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Clinical outcome of canine cardiopulmonary resuscitation following the RECOVER clinical guidelines at a Japanese nighttime animal hospital

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ABSTRACT. A set of evidence-based consensus guidelines for cardiopulmonary resuscitation (CPR) in dogs and cats (RECOVER guidelines) was published in 2012. The purpose of this study was to investigate the clinical outcomes of CPR performed according to those guidelines in dogs. A total of 141 dogs with cardiopulmonary arrest (CPA) were identified and underwent CPR between January 2012 and December 2015 at the Sapporo Nighttime Animal Hospital. CPR was performed according to no-consensus traditional veterinary CPR procedures in 68 dogs (TRADITIONAL group), and according to the RECOVER guidelines in 73 dogs (RECOVER group). There was no significant difference in the age, body weight, or time from CPA identification to initiation of CPR between the TRADITIONAL and RECOVER groups (median [range]: 10 [0–16] vs. 11 [0–16] years; 6.6 [1.0–58.6] vs. 5.5 [1.1–30.4] kg; and 0 [0–30] vs. 0 [0–30] min, respectively). In the TRADITIONAL group, 12 dogs (17%) achieved a return of spontaneous circulation (ROSC), but none survived to hospital discharge. However, 32 dogs (43%) in the RECOVER group achieved ROSC, and 4 dogs (5%) were discharged from the hospital. Incorporating the RECOVER guidelines into clinical practice significantly improved the ROSC rate ($P<0.001$). However, the rate of survival to hospital discharge was still low. This may suggest that a superior intensive care unit that provides advanced post-CPA care could benefit veterinary CPR patients.

KEY WORDS: cardiopulmonary resuscitation, CPR, dog, RECOVER guidelines

Cardiopulmonary resuscitation (CPR) is the attempt to achieve the return of spontaneous circulation (ROSC) in patients in cardiopulmonary arrest (CPA) [14]. The incidence and prevalence of CPA in hospitalized and outpatient dogs and cats are unknown. Some reports of CPR in veterinary patients were published between 1992 and 2009 [17, 21, 32, 34, 37]. The prognosis was grave for dogs in CPA, and the rates of ROSC and survival to discharge from the hospital for dogs in CPA in those reports were 13 and 4% [37], 28 and 3% [21] and 35 and 6% [17].

In human medicine, the International Liaison Committee on Resuscitation formulated evidence-based guidelines for CPR after conducting a large-scale survey of the literature. In 1991, recommendations for standardized definitions, known as the "Utstein Style" reporting guidelines, were made in human medicine [7]. An update of these guidelines was published in 2004, and several other Utstein-style reporting guidelines have been published to report specific CPR-related issues [20, 29].

McIntyre *et al.* [26] evaluated the potential factors that influence the outcome of CPR in dogs and cats at a university teaching hospital using the Utstein-style reporting guidelines. They showed a high ROSC rate (58% overall, 35% sustained ROSC >20 min in dogs) and concluded that early CPR intervention was associated with a greater likelihood of ROSC, which emphasized the importance of prompt recognition of the condition and initiation of CPR [26].

Based on a large-scale, systematic literature survey, the "Reassessment Campaign on Veterinary Resuscitation (RECOVER)", evidence-based consensus clinical CPR guidelines for dogs and cats (RECOVER guidelines) [9] were introduced in veterinary practice in June 2012. It is strongly anticipated that the outcome of veterinary CPR may be improved by incorporating the RECOVER guidelines into veterinary practice. However, there has been no study verifying the outcomes of CPR performed according to the RECOVER guidelines. In 2016, Boller *et al.* [3] published Utstein-style reporting guidelines that provided recommendations to report clinical in-hospital CPR events in dogs and cats, and established non-ambiguous operational definitions

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for CPR terminology. The purpose of the present study was to investigate the clinical outcome of CPR performed according to the RECOVER guidelines in dogs. We hypothesized that the clinical outcome of CPR in dogs may be improved by incorporating the RECOVER guidelines.

MATERIALS AND METHODS

CPR cases

We performed a retrospective survey of all dogs that experienced CPA and underwent CPR during a 48-month period between January 2012 and December 2015 at the Sapporo Nighttime Animal Hospital. Dogs that experienced respiratory arrest without cardiac arrest were excluded. A total of 141 dogs in CPA were identified and underwent CPR. Between January 2012 and December 2013, 68 dogs underwent CPR using non-consensus traditional veterinary CPR procedures (TRADITIONAL group). Between January 2014 and December 2015, 73 dogs underwent CPR according to the RECOVER guidelines (RECOVER group).

Diagnostic criteria for CPA, CPR and ROSC

The diagnostic criteria for CPA were the presence of unresponsive mentation, absence of functional respiration (agonal breathing was not included), and lack of detectable pulse or heartbeat [3, 8, 20, 26]. CPR was defined as an attempt to restore spontaneous circulation by performing chest compressions with or without ventilation [3, 26]. As in the Utstein-style registry guidelines [3, 7, 20, 29], only the initial CPA and CPR were included in the analysis if patients went into CPA several times. The ROSC was defined as restoration of a spontaneous perfusing rhythm that resulted in a more than fleeting (>30 sec) palpable pulse [3, 20, 26]. Completion of CPR was defined as either the continuation of ROSC for at least 20 min or discontinuation of CPR without achievement of ROSC. If ROSC was maintained for 20 min between multiple CPR sessions, subsequent CPA was excluded from the record.

CPR procedures

All CPR procedures were performed by at least three rescuers including a supervising clinician. All veterinarians and technicians completed a CPR training program planned by the corresponding author (KY), who had received formal RECOVER-CPR training from Drs. Fletcher and Boller. The training was designed to ensure adherence to the RECOVER guidelines when we incorporated them into clinical practice and twice per year thereafter.

In the TRADITIONAL group, CPR was initiated in ABC order: securing the airway (A), artificial breathing (B), and chest compressions (C). The frequency and duration of artificial ventilation and chest compressions, the administration and dose of emergency drugs, electrical defibrillation attempts, and administration of intravenous fluids were at the discretion of the supervising clinician in each case.

In the RECOVER group, CPR was initiated in CAB order, followed by a 2-min uninterrupted cycle of basic life support (BLS) consisting of chest compressions and artificial respiration [9, 19]. Then, advanced life support (ALS) consisting of electrocardiogram (ECG) and the partial pressure of end-tidal CO_2 monitoring using a patient monitoring system (BIO-SCOPE AM120, Fukuda ME, Chiba, Japan), external electrical defibrillations, and/or administration of emergency drugs were performed with 2-min uninterrupted cycles of BLS until the completion of CPR as defined above [9, 31]. The compressor was rotated after each 2-min BLS cycle [9, 19]. Chest compression was performed at a rate of 100–120 beats/min and artificial ventilation was performed at a rate of 10 breaths/min [9, 19]. Following the first 2-min BLS cycle, chest compression was briefly discontinued (<5 sec) while the ECG was checked [9, 19]. If the ECG showed a shockable rhythm such as ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT), the dog received external electrical defibrillation (4 J/kg) using a monophasic defibrillator (FC-200, Fukuda Denshi, Tokyo, Japan), then the 2-min cycles of BLS were immediately resumed [9, 31]. If defibrillation was unsuccessful, further defibrillation with 50% increased discharge energy was repeated until a non-shockable rhythm was achieved or until ROSC occurred [9, 31]. If the ECG showed asystole or pulseless electrical activity (PEA) after the first 2-min cycle of BLS or defibrillation, BLS was resumed immediately and emergency drugs were administered.

Emergency drugs used in the RECOVER group included 0.01 mg/kg of epinephrine (BOSMIN® INJECTION 1 mg, Daiichi Sankyo, Tokyo, Japan), 0.04 mg/kg of atropine (ATROPINE SULFATE Injection 0.5 mg, Mitsubishi Tanabe Pharma, Osaka, Japan), and 0.8 U/kg of vasopressin (PITRESSIN® INJECTION, Daiichi-Sankyo), which were administered intravenously at 3- to 5-min intervals [9, 31]. If more than 10 min had elapsed since the discovery of CPA, 1.0 mEq/kg of sodium bicarbonate (Sodium Bicarbonate Injection 7%, Nissin Pharmaceutical, Yamagata, Japan) was administered intravenously [9, 31]. Intravenous fluids were administered in cases of hypovolemia [9, 31].

Data collection

The clinician supervising the CPR efforts filled out a CPR record form for each event. Patient variables recorded on the form included whether CPA occurred in-hospital (IHCA) or out-of-hospital (OHCA), the time of CPA identification, time from CPA identification to initiation of CPR (time to CPR), time from initiation of CPR to CPR discontinuation (duration of CPR), changes in ECG rhythm during CPR, position of the dog during CPR, types of drugs administered and their doses and routes, details of defibrillation if performed, and suspected cause of CPA. Outcome variables included the occurrence of ROSC, time from initiation of CPR to attainment of ROSC (time to ROSC), survival to 24 hr, 72 hr, 7 days, and 30 days after ROSC, and survival to discharge from the hospital [3]. The time of CPA of OHCA dogs was inferred from information provided by the owner. The suspected cause

Table 1. Categories of the suspected etiology of cardiopulmonary arrest in dogs

1. Circulatory: heart disease including congestive heart failure
2. Respiratory: dyspnea or abnormal findings on chest radiography with abnormal blood gas oxygenation or ventilatory function
3. Neurological: abnormalities in the central or peripheral nervous system
4. Hemolymphatic: disseminated intravascular coagulation (DIC), coagulopathy, anemia, leukemia, or tumors such as splenic tumors that involve the blood or lymphatic system
5. Digestive: diseases of the liver and digestive tract such as ileus, vomiting, or intestinal resection
6. Multiple organ failure (MOF): the presence of abnormalities in two or more organ systems with systemic inflammation or progressive DIC
7. Other: causes of CPR that are not classified into any of the preceding categories
8. Unknown: cases in which the supervising clinician was unable to reach a provisional diagnosis

Multiple categories were selected if more than one of these classifications applied, but only in cases in which MOF did not develop.

Table 2. Patient and outcome variables of dogs that underwent cardiopulmonary resuscitation (CPR) according to evidence-based veterinary consensus CPR guidelines (RECOVER group) or not (TRADITIONAL group)

	TRADITIONAL group			RECOVER group		
	Overall	IHCA[a)]	OHCA[b)]	Overall	IHCA	OHCA
Number of dogs	68	49	19	73	42	31
Age (years)	10 [0–16]	10.5 [0–16]	9 [1–14]	11 [0–16]	11 [0–15]	11 [3–16]
Body weight (kg)	6.6 [1.0–58.6]	7.5 [1.0–58.6]	4.0 [2–25]	5.5 [1.1–30.4]	6.9 [1.1–30.4]	5.0 [2.0–30.0]
Time to CPR (min)	0 [0–30]	0 [0–3][g)]	10 [5–30]	0 [0–30]	0 [0–3][g)]	16 [5–30]
Duration of CPR (min)	15 [2–52]	15 [2–52]	15 [2–30]	14 [2–45]	10 [2–45][g)]	17 [6–26]
Time to ROSC[c)] (min)	3 [2–10]	5 [2–10]	3 [2–4]	5 [2–20][d)]	5 [2–20][g)]	14 [6–20]
Achievement of ROSC	12 (17%)	10 (20%)	2 (10%)	32 (43%)[e)]	25 (59%)[g)]	7 (22%)
Survival to discharge	0	0	0	4 (5%)	4 (9%)	0

Data are expressed as median [range] or number (percentage) of dogs. a) IHCA: in-hospital cardiac arrest (CPA); b) OHCA: out-of-hospital CPA; c) ROSC: return of spontaneous circulation. Significant difference compared to TRADITIONAL group: d) $P<0.05$, e) $P<0.01$; significant difference compared to OHCA: f) $P<0.05$; g) $P<0.01$.

of CPA was determined based on the CPR record and medical records, and then categorized as cardiac, respiratory, neurological, hemolymphatic, digestive, multiple organ failure (MOF), other, or unknown. Detailed descriptions of the suspected causes of CPA are provided in Table 1.

Statistical analysis

According to the results of the Shapiro-Wilk and Kolmogorov-Smirnov tests for evaluation of normality, continuous data (age, body weight, time to CPR, duration of CPR, time to ROSC, total dose of emergency drugs, total discharge energy, and total dose of emergency drug per 5 min) were analyzed using the Mann-Whitney *U* test. The total dose of emergency drug per 5 min was calculated as follows: total dose per 5 min (mg/kg)=total dose (mg/kg)/ duration of CPR (min) × 5.

Differences between categorical data (administration of emergency drugs, successful defibrillation, ROSC, and survival to hospital discharge) of the RECOVER and TRADITIONAL groups and between IHCA and OHCA patients were analyzed using the χ^2 test. Separate logistic regression models were constructed using ROSC as the dependent variable. To construct each model, categorical variables with *P* values <0.05 according to the χ^2 test were included as independent variables. In each model, the odds ratio (OR) and 95% confidence interval (CI) were calculated to determine the likelihood of ROSC (95% CI >1.00). *P* values <0.05 were considered significant.

RESULTS

The patient and outcome variables are summarized in Table 2. There was no significant difference in patient age, body weight, time to CPR, or duration of CPR between the TRADITIONAL and RECOVER groups. The time to ROSC in the RECOVER group was significantly longer than that in the TRADITIONAL group ($P=0.040$). ROSC was achieved in 12 dogs in the TRADITIONAL group and 32 dogs in the RECOVER group. The overall ROSC rate in the RECOVER group was significantly higher than in the TRADITIONAL group (43% vs. 17%, $P<0.001$). The ROSC rate of IHCA patients was significantly higher than that of OHCA patients in the RECOVER group (59% vs. 22%, $P=0.002$). The incorporation of RECOVER guidelines into CPR was significantly associated with the likelihood of ROSC in our patients (OR, 3.6; 95% CI, 1.7–7.9). In addition, IHCA was significantly associated with the likelihood of ROSC in the RECOVER group (OR, 5.0; 95% CI, 1.8–14.3).

Comparisons of patient and outcome variables between dogs that achieved ROSC (ROSC patients) and dogs that did not (non-ROSC patients) are shown in Table 3. There was no significant difference in patient age or body weight between ROSC and

Table 3. Patient and outcome variables and emergency drugs administered to dogs during cardiopulmonary resuscitation (CPR) according to evidence-based and consensus veterinary CPR guidelines (RECOVER group) or not (TRADITIONAL group)

	TRADITIONAL group			RECOVER group		
	Overall	ROSC[a)]	Non-ROSC[b)]	Overall	ROSC	Non-ROSC
Number of dogs	68	12 (18%)	56	73	32 (44%)	41
Age (years)	10 [0–16]	10 [0–16]	10 [0–15]	11 [0–16]	11 [0–16]	11 [2–14]
Body weight (kg)	6.6 [1.0–58.6]	5.85 [1.0–8.4]	6.6 [1.0–58.6]	5.5 [1.1–30.4]	5.2 [1.6–30.4]	6.8 [1.1–30.0]
Time to CPR (min)	0 [0–30]	0 [0–10]	0 [0–30]	0 [0–30]	0 [0–20][f)]	5 [0–30]
Duration of CPR (min)	15 [2–52]	2 [2–10][f)]	15 [3–52]	14 [2–45]	5 [2–20][f)]	17 [8–45]
Time to ROSC (min)	2 [2–10]	2 [2–10]	-	5 [2–20][c)]	5 [2–20]	-
Emergency drugs administered						
Epinephrine	58	9 (16%)	49	66	25 (38%)	41
Total dose (mg/kg)	0.02 [0.01–0.04]	0.01 [0.01–0.02][f)]	0.02 [0.01–0.04]	0.02 [0.01–0.44]	0.01 [0.01–0.03][f)]	0.03 [0.01–0.44]
Per 5 min (mg/kg)	0.007 [0.003–0.025]	0.02 [0.005–0.025][f)]	0.007 [0.003–0.0125]	0.01 [0.003–0.077][c)]	0.01 [0.005–0.025]	0.01 [0.003–0.077]
Vasopressin	0	0	0	5[c)]	2 (40%)	3
Total dose (U/kg)	-	-	-	0.8	0.8	0.8
Per 5 min (U/kg)	-	-	-	0.27 [0.15–2.0]	2.0 [2.0–2.0]	0.23 [0.15–0.27]
Atropine	58	9 (16%)	49	70[c)]	30 (43%)	40
Total dose (mg/kg)	0.10 [0.05–0.15]	0.05 [0.05–0.10][f)]	0.10 [0.05–0.20]	0.10 [0.05–0.30]	0.05 [0.05–0.15][f)]	0.10 [0.05–0.30]
Per 5 min (mg/kg)	0.03 [0.01–0.125]	0.08 [0.025–0.125][f)]	0.03 [0.014–0.063]	0.05 [0.008–0.125]	0.07 [0.025–0.125][f)]	0.04 [0.008–0.083]
Sodium bicarbonate	0	0	0	28[d)]	6 (21%)	22
Total dose (mEq/kg)	-	-	-	1.0 [1.0–2.0]	1.0 [1.0–2.0]	1.0 [1.0–2.0]
Per 5 min (mEq/kg)	-	-	-	0.36 [0.17–1.00]	0.38 [0.17–0.77]	0.36 [0.17–1.00]
Lidocaine	2	0	2	3	2 (67%)	1
Total dose (mg/kg)	2.0	-	2.0	2.0	2.0	2.0
Per 5 min (mg/kg)	1.0	-	1.0	1.1 [0.8–3.3]	2.2 [1.1–3.3]	0.8
Fluid infusion	58	9 (16%)	49	4[d)]	0	4
Total dose (m*l*/kg)	15.1 [1.8–46.2]	6.8 [2.4–40][e)]	16.0 [1.8–46.2]	16.7 [6.7–20.0]	-	16.7 [6.7–20.0]
Per 5 min (m*l*/kg)	5.0 [0.9–83.3]	11.9 [3.6–83.3][f)]	4.9 [0.9–15.6]	3.6 [1.5–5.6]	-	3.6 [1.5–5.6]
Electrical defibrillation	0	0	0	19[d)]	5 (26%)	14
Total energy (J/kg)	-	-	-	12 [5–36]	11 [5–13]	12 [6–36]

Data are expressed as the number of dogs (ROSC rate) and the median [range]. a) ROSC: return of spontaneous circulation; b) non-ROSC: no return of spontaneous circulation. Significant difference compared to the TRADITIONAL group: c) $P<0.05$; d) $P<0.01$; significant difference compared to the non-ROSC group: e) $P<0.05$, f) $P<0.01$.

non-ROSC patients in each group, or in time to CPR between ROSC and non-ROSC patients the TRADITIONAL group. The time to CPR was significantly shorter in ROSC patients compared to non-ROSC patients in the RECOVER group (P=0.004). The duration of CPR was significantly shorter in ROSC patients compared to non-ROSC patients in each group (RECOVER, $P<0.001$; TRADITIONAL, $P<0.001$).

One dog in the TRADITIONAL group and 3 dogs in the RECOVER group were euthanized after ROSC due to poor prognosis or financial issues. Eleven dogs in the TRADITIONAL group and 22 in the RECOVER group died due to recurrence of CPA within 24 hr after ROSC. In the RECOVER group, 7 dogs survived for 72 hr after ROSC. Survival discharge from the hospital was achieved by 4 IHCA patients in the RECOVER group, and no patient in the TRADITIONAL group. Three dogs with cardiogenic pulmonary edema were discharged from the hospital; discharges occurred on the second day, third day, and fourth day following 4-hr, 7-hr and 31-hr periods of mechanical ventilation, respectively. One dog with cardiac tamponade due to a heart tumor was discharged on the second day following a 2-hr period of mechanical ventilation. The hospital discharge rate in the RECOVER group was not significantly higher than in the TRADITIONAL group, but there was a trend of increased rate of survival to discharge. One dog died due to the recurrence of cardiogenic pulmonary edema 24 hr after discharge. Three dogs survived for an additional 30 days after ROSC.

Emergency drugs administered to the dogs during CPR and the total doses during CPR and per 5 min are summarized in Table 3. In the TRADITIONAL group, the first identified arrest rhythm was asystole in 34 dogs (50%) and PEA in 12 dogs (18%). The other dogs received CPR without ECG diagnosis. Most dogs in the TRADITIONAL group (58 dogs, 85%) received intravenous epinephrine and atropine injections and fluid infusion during CPR. The median (range) total dose of epinephrine and the number of doses were 0.02 (0.01–0.04) mg/kg and 2 (1–4) per patient. The median (range) total dose of atropine and the number of doses were 0.10 (0.05–0.15) mg/kg and 2 (1–3) per patient. The median (range) total dose of fluid infusion was 15.1 (1.8–46.2) m*l*/kg. Two dogs received lidocaine to control ventricular premature contractions.

As mentioned above, ROSC was achieved in 12 dogs in the TRADITIONAL group. The best emergency drug treatment for ROSC was a combination of epinephrine and atropine (67%, 8 dogs of the 12 ROSC patients). ROSC patients received significantly smaller total doses of epinephrine, atropine, and fluid infusion compared to non-ROSC patients ($P<0.001$, $P<0.001$, P=0.047, respectively). However, the ROSC patients received significantly larger total doses per 5 min of epinephrine, atropine,

Table 4. Causes of cardiac arrest (CPA) and rates of return of spontaneous circulation (ROSC) and survival to discharge of dogs that underwent cardiopulmonary resuscitation (CPR) according to evidence-based veterinary consensus CPR guidelines (RECOVER group) or not (TRADITIONAL group)

Cause of CPA	TRADITIONAL group			RECOVER group		
	Non-ROSC[a)]	ROSC[b)]	Survival discharge	Non-ROSC	ROSC	Survival discharge
1. Circulatory	10	4	0	7	11	3
2. Respiratory	3	0	0	3	4	0
3. Neurological	5	2	0	2	4	0
4. Hemolymphatic	2	1	0	10	5	1
5. Digestive	4	0	0	0	2	0
6. MOF[c)]	5	0	0	1	2	0
7. Other reason	5	0	0	5	2	0
8. Unknown	22	5	0	13	2	0

a) non-ROSC: no return of spontaneous circulation; b) ROSC: return of spontaneous circulation; c) MOF: multiple organ failure.

and fluid infusion compared with non-ROSC patients (*P*<0.001, *P*<0.001, *P*=0.006, respectively).

In the RECOVER group, the first identified arrest rhythm was asystole in 50 dogs (69%), PEA in 15 dogs (21%), and VF in 8 dogs (11%). VF also developed later during CPR in 11 dogs. A total of 19 dogs received electrical defibrillation, and defibrillation was successful in 13 (68%). The successfully defibrillated dogs received significantly lower total energy compared to the dogs that were not successfully defibrillated (median total energy, 9 vs. 17 J/kg; *P*=0.014). ROSC was achieved in 5 of the 19 dogs (26%), but no patient receiving electrical defibrillation survived to discharge.

Most dogs in the RECOVER group received intravenous injections of epinephrine (66 dogs, 90%) and atropine (70 dogs, 96%) during ALS. The median (range) total dose of epinephrine and the number of doses was 0.02 (0.01–0.44) mg/kg and 2 (1–5) per patient. The median (range) total dose of atropine and the number of doses was 0.10 (0.05–0.15) mg/kg and 2 (1–3) per patient. Five dogs (7%) received a single intravenous injection of vasopressin (0.8 U/kg). Twenty-eight dogs (38%) received sodium bicarbonate therapy during CPR. Three dogs received lidocaine to control ventricular premature contractions after ROSC. As mentioned above, ROSC was achieved in 32 dogs in the RECOVER group.

The most promising emergency drug treatment to achieve ROSC was a combination of epinephrine and atropine (78%, 25 of the 32 ROSC patients); the second most promising was a combination of epinephrine, atropine, and sodium bicarbonate (19%, 6 of the 32 ROSC patients). ROSC patients received significantly smaller total doses of epinephrine (*P*<0.001) and atropine (*P*<0.001) compared to non-ROSC patients. However, there was no significant difference in the total dose per 5 min of epinephrine between ROSC and non-ROSC patients, while the total dose per 5 min of atropine was significantly larger in ROSC patients (*P*<0.001). In addition, the overall total dose per 5 min of epinephrine was significantly larger in the RECOVER group compared to the TRADITIONAL group (*P*=0.015).

Causes of CPA in the RECOVER and TRADITIONAL groups are summarized in Table 4. No dog experienced CPA in the peri-anesthetic period. Cardiac causes were the most common reasons for CPA in both groups. The ROSC rate and rate of survival to hospital discharge in dogs with cardiac causes were 36% (5 of 14 dogs) and 0% (0 dogs) in the TRADITIONAL group and 61% (11 of 18 dogs) and 17% (3 of 18 dogs) in the RECOVER group, respectively. There was no significant difference in these rates between the TRADITIONAL and RECOVER groups. Other causes were not investigated due to an insufficient number of cases.

DISCUSSION

Our results showed that the incorporation of the RECOVER guidelines into clinical practice significantly improved the ROSC rate in CPA dogs. The overall ROSC rate in the present study was higher than those in previous canine studies [17, 21, 37] and equal to those in studies using evidence-based consensus clinical CPR guidelines for human patients [10, 16, 26, 27, 30, 36]. Training with the RECOVER guidelines seemed to result in better adherence to the 2-min uninterrupted cycle of BLS with compressor rotation and to administration of recommended doses of emergency drugs, particularly epinephrine. Epinephrine was administered according to the guidelines in the RECOVER group, but not in the TRADITIONAL group. However, the survival discharge rate was still low (5%), which was similar to previous canine studies [17, 21, 26, 37]. This may suggest that a superior intensive care unit providing advanced post-CPA care could benefit veterinary CPR patients.

Delay of the recognition of CPA and initiation of CPR are likely to reduce the success of CPR, and efforts to reduce these delays could be beneficial [8, 9, 19, 26]. Early intervention with an effective CPR technique is emphasized for successful veterinary CPR [9, 19, 25]. The incorporation of the RECOVER guidelines into our clinical practice considerably improved the ROSC rate. This improvement might be caused by an effective CPR technique rather than early intervention, because the time to CPR was not different between the TRADITIONAL and RECOVER groups. Furthermore, the time to ROSC was longer in the RECOVER group. The performance of chest compressions is strenuous and results in rescuer fatigue. Several mannequin-based human studies have demonstrated that the quality of chest compressions decreases within the first 1 to 3 min of CPR [1, 2, 5, 12, 15, 28]. The 2-min uninterrupted cycle of BLS with compressor rotation might enable administration of effective chest compressions, and may have resulted in the high ROSC rate of the dogs in the RECOVER group.

The ABC order of CPR initiation has been the recommended approach to victims of cardiac arrest for decades in both human and veterinary medicine [14, 16, 21, 37]. However, human studies have shown that delayed initiation of chest compressions due to prolonged intubation times has a potential negative impact on ROSC [6, 13, 35]. The American Heart Association 2010 guidelines justified the change from the ABC to the CAB approach with the statement "While no published human or animal evidence demonstrates that starting CPR with 30 compressions rather than 2 ventilations leads to improved outcomes, it is clear that blood flow depends on chest compressions" [8]. The RECOVER guidelines also endorse the CAB approach when multiple rescuers are available, while the ABC approach is recommended when only 1 rescuer is present. Recently, a human patient simulator was used to demonstrate that the CAB approach is easier to perform correctly and in a timely fashion than the ABC approach [25]. There is no direct evidence comparing the efficacy of the CAB and ABC approaches in veterinary patients. In the present study, a higher ROSC rate was achieved in dogs using the CAB approach.

In previous veterinary CPR studies, asystole/PEA was the most common arrest rhythm identified in CPA dogs [17, 26, 32]. In the present study, asystole/PEA was also observed in most of the dogs (asystole, 69%; PEA, 21%) in the RECOVER group. According to the RECOVER guidelines, epinephrine, vasopressin, and atropine are the emergency drugs recommended for the treatment of asystole/PEA in dogs and cats [9, 31]. As only 25–30% of normal cardiac output is achieved with even high-quality external chest compressions, the generation of adequate coronary and cerebral perfusion pressures during CPR requires high peripheral vascular resistance [9, 31]. Therefore, vasopressors such as epinephrine and vasopressin are an essential component of ALS drug therapy [9, 17, 26, 31]. Vagolytic therapy with atropine has been proposed to counteract the high vagal tone that may result in bradycardia or sinus arrest in dogs [17, 34]. Several experimental studies in dogs have documented improved survival with bicarbonate therapy with prolonged (>10 min) duration of CPA [23, 33]. One study suggested an association between vasopressin administration and successful resuscitation in dogs [17], but no advantage of vasopressin over epinephrine has been indicated [4]. Furthermore, vasopressin has been deleted from the descriptions of drug therapy during ALS in the most recent human CPR guidelines [11]. In the present study, ROSC was achieved using epinephrine, atropine, and vasopressin in 21–43% of dogs. Vasopressin may be an indirectly validated emergency drug for ALS in dogs, in addition to epinephrine and atropine.

A shockable rhythm was the first identified arrest rhythm in 8% [17] and 18% [26] of CPA dogs. A similar population of VF (11%) was the first identified arrest rhythm in the dogs in the RECOVER group. In the present study, VF was successfully defibrillated in 68% and ROSC was achieved in 26% of the dogs, similar to a previous veterinary CPR study [26]. In human medicine, the rate of survival to hospital discharge is higher in CPA patients in whom VF/VT is identified as the first arrest rhythm (37%) than those with asystole/PEA (11–12%) [27]. However, the overall rate of survival to hospital discharge was very low in our patients, which is similar to previous veterinary CPR studies [17, 21, 26, 37]. In the present study, our patients were defibrillated using a monophasic defibrillator, and greater total energy than the recommended single energy (4–6 J/kg) in the RECOVER guidelines was discharged [9, 31]. Dogs defibrillated with a biphasic defibrillator required lower doses and achieved ROSC more rapidly compared to a monophasic defibrillator [22]. Greater discharged energy caused more damage to the heart muscles. The biphasic defibrillator may improve the outcomes of defibrillation and CPR in dogs.

The ROSC rate for IHCA patients was significantly higher than that for OHCA patients in the RECOVER group, and survival to hospital discharge was achieved in 4 IHCA patients in the RECOVER group. The duration of CPR was shorter in ROSC patients compared to non-ROSC patients in both the RECOVER and TRADITIONAL groups. Furthermore, the ROSC patients received significantly smaller total doses of epinephrine and atropine compared to non-ROSC patients in both groups. These results are similar to the results of previous veterinary CPR studies [17, 26]. As mentioned above, no OHCA patient survived until discharge in the present study. This is in contrast to the discharge rate of 8% for human OHCA patients [24]. CPR of human OHCA patients may be initiated in an ambulance during transport, whereas CPR is not often provided during transport for veterinary OHCA patients. Bystander-initiated CPR is also an important component of the success rate for human OHCA patients, although the success rate is significantly lower than the success rate of human IHCA patients [18]. It is expected that an expansion of veterinary CPR education to more pet owners may result in increased attempts to use CPR in OHCA patients and improve the outcome of CPR in dogs and cats.

However, ROSC is not a goal of treatment, and CPR becomes meaningful when the patient survives until discharge from the hospital. Hofmeister *et al.* [17] reported that the survival discharge rate was dramatically higher for dogs that were anesthetized at the time of CPA (6/12 dogs, 50%) compared to dogs that were not (9/161 dogs, 6%). With the exception of patients that were anesthetized at the time of CPA [17], the survival discharge rates of veterinary CPR patients in the present study and previous studies [17, 21, 26, 37] are not satisfactory compared to those of human CPR patients. Patients with chronic, non-reversible diseases are unlikely to survive to discharge. Evaluation of the cause of the arrest and identification of patients with better prognoses may be critical. Furthermore, a rigorous implementation of post-PCA care considering the optimization of cardiorespiratory functions and neuroprotection is indispensable to improve the survival discharge rate for veterinary CPR patients.

In conclusion, the outcome of canine CPR patients, and ROSC in particular, could be improved by the incorporation of the RECOVER guidelines into veterinary practice. Training in the RECOVER guidelines seemed to result in better adherence to the 2-min uninterrupted cycle of BLS with compressor rotation and to administration of the recommended doses of emergency drugs. However, the rate of survival to hospital discharge remains low compared to that of human CPR patients. This may suggest that a superior intensive care unit providing advanced post-CPA care could benefit veterinary CPR patients, as could the selection of patients with acute and reversible disease.

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