

Assessment of cardiopulmonary resuscitation in 121 dogs and 30 cats at a university teaching hospital (2009–2012)

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Abstract

Objective – To prospectively describe cardiopulmonary resuscitation (CPR) and evaluate factors associated with outcome in dogs and cats with cardiopulmonary arrest (CPA).

Design – Prospective observational study.

Setting – University teaching hospital.

Animals – One hundred twenty-one dogs and 30 cats that underwent CPR.

Interventions – None.

Measurements and Main Results – Supervising clinicians completed a data form immediately following completion of CPR. Eighty-seven (58%) animals attained return of spontaneous circulation (ROSC), 49 (32%) had ROSC >20 minutes, 15 (10%) were alive at 24 hours, and 8 (5%) were discharged alive. Cardiovascular abnormalities were the most common suspected precipitating cause of CPA (51/151, 34%). Presence of an IV catheter before CPA ($P = 0.01$) and the presence of palpable pulses during CPR ($P = 0.007$) were both associated with ROSC. Increased time from CPA to CPR ($P = 0.04$), longer duration of CPR ($P < 0.0001$), and neurologic cause of arrest ($P = 0.02$) were associated with not achieving ROSC. There was no association between ROSC and the initial arrest rhythm identified on ECG, animal weight, number of people present, and ventilation or compression rate. In patients achieving ROSC, those with a “survived event” were more likely to be euthanized and less likely to experience a second CPA than those with ROSC \leq 20 minutes. Thirty-four percent of patients submitted for necropsy had gross and histological lesions considered secondary to CPR.

Conclusions – Early CPR interventions were associated with a greater likelihood of ROSC, emphasizing the importance of prompt recognition, and initiation of CPR efforts. Although ROSC rates in this study were comparable or higher than previous human and veterinary studies, the rate of “survived events” was lower than that reported in human patients. This may suggest that advances in post CPR care could have benefits to the veterinary CPR patient in the future.

(*J Vet Emerg Crit Care* 2014; 24(6): 693–704) doi: 10.1111/vec.12250

Keywords: cardiopulmonary arrest, cardiac arrest, epinephrine, return of spontaneous circulation, veterinary

Abbreviations

CPA	cardiopulmonary arrest
CPR	cardiopulmonary resuscitation
DOA	dead on arrival
PEA	pulseless electrical activity

RECOVER	Reassessment Campaign on Veterinary Resuscitation
ROSC	return of spontaneous circulation

Introduction

There is a growing interest in veterinary cardiopulmonary resuscitation (CPR), and the recent Reassessment Campaign on Veterinary Resuscitation (RECOVER) endeavor in 2012 identified vast knowledge gaps present in our current understanding of the incidence of cardiopulmonary arrest (CPA) as well as outcome, patient, hospital, and arrest variables.^{1–3}

Data are limited and difficult to interpret regarding CPR in veterinary medicine because most of the reported

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The authors declare no conflict of interests.

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Submitted December 23, 2013; Accepted May 17, 2014.

studies are retrospective reviews or case series of small numbers of patients, without consistent use of standardized definitions. Further information on the technique of CPR in clinical patients is clearly warranted. There have only been 3 clinical studies of CPR in dogs and cats published since 2000.⁴⁻⁶ There are no prospective studies that have evaluated successful CPR (ROSC > 20 min) as is now recommended by the International Liaison Committee on Resuscitation (ILCOR).⁷ Findings such as palpable pulses, complications during CPR, and necropsy results have never been published before. The present study collected data before and after the 2010 AHA guidelines that included updates on compression rate and depth, and more emphasis on chest recoil, minimizing interruptions in chest compressions, and avoiding excess ventilation.⁷

In order to study CPR objectively and compare results from experimental and clinical studies in a meaningful way it is necessary to use standardized terminology and definitions for reporting CPA and CPR related events. In 1991, recommendations for such standardized definitions were made in human medicine known as the "Utstein Style" guidelines for reporting CPR.⁸ The name Utstein was adopted as the first meeting to discuss these guidelines was held at the Utstein Abbey in Norway. An update of these guidelines was published in 2004 and several other Utstein style guidelines have been published for reporting specific CPR related issues in human medicine since then.⁸⁻¹⁰

The purpose of this study was to prospectively describe CPR and evaluate potential factors that may influence outcome of CPR in dogs and cats at a university teaching hospital using Utstein style guidelines. This prospective, observational study on CPR was performed prior to the publication of the RECOVER guidelines.

Materials and Methods

All dogs and cats that were identified with CPA and underwent CPR during the period from February 1, 2009 through January 31, 2012 at the William R. Pritchard Veterinary Medical Teaching Hospital of the University of California at Davis were enrolled on a prospective basis. Dogs and cats that experienced respiratory arrest without cardiac arrest were not included.

Patients with CPA were identified by the presence of the following criteria: unresponsive mentation, absence of effective respiratory efforts (agonal breathing was not considered effective respiratory efforts), lack of a detectable pulse or heartbeat or bradycardia with poor perfusion.¹⁰⁻¹² CPR was defined as an attempt to restore spontaneous circulation by performing chest compressions with or without ventilation.¹⁰

Consistent with the Utstein style registry guidelines, only the first cardiac arrest and resuscitation were described and analyzed for patients with multiple arrests.¹⁰ For this study, a single arrest and CPR event was defined to end when ROSC for >2 minutes was achieved or CPR efforts were stopped. If ROSC lasted for >2 minutes in between CPR events, the second arrest and resuscitation was considered a separate event and was not recorded.

CPR at our institution during the study adhered to standard algorithm where the order of resuscitation events was as follows: Airway, breathing, chest compressions, drug administration, and ECG placement. Where possible, many of these procedures would be performed simultaneously but if numbers of rescuers were limited this order would generally be followed. During the period of this study the 2010 AHA guidelines were introduced and a focus on 2 minute, uninterrupted cycles for chest compressions was included in the approach to CPR.⁷

The supervising clinician filled out a purpose made data form for each CPR event immediately following completion of CPR. Data recorded included 4 sets of variables (outcome, patient, hospital, and arrest) based on the Utstein style. Outcome variables included occurrence of ROSC, duration of ROSC, survival to 24 hours, and discharge from the hospital. Patient-related variables such as chronic or underlying diseases were gathered from the medical record retrospectively. Any blood gas results obtained during the CPR or within 5 minutes of ROSC were also recorded. These data have been reported in a separate publication.¹³ Hospital variables included qualifications of the supervising clinician and the number of people present to assist CPR. Arrest variables recorded included the time from CPA to the start of CPR, duration of the CPR attempt, success of endotracheal intubation, ventilation rate and method, chest compression rate, whether chest compressions generated palpable femoral pulses, medications administered and route, first identified rhythm on the ECG, rhythm changes, IV fluids administered, details of any defibrillation performed, whether there was an indication for open chest CPR and why, details of any open chest CPR performed, and any complications that occurred during CPR. The times from CPA to CPR for animals that arrived dead on arrival (DOA) or had an unwitnessed arrest were estimated based on owner history and time last seen alive in the wards, respectively. Success of intubation was based on the clinical judgment of the supervising clinician. It is estimated that most if not all CPR was performed in lateral recumbency, but this was not recorded prospectively on the data sheets.

The suspected cause of arrest was recorded based on the supervising clinician's evaluation of the case at the time of CPA as recorded on the data form along with a

retrospective review of the medical record. Further description of the suspected causes of CPA is provided in Table 1.

Return of spontaneous circulation was defined as the restoration of a spontaneous perfusing rhythm that resulted in more than an occasional gasp, fleeting palpable pulse, or arterial waveform.¹⁰ A “survived event,” also referred to as sustained ROSC, was defined as ROSC that lasts for > 20 minutes.¹⁰ The first noted rhythm was defined as the first cardiac rhythm present when a monitor was attached to a patient after a cardiac arrest and evaluated when cardiac compressions were not being performed. Successful defibrillation was defined as the termination of ventricular fibrillation to any rhythm (including asystole or pulseless electrical activity).¹⁰ A shockable rhythm was defined as a rhythm, when analyzed by the person interpreting the monitor, which is treatable by attempted defibrillation.¹⁰ Shockable cardiac arrest rhythms consisted of ventricular fibrillation and pulseless ventricular tachycardia. Non-shockable rhythms include pulseless electrical activity, asystole, sinus bradycardia, and 3rd degree AV block.

Medical records for all patients were reviewed retrospectively for a history and the data to calculate an Acute Patient Physiologic and Laboratory Evaluation (APPLE) fast score in the 24 hours preceding CPA and potential precipitating factors for CPA.¹⁴ If a necropsy was performed, the pathology report was reviewed for evidence of CPR-related trauma. None of the patients that suffered trauma had a necropsy performed.

Statistics

All statistical analyses were performed using commercial software.^a Normality testing via the Shapiro–Wilk test was performed on all continuous variable datasets. None of the datasets were found to be normally distributed and nonparametric analytic tools were used for all further statistical analyses. Mann–Whitney *U* testing was used to compare group distributions between groups with ROSC and not achieving ROSC. The Kruskal–Wallis test was used to compare group distribution between groups not achieving ROSC, ROSC ≤ 20 minutes, and ROSC >20 minutes. When significant differences were found, a post-hoc Dunn test was applied. Categorical data were analyzed with the Fisher’s exact test, except for supervisor status, which was analyzed with chi-square test for trend. Significance was set at *P* < 0.05. All variables (weight, number of people involved, time from CPA to CPR, ventilation rate, compression rate, duration of CPR, supervisor, presence of an IV catheter before CPA, whether the animal was already intubated, whether palpable femoral pulses were present during compressions, the time of arrest, and whether the

Table 1: Categories for the suspected etiology of cardiopulmonary arrest in dogs and cats

1. Cardiovascular
 - a. Heart disease including arrhythmia, myocardial infarction, myocarditis, cardiac chamber thrombus, acquired, or congenital structural heart disease
 - b. Blood disorders including anemia, hypovolemia, hemorrhage
 - c. Vascular disorders including clinical signs of poor perfusion suspected to be secondary to septic shock and severe persistent hypotension despite adequate fluid resuscitation
 - d. Pericardial effusion
2. Respiratory
 - a. Pulmonary parenchymal disease including pneumonia, noncardiogenic pulmonary edema, cardiogenic pulmonary edema, lung lobe torsion, pulmonary hemorrhage, pulmonary hypertension
 - b. Upper airway obstruction
3. Neurologic including intracranial disease such as hemorrhage, meningitis, seizures, or tumor, cervical myelopathy, and neuromuscular disease such as tetanus
4. Vagal-tone related suspected based on knowledge of underlying disease process, activity during and preceding arrest, and/or bradycardic arrest
5. Anesthesia related
 - a. Simple including patients undergoing an elective procedure or those that experienced an anesthetic overdose
 - b. Complex cases in which the animal has a severe underlying disease and was anesthetized or recently extubated at the time of CPA
6. Electrolyte/metabolic disturbances including hyperkalemia, hyper/hypoglycemia, ketoacidosis, uremia
7. Severe systemic disease including acute necrotizing pancreatitis, kidney disease, disseminated neoplasia, sepsis, MODS
8. Multiple trauma including animals that are hit by car or suffer bite wounds to multiple body parts/cavities
9. Multiple causes that include one or more of any of the above categories
10. Cause of arrest is unknown

MODS, multiorgan dysfunction syndrome; CPA, cardiopulmonary arrest.

first rhythm was shockable) other than cause of arrest were analyzed for cats and dogs separately and together. Only significant results are reported.

Results

Outcome variables

Of 90,938 canine and feline visits to the hospital, a total of 151 (0.02%) CPR episodes were recorded during the 36-month study period in 121 dogs and 30 cats. Of the total dogs and cats that had CPR, 58% (70/121) of dogs and 57% (17/30) of cats had ROSC, 35% (42/121) of dogs and 23% (7/30) of cats had a "survived event" (ROSC > 20 min), 10% (12/121) of dogs and 10% (3/30) of cats were alive at 24 hours, and 6% (7/121) of dogs and 3% (1/30) of cats were discharged alive from the hospital (Figure 1).

Of the animals that had ROSC for ≤ 20 minutes, 43% (12/28) of dogs and 60% (6/10) of cats were euthanized due to poor prognosis or financial concerns. The remaining animals experienced another CPA, of which none survived. Of the animals that had a "survived event," 60% of dogs and 57% of cats were euthanized. The remaining animals had a CPA for a second time, of which none survived. Of the animals that survived 24 hours, 42% of dogs and 33% of cats were euthanized. The remaining animals that were not discharged alive from the hospital experienced another CPA, of which none survived. Of animals with ROSC, the total rate of euthanasia for dogs was 60% and for cats was 65% and the total rate for repeat CPA was 30% for dogs and 29% for cats. The proportion of animals euthanized in the ROSC ≤ 20 minutes group was 47% and in the survived event group 71% ($P = 0.03$), while the proportion of patients with repeat CPA in the ROSC ≤ 20 minutes was 53% and in the survived event group was 12.2% ($P = 0.001$).

Thirteen animals (8 dogs, 5 cats) were anesthetized or recently extubated at the time of CPA. Three of these patients had multiple identifiable factors contributing to their cardiac arrest (eg, receiving positive pressure ventilation for pneumonia, hemorrhage, upper airway obstruction postextubation). None of these animals survived to discharge. Of the remaining 10 animals, 7 of these were categorized as complex anesthesia cases (ie, systemic disease or nonelective procedure) and 3 were considered simple anesthesia cases (ie, no systemic disease and an elective procedure). Of the 13 animals with CPA during or shortly after anesthesia, 50% (4/8) of dogs and 60% (3/5) of cats had a survived event, 50% (4/8) of dogs and 40% (2/5) of cats were alive at 24 hours, and 25% (2/8) of dogs and 20% (1/5) of cats survived to discharge. Of the simple anesthetic arrests, 67% (2/3) had a survived event and 33% (1/3) survived to discharge from the hospital. Of the 5 patients that received nalox-

one, 1 patient was anesthetized, 1 recently extubated, 2 were sedated, and 1 was receiving a fentanyl constant rate infusion. No patients were reported to have received any other reversal agents in this study.

Patient variables

The most common suspected cause for CPA was cardiovascular disease in both dogs (39%) and cats (23%; Table 2). Within this category the most common precipitating factors for CPA were hypovolemia, hemorrhage, and anemia. Respiratory failure was the second largest category causing CPA in both dogs (18%) and cats (23%). Pulmonary parenchymal disease was more common in dogs and upper airway obstruction was more common in cats. Neurologic disorders were also common in dogs, with intracranial disease being the most common. Dogs identified with neurologic disease as the cause of their CPA had a lower chance of achieving ROSC when compared to other disease categories ($P = 0.02$). No other disease category was statistically associated with ROSC.

There were sufficient data available to permit calculation of APPLE fast scores in the 24 hours preceding CPA in only 20/121 dogs and 1/30 cats. Given the low numbers, no statistical correlation between APPLE scores and outcome was performed.

Median weight (range) of all patients with ROSC was 9.45 kg (1.5–60 kg) and without ROSC was 11 kg (0.5–60 kg) (Figure 2). When evaluating dogs only, the median weight (range) with ROSC was 12 kg (1.5–60 kg) and without ROSC was 20 kg (0.5–60 kg). There was no significance between groups for dogs and cats or dogs only ($P = 0.17$, $P = 0.22$, respectively).

Hospital variables

There was no association with the presence of an emergency and critical care diplomat or resident versus others as the supervising clinician with ROSC ($P = 0.29$). There was no difference in the median number of people present to perform CPR in animals with ROSC compared to those without ROSC in dogs and cats ($P = 0.42$) (Figure 2). Cardiac arrests that occurred overnight, between the hours of 7 PM and 7 AM (70%), were more likely to have ROSC than cardiac arrests between 7 AM and 7 PM (52%) ($P = 0.04$).

Arrest variables

The median time (range) from CPA to the start of CPR in all patients with ROSC was 0.5 minutes (0.08–10 min) compared to 1 minute (0.08–30 min) in animals without ROSC ($P = 0.04$) (Figure 2). Of the animals that arrived DOA, 9/12 had no ROSC, of those that had unwitnessed arrests, 8/9 had no ROSC. None survived to discharge.

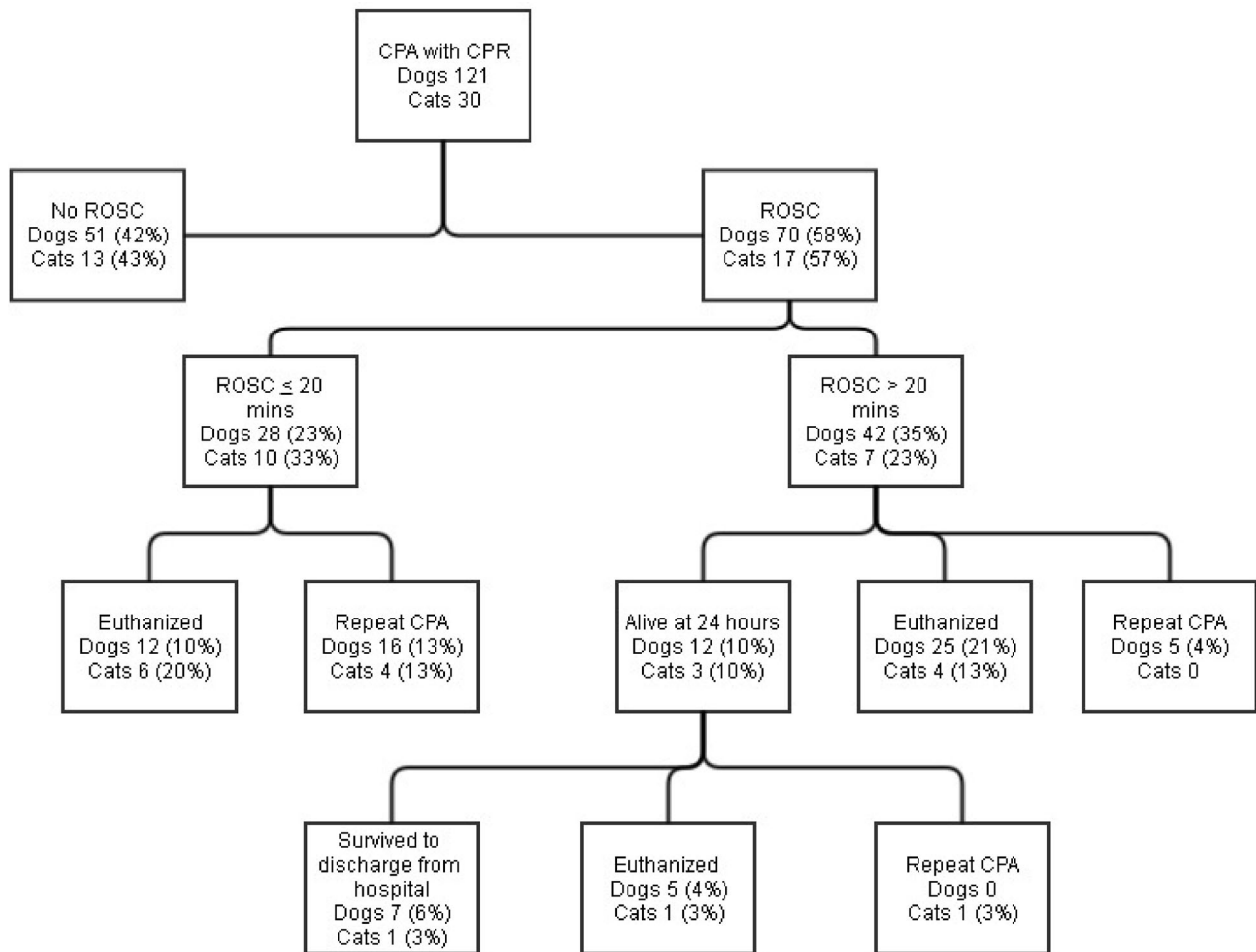


Figure 1: Outcome data for dogs and cats that experienced cardiopulmonary arrest and had cardiopulmonary resuscitation performed. (N,%) CPA, cardiopulmonary arrest; ROSC, return of spontaneous circulation.

The median (range) from CPA to the start of CPR in dogs with ROSC was 0.5 minutes (0.08–10 min) and 1 minute (0.08–30 min) without ROSC ($P = 0.008$). Time between CPA and initiation of CPR was not statistically significantly associated with ROSC when cats were considered separately ($P = 0.68$).

The median duration (range) of CPR in all patients with ROSC was 5 minutes (0.5–40 min) compared to 13 minutes (2–40 min) in patients without ROSC ($P < 0.001$) (Figure 2). In dogs, the median duration (range) of CPR with ROSC was 5 minutes (0.4–40 min), without ROSC, it was 12 minutes (2–30 min). Duration of CPR of dogs with ROSC ≤ 20 minutes was 5 minutes (1–40 min) and a survived event was also 5 minutes (0.5–20 min). Achieving ROSC in dogs was associated with shorter median duration of CPR ($P < 0.001$) with both ROSC ≤ 20 minutes and a survived event being associated with shorter median duration of CPR in post-hoc testing

($P < 0.05$). The median duration (range) of CPR in cats with ROSC was 7 minutes (0.5–30 min) and 15 minutes (5–40 min) without ROSC ($P = 0.002$). The median duration of CPR in all animals that survived to discharge was 3 minutes (0.5–15 min).

The median (range) ventilation rate in patients with ROSC was 12/min (6–60/min) compared to 12/min (5–60/min) in patients without ROSC (Figure 2). This was not statistically significant in dogs and cats ($P = 0.89$), in dogs alone ($P = 0.89$), or cats alone (0.74). There was also no statistically significant difference between animals with or without ROSC if their intubation was recorded as easy or difficult ($P = 0.18$) or if they were already intubated ($P = 0.79$). The median (range) rate of chest compressions in patients with ROSC was 100/min (65–230/min) compared to 105/min (70–160/min) in patients without ROSC (Figure 2). This was not statistically significant in dogs and cats ($P = 0.99$), dogs alone ($P = 0.95$), or cats alone ($P = 0.95$).

Table 2: Causes of cardiopulmonary arrest and rates of ROSC in dogs and cats

Cause	Dogs (n)			Cats (n)		
	No ROSC	All ROSC	ROSC > 20 min	No ROSC	All ROSC	ROSC > 20 min
Cardiovascular (n = 51, 34%)	15	30	16	4	2	1
Blood (n = 26, 51%)	8	15	6	2	1	1
Heart (n = 11, 22%)	3	7	5	1	0	0
Vascular (n = 9, 18%)	2	5	3	1	1	0
Pericardial (n = 5, 10%)	2	3	2	0	0	0
Respiratory (n = 27, 18%)	8	13	9	1	5	1
Pulmonary parenchymal (n = 16, 59%)	5	9	6	1	1	0
Upper airway obstruction (n = 11, 41%)	3	4	3	0	4	1
Neurologic (n = 21, 14%)	13	6*	5	1	1	0
Severe systemic disease (n = 14, 9%)	3	9	3	1	1	0
Anesthesia-related (n = 10, 7%)	4	3	3	1	2	2
Complex (n = 7, 70%)	4	1	1	0	2	2
Simple (n = 3, 30%)	0	2	2	1	0	0
Multiple trauma (n = 6, 4%)	3	1	0	1	1	0
Multiple cause (n = 5, 3%)	1	2	2	1	1	1
Vagal (n = 2, 1%)	0	2	1	0	0	0
Metabolic/electrolyte (n = 5, 3%)	0	2	1	1	2	2
Unknown (n = 9, 6%)	3	2	2	2	2	0
Total	50	70	42	13	17	7

CPA, cardiopulmonary arrest; ROSC, return of spontaneous circulation; min, minutes.

*Designates groups that are different than the no ROSC group ($P = 0.02$).

Palpable femoral pulses were present during chest compressions in 68% of dogs and 75% of cats. Palpable pulses were evident during chest compressions more often in dogs and cats that attained ROSC compared to those that did not (82% versus 54%) ($P = 0.0007$), as well as when comparing dogs that had ROSC to those that did not (81% versus 53%) ($P = 0.002$). Dogs that had a “survived event” were more likely to have palpable pulses during CPR than dogs that did not have a “survived event” (82% versus 62%) ($P = 0.04$). There was no significant association of palpable pulses during CPR and ROSC or a “survived event” in cats.

Most animals received epinephrine during CPR (93% of dogs and 100% of cats). The median (range) total dose of epinephrine was 0.02 mg/kg (0.003–0.33 mg/kg) and the median (range) number of epinephrine doses was 2 per patient (0–13). Only 23 (19%) dogs and 3 (10%) cats received vasopressin. No animals received vasopressin without concurrent administration of epinephrine. The median (range) total dose of vasopressin was 0.5 units/kg (0.1–0.8 units/kg) and the median (range) number of doses of vasopressin if given was 1 (1–2). Most animals received atropine during CPR (89% of dogs and 93% of cats).

Vascular access was present in 108 patients at the time of CPA. Of the 43 patients that had no vascular access, a peripheral IV catheter was placed in 32 patients, intraosseous (IO) catheters were placed in 16 patients, 5 patients received both an IO and IV catheter during

CPR, and no vascular access was able to be obtained in 2 patients (1 with no ROSC, 1 with ROSC \leq 20 min). The presence of an IV catheter at the time of cardiac arrest was not associated with ROSC (77% versus 64%) ($P = 0.20$) but was significantly associated with a “survived event” in all patients (85% versus 65%) ($P = 0.01$). The odds (95% CI) of a “survived event” were 3.1 times greater (1.3–7.7) if an IV catheter was in place at the time of CPA. There was no significant difference in presence of an IV catheter at the time of cardiac arrest comparing a “survived event” and no ROSC when looking at dogs (81% versus 68%) ($P = 0.20$) or cats alone; however, there was a trend toward significance in cats (100% versus 57%) ($P = 0.06$).

The first identified arrest rhythm, available in 91 dogs and 24 cats, was asystole in 34% of dogs and 54% of cats, PEA in 39% of dogs and 46% of cats, ventricular fibrillation in 15% of dogs, pulseless ventricular tachycardia in 3% of dogs, 3rd degree AV block in 3% of dogs, sinus bradycardia in 6% of dogs. Ventricular fibrillation occurred in 34% of dogs and 21% of cats at any time during CPA (either as the first arrest rhythm or developed later in CPR). A total of 24 patients (19 dogs, 5 cats) were defibrillated. Defibrillation was successful in 15 (63%) cases, 4 (27%) to a perfusing rhythm and 11 (73%) to a nonperfusing rhythm. During defibrillation in one patient the ECG leads detached. The resulting rhythm was unknown, but it was unlikely to be a perfusing rhythm as no pulses were reportedly palpable. Ventricular

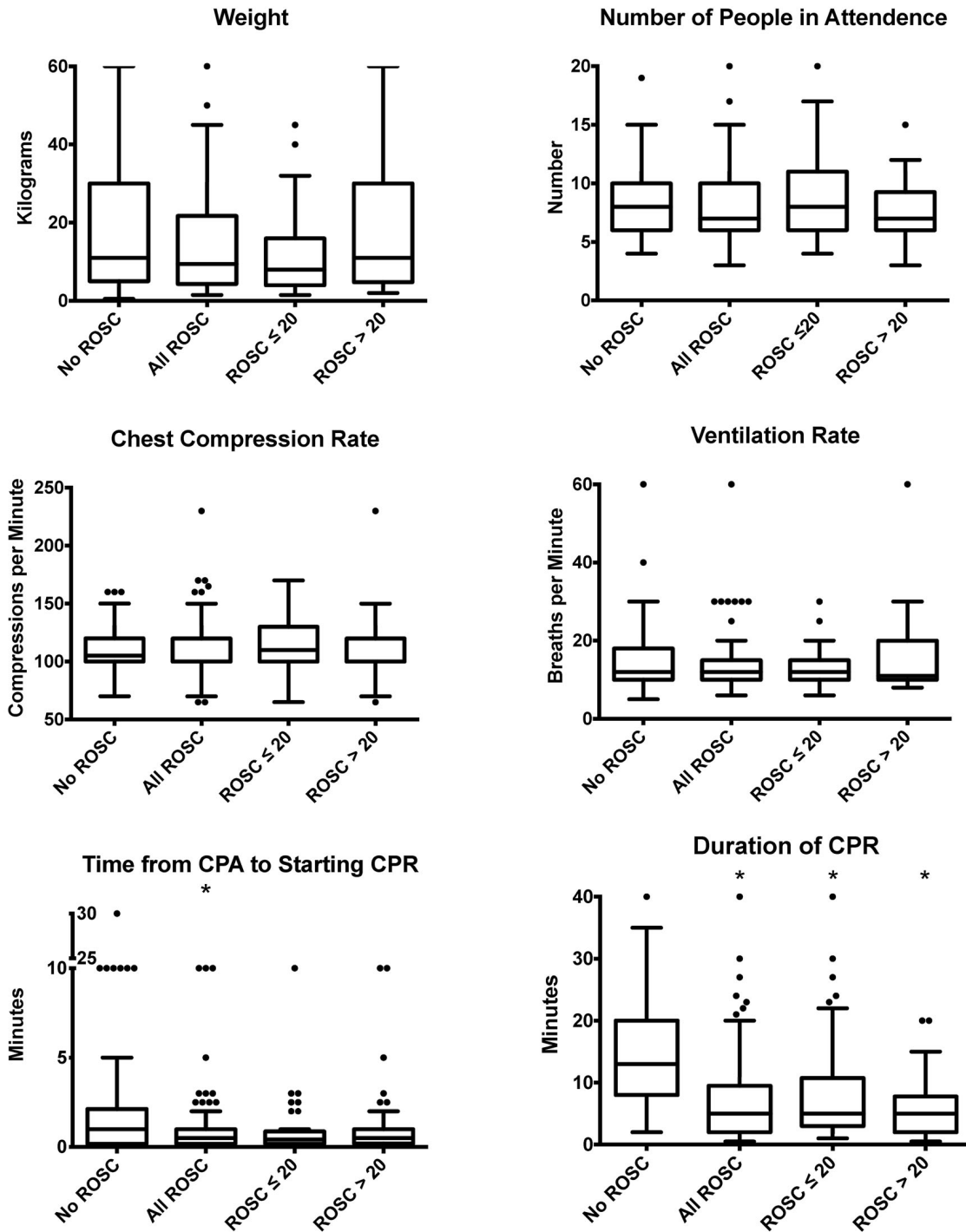


Figure 2: Box and whisker plots representing continuous data from both dogs and cats. The box represents the 25th and 75th quartile with the horizontal line at the median. The whiskers represent the range of data. Outliers as determined by 1.5 times the interquartile range above the 75th or below the 25th quartile are represented by dots. *Designates groups that are different than the no ROSC group. ROSC, return of spontaneous circulation.

fibrillation or pulseless ventricular tachycardia (shockable rhythms) versus other arrest rhythms as the first identified rhythm did not have a statistically significant association with ROSC ($P = 0.20$).

The supervising clinician considered open chest CPR indicated in 20 patients, of which it was performed in 9 patients. Reasons cited as indications for open chest CPR included size or body condition of the animal (4), pericardial effusion (2), ineffective (unable to generate palpable femoral pulses with chest compressions) closed chest compressions (4), rib fractures (1), pleural effusion (1), tension pneumothorax (1), recent cardiac surgery (1), anesthetized animal with an open abdomen (1), owner request (1), and reason not stated (2). Of the 11 patients in which open chest CPR was considered but not performed, 3 patients obtained ROSC. Of the 9 patients in which open chest CPR was performed, 4 had a "survived event," including one that was discharged from the hospital.

A total of 55 complications were reported in 47 patients, some patients having more than one complication. Difficult or no intubation (23), delay in obtaining IV access (8), difficulty ventilating (hemorrhage in Bain circuit) (8), the endotracheal tube accidentally dislodging (4), IO catheter displacement (2), fractured ribs (2), cut into rib during open chest (1), 1:10,000 epinephrine instead of 1:1,000 given, resulting in under dosing (1), alcohol on the ECG leads when defibrillation was necessary (1), obese patient making pulses difficult to palpate (1), polypropylene catheter lost down ETT (1), too few people present (1), ECG leads detaching (1), IO catheter not working (1).

Of the 62 animals that had a necropsy performed, 21 (34%) had gross and histological findings (10 had more than one finding) considered secondary to CPR including myocardial hemorrhage (11), liver fractures (4), hemothorax (1), hemomediastinum (1), hemopericardium (3), hemoabdomen (3), pulmonary hemorrhage (7), intercostal hemorrhage (1), pleural hemorrhage (2), and myocardial edema (1).

Discussion

In this study, 58% of dogs and 57% of cats achieved ROSC compared to previous veterinary studies that have reported ROSC rates in dogs of 28–60% and cats of 42–44%.^{4,5,15,16} The ROSC rates in this study are similar to other recent veterinary CPR reports and higher than those reported by earlier veterinary CPR studies. This may reflect improvement in CPR understanding and technique or factors such as patient selection. Animals that are given a resuscitation code versus those already made a "do not resuscitate" certainly introduce bias in a CPR study. The rate of ROSC in this study

is similar to the 54% reported in a human study of in-hospital cardiac arrest.¹⁷ Although having a high rate of ROSC is encouraging, only 35% of dogs and 23% of cats had a "survived event" compared to 48–54% for human in-hospital cardiac arrest.^{18–20} One previous veterinary study by Buckley *et al*⁵ reported a similar "survived event" rate of 32% for dogs.⁵ Few patients had long-term survival following CPR, with 10% of dogs and 10% of cats alive at 24 hours and 6% of dogs and 3% of cats surviving to hospital discharge. These survival rates are similar to those previously reported in veterinary studies with survival to discharge rates for dogs of 1.6–16% and cats 2.3–16%.^{4,5,15} Not surprisingly, these rates are lower than human survival rates from in-hospital CPR, with reported survival to 24 hours ranging from 30–39% and survival to discharge from 7–24%.^{20–22} It is important to remember that veterinary studies include both in and out-of-hospital CPA and this limits direct comparison with studies of in-hospital cardiac arrest in people.

Management of CPA does not end with ROSC. Many of these patients continue to be unstable and are prone to additional episodes of CPA. Wingfield *et al*¹⁵ reported rearrest in 68% of dogs and 37.5% of cats and Kass *et al*¹⁶ reported rearrest in 61% of dogs.^{15,16} Of the 58% of patients that achieved ROSC in the current study, 30% rearrested while 60% were euthanized. Animals are more likely to be euthanized > 20 minutes after ROSC rather than having a second episode of CPA. If these animals had not been euthanized it is unknown what their outcome would have been. Further studies evaluating the postarrest period are needed to better determine this.

It is generally accepted that patients with CPA due to a reversible precipitating state will have a greater chance of successful CPR compared to patients with advanced states of disease. Anesthesia related CPA has been previously reported in veterinary medicine to be associated with increased survival compared to other causes of CPA for reasons such as having reversible abnormalities (eg, anesthetic overdose) as well as anesthetized animals likely having more instrumentation and monitoring than many other hospitalized patients.^{4,6,15,23} In addition to epinephrine and atropine, clinicians should be aware if their patient could benefit from a reversal agent if CPA occurs during sedation or anesthesia.

In the current study, patients with simple anesthetic procedures that have CPA appeared to have a better chance of a survived event and survival to discharge as previous studies have reported. It should be noted that 29% of dogs and the one cat that survived to discharge had a simple anesthetic classification as the cause of their arrest and, given the low numbers of survival to discharge, statistical analysis was precluded. However, in this study when all patients with CPA associated with anesthesia were considered, there was no statistical

association with increased ROSC rates. This is attributed to the severity of disease of most of the patients in this group. The likelihood of successful CPR in a critically ill, anesthetized ventilator patient seems far less than that of a healthy animal being anesthetized for an elective procedure.

Cardiopulmonary arrest in patients with neurologic disease was associated with a lower likelihood of ROSC compared to all other precipitating causes in this study. Neurologic disease as a cause of CPA represents a very small portion of human CPR patients (2% in one study) so there is limited comparative information available.²⁴ The ROSC rates of people with subarachnoid hemorrhage are high (71–100%) although the survival from CPR in these patients is variable (0–27%).²⁴ The reason for poor ROSC rates in animals with neurologic disease in this study is unclear and may be an interesting area for future evaluation.

There was no significant association between patient weight and ROSC in this study, which agrees with an earlier veterinary study.¹⁵ This was true when considering all patients as well as cats and dogs alone. Pulse generating chest compressions, however, were significantly associated with ROSC when compared to non-pulse generating compressions. This suggests there may be value in femoral pulse palpation as a mechanism for monitoring CPR effectiveness, especially in the absence of a capnograph. The difference in groups noted for dogs and cats was due to the difference found in dogs only, which had much higher numbers of patients available for analysis. Generation of pulses with chest compressions seems more likely in smaller patients who tend to have compliant chest walls and a greater likelihood of effective utilization of the cardiac pump mechanism for blood flow during CPR. In cats, 75% of the patients did indeed have a palpable femoral pulse with chest compressions. The small number of cats and heterogeneity of the underlying disease processes made finding a potential difference in cats challenging. End tidal CO₂ was used uncommonly during CPR at our institution during the period of this study. It would have been ideal to have end tidal CO₂ monitoring to better evaluate the effectiveness of chest compressions and to correlate with the presence or absence of palpable femoral pulses.²⁶

Hofmeister et al⁴ found an association between ROSC and lateral recumbency.⁴ It is estimated that most if not all CPR described in the present study was performed with patients in lateral recumbency, but as this was not recorded prospectively on the data sheets this information could not be analyzed further.

In this study, having an Emergency and Critical Care faculty or resident present for CPR was not associated with an increased likelihood for ROSC versus not obtaining ROSC. Although this is consistent with RECOVER

guidelines, this result was still somewhat surprising as it would be thought that ECC faculty and residents would provide high quality rescue efforts.¹ As ECC faculty and residents primarily perform CPR during weekdays these findings may reflect a difference in the after hours patient population at our institution. There is no consensus in veterinary medicine on optimal team size for CPR.¹ The median number of people in the room in this study was the same for animals that did and did not achieve ROSC. It is clear that a minimum number of people are required to perform adequate CPR and there may be an optimal number of people required. It is possible that the number of people present for CPR in this study was greater than the optimal number most of the time, hence any impact on outcome could not be identified. Additionally, the complication of insufficient people to perform CPR was infrequently reported as a concern on the data sheets.

The greater rate of ROSC in patients that experienced CPA between the hours of 7 PM and 7 AM was surprising and does not reflect the results of previous human studies.^{27–30} Investigators have documented lower survival from adult in-hospital cardiac arrest on nights and weekends, likely due to delays in vasoconstrictor administration, defibrillation, airway management, and chest compression performance errors.³⁰ This finding may reflect a difference in the nature of patients experiencing CPA overnight compared to during the day at our hospital. In general, more critical and complex cases arrive and have procedures performed during the day and more simple primary emergency cases are received after hours. An index of disease severity such as the APPLE score would have been ideal in order to compare these two patient populations if there had been sufficient data to perform statistical analysis.

A successful outcome from CPR depends on the prompt initiation of rescue efforts.^{31–33} The median time from identification of CPA to CPR was significantly less in dogs (but not cats) that had ROSC compared to those that didn't. In addition, the presence of an IV catheter at the time of cardiac arrest was statistically significantly associated with a survived event in all animals. True cause and effect for these results cannot be determined. A patient having an IV catheter at the time of arrest may have led to earlier drug and/or fluid administration but this could not be verified in this study. Alternatively, it may have allowed rescuers to concentrate on other aspects of advanced life support, not losing valuable time on obtaining IV access. Being intubated at the time of CPA or the ease of intubation was not associated with an increased rate of ROSC. Given the small size of this study and the relatively low incidence of difficulty in intubation (16%), the impact of delayed intubation may have been too small to detect. There is a growing

emphasis on chest compressions in CPR guidelines but ventilation is still considered an essential aspect of CPR, especially in patients with hypoxemia as a cause of arrest.^{34,35} The results of this study should not be considered evidence for delaying intubation and ventilation during CPR.

The median duration of CPR in patients with ROSC was significantly less than those without ROSC, suggesting that prolonged CPR in the small animal patient has a guarded prognosis for success compared to those patients that rapidly respond. There have been similar findings in human medicine where patients with a shorter duration of CPR survived longer.^{27,36,37} It should be noted that the longest duration of CPR was 40 minutes in both the group without ROSC and the group with ROSC. This may suggest that an arbitrary time at which CPR should be discontinued is not going to be clinically applicable and that clinical judgment considering factors such as the cause of CPA and the effectiveness of CPR may be the best approach.

The median ventilation and chest compression rates were not significantly different between patients with and without ROSC. The median respiratory rate (12 with ROSC, 12 without) and chest compression rate (100 with ROSC, 105 without) both fall into the recommended range in the RECOVER guidelines, although the range was large and may reflect inadequate CPR training during this study period that occurred prior to publication of the RECOVER guidelines. These variations could have impacted the outcome of CPR in this study. It is recognized that high ventilation rates can negatively impact cardiovascular performance during CPR.³⁸ Experimental animal studies have reported that higher chest compression rates are associated with better blood flow to the myocardium and so lower compression rates are likely to reduce the likelihood of ROSC.³⁹

Pulseless electrical activity and asystole were the most common first documented arrest rhythms identified in this study, occurring in 38% and 40% of all cases, respectively. This was similar to the 48% of dogs and cats in a previous study that had asystole as the first documented rhythm, but our rate of PEA was greater (38% versus 12%).⁴ Ventricular fibrillation was the first documented arrest rhythm in 15% of all cases and ventricular tachycardia occurred in 3%. Our rate of ventricular fibrillation was similar to a previous study (15% versus 17%), but our rate of PEA was greater (38% versus 11%) and asystole was lower (40% versus 72%).⁶ This is similar to the occurrence in adult human in-hospital CPA, where asystole occurs in 39%, PEA occurs in 37%, ventricular fibrillation in 17%, and ventricular tachycardia in 7% of patients as the first identified rhythm.¹⁹ Human patients, with a first witnessed arrest rhythm of ventricular fibrillation or pulseless ventricular tachycardia, have

a better survival than first witnessed arrest rhythms of asystole or PEA.¹⁹ In this study there was no difference in outcome between the first witnessed arrest rhythm being shockable or nonshockable, although given the small number of patients that were defibrillated this may not be an accurate reflection of the relationship between rhythm and outcome. Defibrillation was considered successful in 63% of cases (ie, conversion to any rhythm), but only 27% changed to a perfusing rhythm. In contrast, 64% of people with in-hospital cardiac arrest where the first documented rhythm was shockable had a "survived event."¹⁹ One potential reason for this difference is that some of our patients developed a shockable rhythm later in CPR.

Open chest CPR was performed in very few cases (6%) in this study, which is slightly less than previous veterinary reports of 11–13%.^{5,6} In several cases open chest CPR was considered indicated but not performed; the reasons for this were not recorded but it is likely that owner request, cost, and the clinical consequences of open chest CPR may have influenced the decision. It is interesting to note that in a few cases where open chest CPR was considered indicated by the supervising clinician, ROSC occurred with closed chest CPR alone. This suggests that high quality closed chest CPR should be emphasized in all patients, even when clinicians perceive it unlikely to be successful.

The incidence and nature of complications occurring during veterinary CPR have not been previously reported. In this study, complications were recorded in 31% of CPR events. This number may underestimate the true complication rate during CPR as reporting complications required clinicians to write specific issues on the data collection form, something that may have been overlooked during busy periods, while some reported complications such as obesity making pulse palpation difficult may not be considered complications of CPR by some. Most complications reported could be attributed to mistakes made due to haste, issues including not tying in the endotracheal tube appropriately and drawing up the incorrect epinephrine concentration. Some of these complications may be minimized with improved team training.

Of the patients submitted for necropsy (this did not include any patients that had trauma as cause for arrest), 34% had gross and histological findings considered secondary to CPR and could have contributed to patient morbidity and mortality in the postarrest period if ROSC was achieved. Rib fractures, sternal fracture, pulmonary contusions, hemothorax, pneumothorax, and pneumomediastinum have all been reported in human CPR patients with a similar incidence of CPR related injury as identified in this study.^{40,41} In a prospective computed tomography study of adult humans, rib fractures were

the most common injury, occurring in 31% of patients evaluated while pulmonary and/or pleural space disease was evident in 11% of patients.⁴¹

Although this was a prospective study, it has limitations because of the inherent challenges to studying CPR. Many animals arrived DOA or arrested shortly after arrival to the hospital so there are limited medical data on them in the prearrest period while the time from CPA to initiation of CPR had to be estimated in unwitnessed arrests. In-hospital patients had diagnostics performed at variable time points during their hospitalization period, often several days before CPA. Hence, very few medical records contained all the relevant data required to calculate APPLE scores for the 24-hour period immediately preceding the arrest. The number of patients enrolled and variability of interventions during and after CPR limits our ability to identify factors associated with ROSC and outcome. A future prospective study of CPR performed according to specific guidelines would be ideal. Euthanasia further impacts the assessment of outcome as it is unknown how many patients would have survived if post-CPR care was provided to all animals that attained ROSC.

Conclusions

Overall, ROSC rates in this study were similar to or increased compared to previous human and veterinary studies, but a “survived event” and survival to discharge was still lower than published outcomes in human patients. Delay from recognition of CPA and initiation of CPR is likely to reduce the success of CPR and efforts to reduce these delays could be beneficial. Regularly scheduled training of personnel for CPR may improve the recognition of CPA, speed of initiation of CPR and reduce preventable mistakes occurring during resuscitation and should be prioritized in Emergency and Critical Care facilities. Effective CPR technique is important for CPR success and further emphasizes the need for appropriate and ongoing CPR training. The most common cause of death in postarrest patients was euthanasia after ROSC. It is hoped that the improved ROSC rates being achieved in veterinary patients will eventually lead to improved survival rates with further advances in understanding and performance of veterinary CPR.

Footnote

^a Prism 6.0, Graph Pad Software, La Jolla, CA.

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