80 mm Hg in 33 of 44 (75%) cats. The SAP increased > 20 mm Hg above baseline value in 29 of these 33 cats and in 4 cats in which SAP did not exceed 80 mm Hg. A CRI (mean \pm SD rate, 0.8 ± 0.5 mL/kg/h [0.36 ± 0.23 mL/lb/h]) of Hb-200 was administered to 37 cats (after bolus infusion in 36). Mean SAP during the CRI was 92 ± 18 mm Hg. Adverse effects included respiratory changes ($n = 8$ cats), vomiting (2), and pigmented serum (30). Seventeen (39%) cats survived to discharge from the hospital, 6 died, and 21 were euthanized.

Conclusions and Clinical Relevance—Hb-200 effectively increased SAP in hypotensive cats with few adverse effects. (*J Am Vet Med Assoc* 2011;238:909–914)

Circulatory shock results in inadequate organ perfusion and tissue hypoxia and is a life-threatening complication of many diseases in cats.^{1–3} There are 3 hallmark signs of circulatory shock identified in cats: bradycardia, hypothermia, and hypotension.^{4–6} The main causes of hypotension include decreased preload, heart disease, and decreased vascular tone, alone or in combination.^{7,8} Decreased vascular tone may result from electrolyte abnormalities, hypoxia, acidosis, drugs, toxins, hypothermia, and systemic inflammatory response syndrome attributable to any cause, including sepsis.^{5–8} Silverstein et al⁸ reported that critically ill cats that had hypotension (defined as Doppler SAP \leq 90 mm Hg for purposes of that study) at some time during their hospitalization had a higher mortality rate (25/39 [64%]) than did cats that were normotensive throughout hospitalization (14/44 [32%]). In addition, hypotensive cats in which the SAP was increased by ≥ 20 mm Hg above the lowest determined value were more likely to survive to discharge than were cats in which the SAP was increased by < 20 mm Hg.⁸

Initial intervention for the treatment of hypotension due to hypovolemia includes IV administration of crystalloid solutions with or without infusion of a colloid so-

ABBREVIATIONS

COP	Colloid osmotic pressure
CRI	Continuous rate infusion
Hb-200	Hemoglobin glutamer-200
HBOC	Hemoglobin-based oxygen carrier
SAP	Systolic arterial blood pressure

lution.^{7,8} Colloidal fluids contain large organic molecules that maintain COP; examples include synthetic colloids (eg, hetastarch) and HBOCs. The HBOCs have an advantage over synthetic colloids for restoration of tissue perfusion because the dissolved hemoglobin carries additional oxygen to the capillaries for release in the tissues.^{9,10} In addition, studies^{11–14} have shown that HBOCs have vasoconstrictive effects in dogs, humans, and swine.

Hemoglobin glutamer-200 (bovine)^a is an ultrapurified, polymerized HBOC of bovine origin that contains 13 g/dL of hemoglobin in a modified lactated Ringer's solution. The COP of Hb-200 (42 mm Hg)⁹ is greater than the reference interval of feline blood COP (21 to 34 mm Hg).^{15,16} Adverse events reported in cats following Hb-200 infusion include respiratory distress, pulmonary edema, pleural effusion, mucous membrane discoloration, pigmenturia, vomiting and neurologic abnormalities.^{17,18}

Two retrospective studies^{17,18} have reported the use of Hb-200 in cats. The majority of cats in both studies (70/72 and 48/48, respectively) were anemic, and the preinfusion SAP was 93 ± 40 mm Hg in the cats of 1 study.¹⁷

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To the authors' knowledge, no studies have been published in which the effect of Hb-200 was evaluated for the treatment of hypotension in cats. The purpose of the study reported here was to determine the effect of Hb-200 on the SAP of hypotensive cats and to describe any adverse effects associated with this treatment. Our hypothesis was that Hb-200 would provide an effective means of increasing blood pressure in cats with hypotension without substantial adverse effects.

Materials and Methods

Criteria for selection of cases—Computer database and hard copy medical records of the Animal Emergency Center and Specialty Services were searched to identify hypotensive cats that received Hb-200 between January 1, 1997, and December 31, 2008. Hypotension was defined as SAP \leq 80 mm Hg. Records were excluded if the cat's SAP was $>$ 80 mm Hg at any time prior to administration of Hb-200 or if any required portion of the record was incomplete.

Measurement of SAP and monitoring during Hb-200 administration—In all cases, SAP was indirectly measured by experienced intensive care veterinary nurses using an ultrasonic Doppler flow detector.^b A small area was clipped over the dorsal metatarsal or common digital artery. An inflatable cuff with a width approximately 40% of the circumference of the limb was placed proximal to the carpus or over the metatarsus and attached to a sphygmomanometer. Acoustic coupling gel was applied to the area, and a piezoelectric crystal probe was placed over the artery. Following detection of blood flow, the cuff was inflated 20 mm Hg beyond the pressure at which the signal was no longer audible. The cuff was deflated, and the measurement at which the signal returned was recorded.

The SAP was measured immediately before and after each IV fluid bolus and every 1 to 4 hours during CRIs of IV fluids. Temperature, pulse, respiratory rate, mucous membrane color, and capillary refill time were monitored in all cats during Hb-200 infusions.

Medical records review—Data collected from the medical records included signalment, evidence of hypovolemia, and causes of hypotension, if known. Physical examination findings and results of laboratory and other diagnostic tests (eg, CBC, serum biochemical analysis, and echocardiography) were evaluated.

Hypovolemia was presumed when clinical signs of inadequate perfusion were present (eg, pale mucous membrane color, prolonged capillary refill time, poor pulse quality, cool peripheral extremities, and hypothermia), when causes for volume depletion were known (eg, decreased water intake, increased water loss, or hemorrhage [anemia associated with evidence of bleeding]), or both.

Types, volumes, and routes of administration of crystalloid or colloid solutions and any vasopressor treatment (eg, vasopressin or dopamine) administered prior to Hb-200 administration were recorded. In addition, volumes and times of Hb-200 administration and SAP within 30 minutes before (ie, baseline values) and within 30 minutes after Hb-200 bolus administration in 43 cats or CRI administration in 1 cat (end SAPs) were recorded.

Other variables that could affect blood pressure were also reported if data were available. These included hypoglycemia (ie, blood glucose concentrations $<$ 90 mg/dL), heart disease (structural abnormalities diagnosed via echocardiography), anemia (PCV \leq 30%) with blood loss, anemia without blood loss, acidemia (venous blood pH \leq 7.39), hypothermia (temperature per rectum \leq 37.2°C [$<$ 99°F]), and hypovolemia with no evidence of blood loss.

Short-term survival (ie, survival to discharge from the hospital) was assessed. Adverse effects that may have been related to Hb-200 infusion, including changes in respiratory rate ($>$ 40 breaths/min at rest) or effort (increased movement of the chest wall or abdomen), vomiting, and pigmented serum, were also reported.

Statistical analysis—Data were reported as mean \pm SD for continuous variables and as frequency and percentages for categorical data. A Wilcoxon rank sum test was used to determine the effect of Hb-200 administration on blood pressure. A Fisher exact test was used to determine whether confounding factors (hypoglycemia, heart disease, anemia with blood loss, anemia without blood loss, acidemia, hypothermia, and hypovolemia with no evidence of blood loss) were associated with a change in SAP. All analyses were performed by use of commercially available software.^c Values of $P <$ 0.05 were considered significant.

Results

Eighty-two cats admitted to the facility during the study period received Hb-200 treatment. Of these, 14 cats had SAPs $>$ 80 mm Hg before Hb-200 administration and 24 had incomplete records; 44 cats (29 males [27 castrated and 2 sexually intact] and 15 females [13 spayed and 2 sexually intact]; mean age, 8.8 ± 4.9 years; mean weight, 4.41 ± 1.31 kg [9.70 ± 2.88 lb]) met inclusion criteria for the study. Breeds included domestic shorthair cat ($n = 32$), domestic longhair cat (4), Maine Coon (2), Siamese (2), Himalayan (2), Balinese (1), and Norwegian Forest Cat (1).

All cats had received a CRI of a balanced isotonic crystalloid solution (6.57 ± 3.63 mL/kg/h [2.99 ± 1.65 mL/lb/h; range, 0.96 to 34.78 mL/kg/h [0.44 to 15.81 mL/lb/h], IV) for 1 to 24 hours prior to administration of Hb-200. Thirty-three of 44 cats also received rapid IV bolus infusions of isotonic crystalloid solutions prior to Hb-200 administration. The mean volume of crystalloid solution administered as a bolus was 31.90 ± 18.91 mL/kg (14.50 ± 8.60 mL/lb; range, 5.56 to 109.10 mL/kg [2.53 to 49.60 mL/lb]).

A synthetic colloid solution (6% hetastarch 450/0.7) was administered as a bolus IV prior to Hb-200 administration in 39 of 44 cats, with a mean volume reported for 35 cats of 9.14 ± 5.20 mL/kg (4.15 ± 2.36 mL/lb; range, 1.96 to 25.55 mL/kg [0.89 to 11.61 mL/lb]). Twelve of the cats that received bolus infusions of hetastarch solution then received hetastarch solution via CRI, and 4 cats were given hetastarch solution via CRI alone; the mean rate of CRIs was 1.30 ± 0.94 mL/kg/h (0.59 ± 0.43 mL/lb/h; range, 0.37 to 1.81 mL/kg/h [0.17 to 0.82 mL/lb/h]). The duration of crystalloid and colloid bolus administration was not recorded, but was typically between 5 and 30 minutes for cats in the hospital where the study was performed.

Additional treatments for hypotension administered prior to Hb-200 infusion included whole blood transfusion (19.68 ± 6.25 mL/kg [8.95 ± 2.84 mL/lb], IV; $n = 7$ cats), packed RBCs (9.3 mL/kg [4.23 mL/lb], IV; 1 cat), plasma transfusions (31.09 ± 5.28 mL/kg [14.13 ± 2.40 mL/lb], IV; 2 cats), dopamine (CRI, 2.0 to 5.0 μ g/kg/h [0.91 to 2.27 μ g/lb/h], IV; 2 cats), and vasopressin (bolus dose, 0.80 U/kg [0.36 U/lb], IV; 1 cat). Transfusions were administered throughout a 4- to 6-hour period. Administration of dopamine or vasopressin did not increase SAP.

Mean SAP for all cats immediately prior to Hb-200 administration (ie, baseline value) was 52 ± 11 mm Hg.

Table 1—Changes in SAP and short-term outcome in 44 hypotensive cats that received IV bolus infusion or CRI of Hb-200.

Variable	No. of cats	Survived	Euthanized	Died
End SAP > 80 mm Hg				
≥ 20 mm Hg increase	29	16	11	2
< 20 mm Hg increase	4	0	4	0
End SAP ≤ 80 mm Hg				
≥ 20 mm Hg increase	4	0	3	1
< 20 mm Hg increase	7	1	3	3

The SAPs were measured by use of Doppler ultrasonography within 30 minutes before (ie, baseline) and within 30 minutes after (ie, end SAP) administration of Hb-200 via IV bolus (43 cats) or via CRI (1 cat). Thirty-six of the cats that received Hb-200 via IV bolus administration also received a CRI after the measurement was obtained. The end SAP value was compared with that measured at baseline and categorized as an increase of \geq or < 20 mm Hg. Surviving cats lived to be discharged from the hospital.

Table 2—Mean \pm SD Hb-200 IV infusion volumes and times for 44 hypotensive cats that did ($n = 33$) or did not (11) have end SAP values > 80 mm Hg after this treatment.

Variable	End SAP	
	> 80 mm Hg	≤ 80 mm Hg
Bolus volume (mL/kg)	2.68 ± 1.94	4.28 ± 2.35
Total volume (mL/kg)*	7.48 ± 4.07	13.48 ± 10.87
Duration of bolus administration (min)†	23.96 ± 17.38	26.56 ± 15.18

*Total volume represents bolus plus CRI volume; 29 cats with end SAP > 80 mm Hg and 8 cats with end SAP ≤ 80 mm Hg received a CRI (36 cats after bolus administration of Hb-200). †Duration of bolus administration was recorded in 31 of 43 cats that received the Hb-200 bolus (22/32 cats with end SAP > 80 mm Hg and 9/11 cats with end SAP ≤ 80 mm Hg). One cat received a CRI without a bolus administration of Hb-200.

The Hb-200 was given by means of IV bolus infusion to 43 cats at a mean volume of 3.1 ± 2.2 mL/kg (1.41 ± 1.0 mL/lb). The duration (mean, 25.17 ± 17.51 minutes) of Hb-200 bolus infusion was reported in the records of 31 cats. A CRI of Hb-200 (0.80 ± 0.50 mL/kg/h [0.36 ± 0.23 mL/lb/h], IV) was administered to 36 of 37 cats that had received a bolus infusion; 1 cat had immediately been started on a CRI without a bolus infusion. The mean total volume of Hb-200 given to all cats was 9.0 ± 5.5 mL/kg (4.09 ± 2.50 mL/lb). Mean total duration of Hb-200 administration was 10.1 ± 7.3 hours.

Within 30 minutes of completion of the Hb-200 bolus ($n = 43$ cats) or CRI (1), mean end SAP for all cats was 90 ± 18 mm Hg. This was a significant ($P < 0.001$) increase from the mean SAP prior to Hb-200 treatment. One cat did not have any change in SAP at any time after Hb-200 administration. Mean SAP for the 37 cats during CRI of Hb-200 was 92 ± 18 mm Hg.

An end SAP > 80 mm Hg was achieved in 33 of 44 (75%) cats, and 16 (48%) of these cats survived to discharge from the hospital (Table 1). Thirty-three of 44 (75%) cats had an increase in SAP of ≥ 20 mm Hg from baseline within 30 minutes of bolus or CRI completion, and 16 (48%) of these cats survived to discharge.

Seventeen of the 44 (39%) cats that received Hb-200 treatment for hypotension survived, regardless of the end SAP value or the change in SAP from baseline. The volumes and durations of Hb-200 infusions in cats that had end SAPs > 80 mm Hg were compared with those of cats in which SAPs remained ≤ 80 mm Hg (Table 2).

Causes of hypotension were categorized as follows: hypovolemia with blood loss ($n = 27$ cats), hypovolemia without blood loss (7), anemia without blood loss (7), cardiac (1), and unknown (2). The most likely cause of hypotension was chosen in cats that had > 1 condition. Loss of RBCs was identified as a cause of hypotension in 34 of 44 (77%) cats that received Hb-200; 16 of these 34 (47%) cats survived to discharge. Fifteen of 27 (56%) cats that had hypovolemia with blood loss and 1 of 7 cats with anemia from other causes survived to discharge. The remaining 10 of 44 cats had other causes of hypotension, and only 1 of these cats survived to discharge.

Confounding factors (anemia with blood loss, anemia without blood loss, hypoglycemia, acidemia, hypothermia, hypovolemia without blood loss, and heart disease) that may have affected SAP independent of Hb-200 administration were analyzed (Table 3). None of these

Table 3—Confounding factors evaluated for potential effects on changes in SAP in 44 hypotensive cats that received Hb-200 treatment.

Variable	Factor	No. of cats	Range	P value*
PCV (%)	Anemia† with blood loss	27	7–29	0.150
	Anemia† without blood loss	7	7–30	0.092
Blood glucose (mg/dL)	Hypoglycemia‡	8	20–87	0.642
Blood pH	Acidemia§	17	7.125–7.390	0.443
Temperature per rectum	Hypothermia	28	35.0°–37.05°C (95.0°–98.7°F)	0.156
Other	Hypovolemia without blood loss¶	7	NA	0.054
	Heart disease#	5	NA	0.155

Some cats had > 1 condition; echocardiography was not performed on all cats.

*Values of $P < 0.05$ were considered significant. †PCV was $\leq 30\%$. ‡Blood glucose was < 90 mg/dL. §Blood pH was ≤ 7.39 . ||Temperature was $\leq 37.2^\circ\text{C}$ ($\leq 99^\circ\text{F}$). ¶Evaluated as present or not present on the basis of physical examination findings and clinical history. #Evaluated as present or not present on the basis of results of echocardiography.

variables were found to have a significant association with the change in SAP.

Adverse effects that could have been attributed to Hb-200 infusion included changes in respiratory rate and effort ($n = 8$ cats), vomiting (2), and red or brown pigmented serum (30). Two of the 8 cats with respiratory changes had radiographic changes consistent with pulmonary edema, 5 had changes consistent with pleural effusion, and 1 had both pulmonary edema and pleural effusion.

Five of the 8 cats with respiratory changes each had a diagnosis of hypertrophic cardiomyopathy determined via echocardiography, which was performed after Hb-200 was administered. The remaining 3 cats did not have an echocardiogram or necropsy performed to determine if underlying heart disease was a factor in the development of respiratory signs. In the 8 cats with respiratory changes, the mean volume of crystalloid solution given via IV bolus administration was 23.41 ± 13.31 mL/kg (10.64 ± 6.05 mL/lb) and the mean volume of colloid solution administered via IV bolus was 6.23 ± 4.03 mL/kg (2.83 ± 1.83 mL/lb). The mean volume of Hb-200 was 3.87 ± 3.18 mL/kg (1.76 ± 1.45 mL/lb), and duration of Hb-200 bolus administration was 48.80 ± 28.48 minutes in cats that developed respiratory changes. The mean SAP increased 44.2 ± 15.25 mm Hg from baseline in these cats. In the 36 cats that did not develop respiratory changes, the mean volume of crystalloid solution given via IV bolus administration was 33.84 ± 19.28 mL/kg (15.38 ± 8.76 mL/lb) and the mean volume of colloid solution was 9.45 ± 5.27 mL/kg (4.30 ± 2.40 mL/lb). The mean volume of Hb-200 was 3.10 ± 2.10 mL/kg (1.41 ± 0.95 mL/lb), and duration of Hb-200 bolus administration was 23.31 ± 17.01 minutes in cats that did not develop respiratory changes. The mean SAP increased 75.44 ± 18.28 mm Hg from baseline in this group of cats.

Six of 30 cats that developed pigmented serum had also received a blood transfusion. Posttransfusion hemolysis may have contributed to the serum discoloration in these cats.

Six of 44 cats died after cardiopulmonary arrest in the hospital; 2 of these died during Hb-200 administration. Twenty-one cats were euthanized because of grave prognosis.

Discussion

To the authors' knowledge, this is the first study that describes the use of Hb-200 to successfully provide fluid resuscitation in hypotensive cats. Intravenous administration of Hb-200 resulted in a significant ($P < 0.001$) increase in the mean SAP from baseline values to an end SAP > 80 mm Hg in 33 of 44 (75%) hypotensive cats. Hemoglobin-based oxygen carriers not only support COP, but can also cause substantial vasoconstriction.^{9-11,19-21} Theories regarding the vasopressor effects of these products include scavenging of circulating nitric oxide by hemoglobin, which prevents activation of cyclic guanine monophosphate^{9,10,21-24}; blockade of nitric oxide by Hb-200 in the interstitium²⁵; and increased circulating concentrations of the potent vasoconstrictor endothelin secondary to increased plasma hemoglobin concentra-

tions.^{9,10,26-28} In contrast to the potent vasopressor arginine vasopressin, Hb-200 has been reported²⁹ to improve perfusion without worsening acidosis.

The manufacturer's recommended volume of Hb-200 for treating anemia in dogs is 10 to 30 mL/kg (4.55 to 13.64 mL/lb). Only 3.1 ± 2.2 mL/kg was needed to effectively increase SAP in 33 of 44 (75%) hypotensive cats in the present study. Investigators in another study³⁰ reported that smaller volumes of Hb-200 resulted in resolution of global ischemia, compared with allogenic blood transfusions given during resuscitation in dogs with intestinal ischemia. The mean total amount of Hb-200 (9.0 ± 5.5 mL/kg) administered in cats of the study reported here was less than that administered to treat anemic cats in a study by Gibson et al,¹⁷ in which the mean \pm SD total volume was 17.10 ± 14.50 mL/kg (7.77 ± 6.60 mL/lb). In the present study, 37 cats (36/43 that received Hb-200 bolus infusion and 1 that received a CRI only) each received a CRI (0.8 ± 0.5 mL/kg/h [0.23 ± 0.23 mL/lb/h], IV) of Hb-200. This is a lesser rate than that administered to cats for the treatment of anemia (4.80 ± 6.20 mL/kg/h [2.18 ± 2.82 mL/lb/h]) in the earlier study.¹⁷

Results of studies^{31,32} in dogs and pigs revealed that treatment of hemorrhagic shock and polytrauma with Hb-200 improves blood pressure faster than does treatment with 6% hetastarch or saline (0.9% NaCl) solutions. The study reported here showed that effective changes in SAP occurred within 30 minutes after the bolus or CRI infusion of Hb-200 in cats that had hypotension after infusion of other fluids, with or without vasopressor treatment.

Administration of Hb-200 resulted in SAPs > 80 mm Hg in 33 of 44 (75%) cats in the present study. Twenty-nine of these 33 cats and 4 of the remaining 11 cats had increases in SAP of ≥ 20 mm Hg after Hb-200 bolus or CRI, compared with baseline values. In a retrospective study of critically ill cats, Silverstein et al⁸ reported that 16 of 39 (41%) hypotensive cats (defined as having Doppler blood pressure values ≤ 90 mm Hg for purposes of that study) had increases in SAP of ≥ 20 mm Hg, compared with the earliest value measured. However, the methods by which this was achieved were not indicated beyond a report that catecholamines were used in some of the cats. The greater percentage of cats with increases of ≥ 20 mm Hg above baseline values in the present study, compared with cats in the Silverstein et al⁸ report, may be attributable to the infusion of Hb-200.

Silverstein et al⁸ also reported that hypotensive cats that had an increase in blood pressure of ≥ 20 mm Hg had a higher short-term survival (ie, survival to discharge) rate, compared with those that did not have an increase (69% vs 17%, respectively). Sixteen of 33 (48%) cats in the present study that had an increase in SAP ≥ 20 mm Hg above baseline values survived to discharge.

All but 3 cats in the present study had received other types of IV fluid treatments and still remained hypotensive (SAP ≤ 80 mm Hg) prior to Hb-200 infusion. It is likely that our population of cats would have fallen into the nonresponsive category of the study by Silverstein et al⁸ (ie, hypotensive cats that do not respond to conventional fluid and vasopressor treatment) if Hb-200 was

not administered. Despite being unresponsive to more traditional fluid and vasopressor administration, when treated with Hb-200, 33 of 44 (75%) cats in the present study responded with SAPs > 80 mm Hg.

The SAPs in 11 of 44 (25%) hypotensive cats in the present study remained \leq 80 mm Hg, and only 1 of these cats survived to discharge. These 11 cats had received a greater mean total volume of Hb-200 (13.50 mL/kg [6.14 mL/lb]) than had cats in which end SAPs reached or exceeded 80 mm Hg (7.50 mL/kg [3.41 mL/lb]). The less-responsive cats were administered Hb-200 over a shorter period (0.4 ± 0.3 hours) than that used for cats in which the SAP increased to > 80 mm Hg (2.8 ± 4.5 hours). These differences may have been attributable to an increased severity of illness and urgency for resuscitation in the less-responsive cats. It was difficult to determine overall short-term survivability because euthanasia was elected in 6 of these 11 cats on the basis of poor prognosis.

Eight cats developed respiratory changes (increased respiratory rate and effort) after Hb-200 infusion. Whether this was a direct result of vasopressor action of the hemoglobin solution, a cumulative effect of the volume of all fluids administered, or a systemic inflammatory response is unknown. The mean volume of crystalloid solution administered as a bolus to cats that did not have respiratory changes (33.84 ± 19.28 mL/kg) was greater than that administered to cats that had these changes (23.41 ± 13.31 mL/kg). The mean volume of colloid solution administered as a bolus to cats that did not have respiratory changes (9.45 ± 5.27 mL/kg) was also greater than that administered to cats that had respiratory changes (6.23 ± 4.03 mL/kg). The mean volume of Hb-200 administered was similar in both groups (cats without respiratory changes, 3.10 ± 2.10 mL/kg; cats with respiratory changes, 3.87 ± 3.18 mL/kg). Five of these 8 cats were evaluated by means of echocardiography, and each had a diagnosis of hypertrophic cardiomyopathy, which could have contributed to the respiratory changes.

The additional 3 cats with respiratory changes may have had occult cardiomyopathy, but echocardiogram or necropsy was not performed in all cases. In cats that developed respiratory changes, a mean increase in SAP of 44.2 ± 15.25 mm Hg from baseline was detected after Hb-200 bolus was given over 48.80 ± 28.48 minutes. The cats that did not develop respiratory changes had a mean increase in SAP of 75.44 ± 18.28 mm Hg after Hb-200 bolus was given over 23.31 ± 17.01 minutes. The cats with respiratory changes had a smaller overall mean change in SAP, and Hb-200 bolus administration was performed at a slower rate in these cats, making cardiac decompensation caused by abrupt changes in SAP unlikely.

Although it was not considered to be significant, cats with hypovolemia appeared more likely to have an increase in SAP to > 80 mm Hg following Hb-200 administration than were cats with other causes of hypotension. Hemoglobin glutamer-200 is an effective colloid solution for volume expansion and contributed to intravascular volume expansion in cats of the present study. However, 25 of 33 (76%) cats that had an increase in SAP to > 80 mm Hg received hetastarch solution, which is also a potent colloid solution, prior

to Hb-200 administration. It is possible that the vasopressor effects of Hb-200 played an important role in increasing the SAP in hypotensive cats that had been unresponsive to more traditional fluid treatment.

Limitations of the study reported here include the retrospective nature of the research and uncontrolled variables such as the amount and type of fluids initially administered, variety and severity of illnesses of cats that received treatment, low numbers analyzed, and blood pressures having been measured by several different individuals. Future prospective studies in cats with hypotension should use a scoring system to evaluate the severity of underlying disease and should evaluate the efficacy of Hb-200 administration earlier in the course of fluid treatment as well as its effects on survival.

Results of the present study supported our hypothesis that Hb-200 would provide an effective means of increasing SAP in cats with hypotension. Low-volume infusion of Hb-200 in cats unresponsive to more traditional fluid treatment increased SAP in 43 of 44 (98%) cats, and a target end SAP value > 80 mm Hg was achieved in 33 (75%) cats. Twenty-nine of these 33 cats and 4 of the remaining 11 cats had increases in SAP of \geq 20 mm Hg. Although potential adverse effects that could be attributed to Hb-200 administration were reported, most were not considered to be clinically significant.

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- a. Oxyglobin, Biopure, Cambridge, Mass.
b. Parks Medical Electronics, Aloha, Ore.
c. SAS, version 9.1.3, Cary, NC.
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