Differences in the clinical practice of small animal CPR before and after the release of the RECOVER guidelines: results from two electronic surveys (2008 and 2017) in the United States and Canada

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Abbreviations

ALS advanced life support

BCS board-certified specialists

BLS basic life support

CI confidence interval

CPA cardiopulmonary arrest

ECC emergency and critical care

GPE general practitioners in emergency clinics

RECOVER Reassessment Campaign on Veterinary Resuscitation

Abstract

Objective: To assess whether the clinical approach to CPR has changed following the publication of the Reassessment Campaign on Veterinary Resuscitation (RECOVER) guidelines in 2012.

Design: Internet-based survey.

Setting: Academia and referral practice.

Subjects: Four hundred and ninety-one small animal veterinarians in clinical practice in the United States and Canada.

Interventions: An internet-based survey assessing the clinical approach to small animal CPR was circulated with the assistance of veterinary professional organizations on 2 separate occasions: prior to (2008) and following (2017) publication of the 2012 (RECOVER) guidelines. Survey questions identical to both surveys solicited details of clinician approaches to CPR preparedness, basic life support (BLS), and advanced life support (ALS). Respondents were grouped into level of expertise (board-certified specialists [BCS, $n = 202$] and general practitioners in emergency clinics [GPE, $n = 289$]), and year of response to the survey (2008, $n = 171$; 2017, $n = 320$).

Measurements and Main Results: Compliance with the RECOVER guidelines pertaining to CPR preparedness ($P < 0.01$), BLS ($P < 0.01$), and ALS ($P < 0.01$) was consistently higher in respondents to the 2017 survey compared to those of the 2008 survey. Being a BCS was associated with significantly higher compliance with the RECOVER recommendations than GPE in the domains of preparedness ($P = 0.02$), BLS ($P < 0.01$), and ALS ($P < 0.01$). Increases in age of the respondent had a negative effect on compliance with the BLS guidelines ($P < 0.01$), while gender had no effect.

Conclusions: Compared to 2008, current practices in small animal CPR in the North American emergency and critical care community shifted toward those recommended in the RECOVER guidelines across all CPR domains. This supports the notion that uptake of the RECOVER guidelines among veterinary emergency or critical care clinicians was sufficient to lead to a change in the practice of CPR.

Keywords: CPR, survey, RECOVER

Introduction

Cardiopulmonary arrest (CPA) is defined as a loss of effective circulation, attributable to cessation of cardiac mechanical activity and vascular forward flow from the heart and cessation of breathing.¹ While CPR is the only treatment for CPA, reported survival rates in dogs and cats are unsatisfactorily low and range between 5% and 7%.^{2,3} A comprehensive strategy including measures for prevention, preparedness, early recognition of CPA, CPR itself, and post-cardiac arrest care is required to reduce avoidable death due to the CPA.⁴ The release of evidence-based, clinically actionable treatment guidelines for dogs and cats with CPA and their implementation in small animal practice are first steps toward this objective. A precedent for this exists in human medicine, in which the institution of clinical guidelines by the American Heart Association (AHA) and the European Resuscitation Council (ERC) significantly improved the probability of survival following CPA.⁵⁻⁷

In 2012, the REassessment Campaign on Veterinary Resuscitation (RECOVER) initiative provided the first evidence and consensus-based small animal CPR guidelines. The RECOVER initiative has since been disseminated internationally through guidelines published in several languages, and via CPR certification courses, delivered both online (recoverinitiative.org) and through clinical practicums. Four years prior to the release of the RECOVER guidelines, we conducted a survey on the clinical practice of small animal CPR that showed wide variation in resuscitation practices. This variation was largely ascribed to the lack of an authoritative, evidence-based set of CPA treatment guidelines for dogs and cats. As a result, clinical practice was informed to a substantial degree by varying recommendations made by veterinary experts in the field and guidelines designed for people.⁸⁻¹¹ Accordingly, compliance with the RECOVER guidelines should be reflective of how effectively these new treatment recommendations have been adopted by veterinarians.

The objective of this study was to assess whether the clinical approach to CPR has changed following the publication of the RECOVER guidelines in 2012. We hypothesized that in the

previously defined populations, compliance with recommendations from the current RECOVER guidelines differed in 2017 compared to 2008.

Materials and methods

A combined data set originating from survey data from 4 years before and 5 years after the publication of the RECOVER guidelines was analyzed. In short, we revisited raw data from the original 2008 internet-based survey that was published in 2010.¹² In March 2017, a revised questionnaire containing questions that were identical to a subset of the 2008 survey was distributed via various electronic pathways to specialists in veterinary emergency and critical care (ECC) and anesthesia, as well as to non-board-certified veterinary emergency clinicians. Responses were compared for the 2 years (ie, 2008 and 2017) to assess for differences in the clinical practice of CPR since the publication of the 2012 RECOVER guidelines.

Survey distribution and data collection

The methodology underlying the initial collection of data for the 2008 internet-based survey is discussed in detail in the original article.¹² The 2008 survey was composed with the assistance of the Veterinary Information Network (VIN) and distributed through the VIN web site. In addition, access to the survey was distributed by email invitation sent via the mailing lists of the American College of Veterinary Anaesthesia (ACVA), the Veterinary Emergency and Critical Care Society (VECCS), and the European Veterinary Emergency and Critical Care Society (EVECCS).

Invitations to the 2017 survey were distributed by email via the mailing lists of VECCS, EVECCS, the American College of Veterinary Emergency and Critical Care (ACVECC), the European College of Veterinary Emergency and Critical Care (ECVECC), the American College of Veterinary Anaesthesia and Analgesia (ACVAA), the European College of Veterinary Anaesthesia and Analgesia (ECVAA), the Latin American Veterinary Emergency and Critical Care Society (LAVECCS), the Australian and New Zealand College of Veterinary Scientists (ANZCVSc), and the Academy of Veterinary Emergency and Critical Care Technicians (AVECCT). Invitations contained a

link to the survey constructed with the online survey tool REDCap.¹³ Invitations were sent by email on March 1, 2017, followed by reminders on March 8 and March 15. Access to the survey closed on March 31. The survey was also accessible via the social media outlets of the aforementioned veterinary organizations during this time period. No reference was made to the RECOVER guidelines in either the email request or the requests distributed via social media.

Both surveys were completed anonymously by respondents and approval for each survey was obtained from the institutional review board of the University of Melbourne (for 2008) and the human ethics committee of the University of Melbourne (for 2017) prior to collection of data.

Survey and population characteristics

The 2008 survey comprised 81 questions requesting details of respondent demographics and perception toward CPR, preparedness for CPR, and routine approaches to basic life support (BLS) and advanced life support (ALS).¹² The first 31 questions asked respondents to provide basic details concerning their age, gender, and place of work, in addition to details of their first veterinary degree and post-graduate qualifications (if any). Based upon this information, respondents were subdivided into 3 professional groups for analysis: board-certified specialists (BCS) in ECC or anesthesia, general practitioners in emergency clinics (GPE), and general practitioners in general practice (GPG). The remaining questions focused on clinical preparedness for CPR (eg, training and equipment available), BLS (eg, approach to chest compression and ventilation), ALS (eg, patient monitoring, access to drugs) and responder opinions on CPR.

The 2017 survey was a truncated version of the 2008 questionnaire, with the majority of the questions worded in exactly the same way. The question formats were predominately binary (requiring a yes or no response), with the remainder comprising either multiple-choice or Likert-type scale questions.

Twenty-eight questions reflecting specific recommendations in the RECOVER guidelines were identical in the 2008 and 2017 surveys (Appendix 1, electronic version). Of these questions, 11 solicited respondent demographic data including level of training, 3 assessed clinician preparedness

for CPR, 5 assessed BLS practices, and 7 assessed ALS practices (Table 1). Among the ALS questions, 7 inquired into clinician access to drugs recommended for ALS, and 2 evaluated the use of ALS monitoring equipment.

The number of responses to the 2008 and 2017 survey varied by continent; therefore, to permit meaningful comparisons of responses across the 2 surveys in which the relative number of responses by continent were similar, we limited data analysis to responses from veterinarians practicing in either the United States or Canada and those in the professional groups BCS and GPE. Bar plots were constructed to compare the age of respondents, conditioned by gender, country of work, and survey year.

Compliance with CPR guidelines

We determined the overall adherence to RECOVER guidelines in each area of interest (preparedness, BLS, and ALS) by assigning a compliance score to the individual respondent based upon the level of relative compliance to RECOVER guideline recommendations in each area. One point was given for each answer that was consistent with the RECOVER guidelines. Maximum scores varied among the 3 areas in concordance to the number of questions that were asked: 0 to 3 for preparedness, 0 to 5 for BLS, and 0 to 7 for ALS (Table 1). We assigned the attribute of CPR preparedness compliance, BLS compliance, or ALS compliance to respondents that obtained the maximum score for the respective domain.

Statistical analyses

Response data from the 2008 and 2017 surveys were imported and collated using a proprietary spreadsheet software package.^a Data were limited to include only the 28 questions that were common to the 2008 and 2017 surveys. Demographic data for each respondent, as well as data pertaining to adherence to specific RECOVER guidelines for each assessment area (CPR preparedness, BLS, and ALS), were exported to a statistical software package for analysis.^{b,c} The

outcomes for our statistical analyses were the number of questions for each domain in which the respondent provided an answer that was consistent with RECOVER guidelines divided by the total number questions for that domain.

Individual respondent-level variables that were likely to confound the association between the proportion of correct CPR preparedness, BLS and ALS scores, and survey year, such as professional group (BCS vs GPE), gender, age, country of work, and the number of CPR cases carried out per year were controlled for using fixed-effects logistic regression. In the remainder of this paper we report the crude proportion of respondents with a given CPR preparedness, BLS, and ALS score (and their 95% confidence intervals [CIs]) when describing the data. For inference, Wald test statistics and their associated *P*-values from the logistic regression models were used. Acknowledging that intuitive interpretation of logistic regression model outputs is difficult, we re-expressed the adjusted odds ratios from each logistic regression model as adjusted proportions. In effect, these are the expected proportion of correct preparedness, BLS, and ALS scores for a nominated “typical” survey respondent adjusted (ie, corrected) to account for the confounding effect of professional group, gender, age, country, and the number of CPR cases carried out per year. For this study our “typical” survey respondent was (arbitrarily) set to a 35-year-old female veterinarian from Canada. Statistical significance was defined as an α value < 0.05 .

Results

Respondent characteristics

The complete survey database included responses from 2,755 participants (2008: $n = 1,004$; 2017: $n = 1,751$). A total of 2,264 responses were excluded from data analysis: 1,036 that were not practicing in either the United States or Canada, a further 1,185 that did not fulfill criteria for BCS or GPE, and a final 43 for incompleteness of responses. Of the 491 survey responses eligible for analysis, 171 originated from the 2008 survey and 320 from the survey conducted in 2017. Among the 2008 respondents, 44 (26%, 95% CI, 20% to 33%) were ACVECC, ECVA, or ACVA diplomats

(BCS), and 127 (74%, 95% CI, 67% to 80%) were GPE. The 2017 dataset had a higher proportion of BCS respondents compared with the 2008 survey (2008: $n = 44$ [26%, 95% CI, 20% to 33%], 2017: $n = 158$ [49%, 95% CI, 44% to 55%]).

Descriptive statistics of respondent age and the number of veterinarians in the workplace for 2008 and 2017 survey respondents, stratified by professional group are shown in Table 2. The proportion of female respondents was higher in 2017 compared with 2008 for both BCS (2008: $n = 26$ [59%, 95% CI, 44% to 72%], 2017: $n = 119$ [76%, 95% CI, 69% to 82%]) and GPE (2008: $n = 84$ [66%, 95% CI, 58% to 74%], 2017: $n = 129$ [80%, 95% CI, 73% to 85%]) groups (Table 3). The proportion of GPE practicing in clinics with no intern or residency program was higher in 2008 compared with 2017 (2008: $n = 96$ [76%, 95% CI, 67% to 82%], 2017: $n = 100$ [62%, 95% CI, 54% to 69%]). Likewise, the proportion of respondent GPE clinicians working in a practice with a BCS was higher in 2017 compared with 2008 (2008: $n = 25$ [20%, 95% CI, 14% to 27%], 2017: $n = 53$ [33%, 95% CI, 26% to 40%]), and GPEs were practicing in clinics with more veterinarians (2008: median 7 [Interquartile range (IQR) 10], 2017: median 10 [IQR 13]). A higher proportion of GPE respondents in 2017 had a team of 4 or more to participate in CPR efforts should the need arise compared with 2008 (2008: $n = 64$ [50%, 95% CI, 42% to 59%], 2017: $n = 112$ [69%, 95% CI, 62% to 76%]). In 2017, fewer respondents were GPE clinicians who worked in clinics offering after-hours emergency service only compared to 2008 (2008: $n = 46$ [36%, 95% CI, 28% to 45%], 2017: $n = 21$ [13%, 95% CI, 9% to 19%]).

Thirty-one percent ($n = 49$, 95% CI, 24% to 39%) of BCS respondents from the 2017 survey worked in a university setting, less than the 55% ($n = 24$, 95% CI, 40% to 68%) of BCS respondents in the 2008 survey (Table 3). Board-certified specialist respondents in the 2017 survey indicated that they carried out CPR attempts with greater frequency than those from the 2008 survey, with 82% ($n = 130$, 95% CI, 76% to 87%) performing CPR 6 times or greater annually in 2017 compared to 66% in 2008 ($n = 29$, 95% CI, 51% to 78%).

A bar plot showing the percentage of veterinarians that responded to the survey in 2008 and 2017 as a function of their age at the time of completion of the survey, conditioned by gender and country of work is shown in Figure 1. The age distribution for male and female veterinarians working in the United States was similar for the 2008 and 2017 surveys, with the majority of respondents less than 45 years (Figure 1, lower panel). For the United States, the modal age group for males for the 2008 survey was 30 to 35 years; this increased to 40 to 45 years in the 2017 survey. The age distribution for Canadian respondents was less distinct, with a higher proportion of males aged 45 to 55 years responding to the 2017 survey.

CPR preparedness

There was a clear shift (by inspection) toward higher compliance scores for CPR preparedness in both GPE and BCS respondents in 2017 compared to 2008 (Figure 2). In 2017, compared with 2008 there was a reduction in the proportion of respondents with a preparedness score of 1 for both the GPE (2008: $n = 23$ [18%, 95% CI, 12% to 26%], 2017: $n = 5$ [3%, 95% CI, 1% to 7%]) and BCS (2008: $n = 7$ [16%, 95% CI, 8% to 29%], 2017: $n = 6$ [4%, 95% CI, 2% to 8%]) groups. While greater numbers of GPE and BCS respondents scored either 2 or above in the 2017 survey compared to 2008 (Figure 2), the proportion of respondents in each group with a score of 3 (ie, complete CPR preparedness compliance) remained below 50% (Table 4).

Basic life support

Compared to 2008, there was an overall shift toward higher BLS compliance scores in 2017 among GPE and BCS clinicians (Figure 3). For GPE clinicians, the proportion with a total BLS score of 0 or 1 decreased from 48% (95% CI, 40% to 57%) in 2008 to 12% (95% CI, 8% to 18%) in 2017. A similar change was noted for BCS clinicians: 25% (95% CI, 15% to 39%) in 2008 compared with 3% (95% CI, 1% to 7%) in 2017. The percentage of GPE and BCS clinicians achieving complete BLS compliance increased from 1% (95% CI, 0% to 5%) and 8% (95% CI, 3% to 20%) in 2008 to 21% (95% CI, 15% to 28%) and 39% (95% CI, 31% to 46%) in 2017 (Table 5).

Advanced life support

A shift of ALS scores towards improved compliance occurred from 2008 to 2017 in both professional groups (Figure 4). The percentage of BCS respondents with lower ALS scores of 0 to 5 decreased from 23% (95% CI, 13% to 37%) in 2008 to 8% (95% CI, 4% to 13%) in 2017. Similarly, the percentage of GPE respondents with an ALS score of 0 to 5 decreased from 74% (95% CI, 66% to 81%) in 2008 to 36% (95% CI, 29% to 44%) in 2017.

The overall proportion of complete ALS compliance across both professional groups quadrupled from 8% (95% CI, 5% to 13%) in 2008 to 34% (95% CI, 29% to 39%) in 2017. The lack of routine use of capnography and the non-discriminatory administration of IV fluid resuscitation during CPR were other common causes for decreased ALS compliance scores in 2008, but both markedly improved in 2017 (Table 6). In 2017, routine IV fluid resuscitation during CPR continued to be a frequent practice in both BCS (57%, 95% CI, 49% to 64%) and GPE (68%, 95% CI, 60% to 75%) professional groups.

Factors influencing compliance scores

Several potential confounding factors were assessed for their independent effects on the proportion of correct compliance responses in each domain. These included demographic variables (ie, age, gender, the country in which the respondent worked, level of training [ie, professional group], and the number of times that CPR is conducted annually).

With respect to CPR preparedness, the level of training attained by the clinician (GPE vs BCS) and the year in which the survey was completed (2008 vs 2017) significantly influenced the proportion of correct compliance responses (Table 7), with BCS clinicians more likely to provide a correct response to CPR preparedness questions than GPE clinicians. After adjusting for the effect of survey year, gender, age, country of work, and the number of cardiopulmonary resuscitations carried out per year, the odds of a BCS clinician recording a correct response to questions about CPR preparedness was 1.4 (95% CI, 1.0 to 1.8; $P = 0.02$) times the odds of a GPE clinician recording a

correct response to questions about CPR preparedness. Respondents to the 2017 survey (both BCS and GPE) were more likely to record a correct response to CPR preparedness questions compared with those that responded to the 2008 survey (OR, 1.7; 95% CI, 1.3 to 2.2; $P < 0.01$).

With respect to BLS, survey year, professional group, and age had a statistically significant effect on the proportion of correct compliance responses (Table 8). Board-certified specialists were more likely to record a correct response to BLS compliance questions than GPE clinicians (OR, 2.0; 95% CI, 1.7 to 2.5; $P < 0.01$), and those that took part in the 2017 survey were more than 3 times as likely to record a correct response to BLS compliance questions compared with 2008 (OR, 3.7; 95% CI, 3.1 to 4.4; $P < 0.01$). After adjusting for the effect of survey year, professional group, gender, country of work, and the number of cardiopulmonary resuscitations carried out per year, a 1-year increase in the age of the respondent decreased the odds of recording a correct response to questions about BLS compliance by a factor of 0.98 (OR, 0.98, 95% CI, 0.97 to 0.99; $P < 0.01$).

Survey year, professional group, and country of work (Canada vs United States) had independent effects on ALS compliance (Table 9). Similar to CPR preparedness and BLS, BCS were more likely to record a correct response to questions about ALS compliance than GPE (OR, 2.3; 95% CI, 1.9 to 2.9; $P < 0.01$). Those that took part in the 2017 survey were more likely to record a correct response to questions about ALS compliance (OR, 1.8; 95% CI, 1.5 to 2.2; $P < 0.01$) compared with 2008. Respondents from the United States were less likely to record a correct response to questions about ALS compliance compared with respondents from Canada (OR, 0.65; 95% CI, 0.43 to 0.95; $P = 0.01$).

The level of clinical exposure to CPR cases as determined by the (self-declared) number of CPR cases treated per year was not significantly associated with the odds of recording a correct response to questions about CPR preparedness, BLS compliance, and ALS compliance.

An error bar plot showing the proportion of correct responses to questions related to CPR preparation, BLS, and ALS for BCS and GPE for the 2008 and 2017 surveys is shown in Figure 5. In Figure 5, the adjusted proportions (and their 95% CIs) have been calculated using the regression coefficients presented in Tables 7 to 9 for a 35-year-old female veterinarian from Canada who carries

out between 2 and 5 cardiopulmonary resuscitations per year. Compared with 2008, the adjusted proportion of correct responses increased for the 3 domains for both BCS and GPE. Changes in the adjusted proportion of correct responses across 2008 and 2017 were greatest for questions related to BLS.

Discussion

Marked improvements in the proportions of correct responses to questions about CPR preparation, BLS, and ALS were identified in the 2017 survey compared with the 2008 survey, and it is plausible that these changes were associated with publication of the RECOVER guidelines in 2012. However, care is required to ensure that the 2 survey populations are comparable and that the differences in responses are reflecting true changes in clinical practice as opposed to inherent differences in the composition of the 2 surveyed populations. To address this issue, we limited our data analysis to respondents working in a region where there has been relative homogeneity in ECC clinical practice over time (ie, Canada and the United States) and to veterinarians that are either specialists in ECC or anesthesia or exclusively working in emergency practices. Changes in respondent demographics were observed in this study (Figure 1), notably, an increase in the proportion of male respondents older than 35 years of age in the 2017 survey compared with 2008. For the United States, this reflects known changes in the veterinary workforce where, in 2013, veterinarians younger than 35 years of age were predominantly female and veterinarians older than 45 years of age were predominantly male.¹⁴ Given that recruitment for the 2008 and 2017 surveys focused on the same North American professional groups (ACVA, VECCS, and ACVECC) and that the age and gender distribution of respondents were reasonably similar for 2008 and 2017, it is our assessment that the findings of this study are appropriate for those members of the North American veterinary profession with an active interest in companion animal ECC.

To reduce the likelihood of selection bias, the term “RECOVER” was not used in the 2017 survey invitation to mitigate selective recruitment of respondents familiar with the RECOVER guidelines. Absence of the term “RECOVER” in the 2017 survey is also to have limited the likelihood

of obsequiousness bias, in which study subjects systematically alter their responses to questions in the direction they perceive to be desired by the investigator.

Taken together, the results of this study indicate that ECC clinicians in the United States and Canada have significantly changed their approach to small animal CPR over the 9-year period between the 2008 and the 2017 surveys. While a direct causal effect is difficult to ascertain, we argue that the release of the RECOVER guidelines in 2012 is likely to have had an influence on the practice change observed in this study. This assertion is supported first by the consistent practice change towards the guidelines benchmark for almost all examined CPR variables and across all domains (eg, BLS and ALS) and professional groups (ie, GPE and BCS). Second, the size of the practice change was highly significant for the clear majority of CPR metrics. Where this was not the case (eg, when evaluating the access to atropine or epinephrine), the near ubiquitous availability of these drugs in 2008 prevented a further improvement. Third, some changes were very specific to the new guidelines. Most notably, the marked variability in targeted compression rates in dogs in 2008, even among BCS, was decreased in 2017 to favor 100 to 120 compressions/min as recommended in the RECOVER guidelines. Attenuation of undesirable variation in clinical practice is a major objective of clinical guidelines.¹⁵

The goal of clinical guidelines is to translate them into practice and, consequently, improve patient outcomes. The results of this study suggest that the initial uptake of guideline information in the target population of emergency, critical care, and anesthesia clinicians in the United States and Canada was measurable, and that some change in CPR practice is likely to have occurred. The RECOVER guidelines were published open access in a key veterinary ECC journal, with the document downloaded 40,600 times by the end of 2016.^d An online and in-person RECOVER certification program based on the guidelines was developed, and some alternative CPR training programs have also adopted the RECOVER guidelines as a standard. Standardized certification programs have been shown to overcome some of the difficulties of implementing guidelines into clinical practice.¹⁶ Evaluation of the effects of widespread implementation of the guidelines on patient

outcomes (eg, survival to hospital discharge) will require clinical research and Utstein-based registry data.¹⁷⁻²⁰

Our study findings also indicate that many aspects of CPR in veterinary clinical settings still require improvement. Full compliance was achieved by less than half of all respondents in the preparedness and prevention and BLS domains, and by less than 20% in the ALS domain. The frequency of CPR training, chest compression delivery at recommended rates in dogs and cats, coordination of breath delivery with chest compressions, selective use of resuscitative fluid therapy, and no routine use of capnography were the predominant factors of non-compliance identified in this study and offer opportunities for improvement. Numerous studies have demonstrated the importance of CPR training drills and the role that refresher training plays in improving psychomotor skills and clinical cognitive performance.²¹⁻²⁵ Through systematic in-house CPR training of staff at intervals of no more than 6 months, it is likely that veterinary clinics will improve hospital quality of CPR and may also positively impact outcomes.^{26,27} The RECOVER guidelines recommend administering resuscitative fluid therapy during CPR only in cases that are hypovolemic.²⁷ The recommendation is based on evidence from 2 experimental studies in normovolemic dogs in which bolus administration of 11 to 50 mL/kg of isotonic crystalloid solution during CPR significantly decreased coronary and cerebral perfusion pressure and in extension coronary and cerebral blood flow.^{28,29} These effects were the consequence of fluid loading leading to disproportional increases in right atrial and intracranial pressures compared to diastolic aortic pressure. Our study results indicate some uptake of this recommendation with increased adherence in 2017 in both professional groups. However, 43% of BCS and 68% of GPE still indicated routine use of fluid administration during CPR.

Given the dependence on questions asked in 2008, only a selection of recommendations for each CPR domain could be investigated in the 2017 questionnaire. Thus, the responses should be regarded as mere compliance surrogates rather than a comprehensive reflection of the entire breadth of knowledge and skills recommended. The consistency of the changes from 2008 to 2017 and across all domains nevertheless justifies the assumption that these findings may serve as a valid representation of improvement in the entire CPR approach.

The survey format precludes assessing the actual clinical performance of certain resuscitation actions, such as the delivery of chest compressions. Self-reported practice in surveys can be markedly different from actual guideline adherence.³⁰ Prospective studies capturing CPR performance metrics in applied clinical practice as evidence for effective local implementation and to link performance to survival is desirable but demanding and may not be feasible in the foreseeable future.³¹

The effect of the RECOVER guidelines on the observed practice change can only be assumed by deduction, as outlined earlier in the discussion. A study design that includes a control population of survey respondents that reside in a location in which the guidelines were not disseminated but is comparable in all other aspects would be necessary to ascertain the effect of the guidelines.³² Also, the study design does not allow to assess whether an individual respondent in the 2008 survey actually changed its CPR practice in 2017, only whether there was a shift in CPR practice noted in the general BCS and GPE populations over this time period.

An important limitation of this study is the uncertainty of the survey response rate that originates from the unknown number of people reached by the survey invitations. This is a common issue with online surveys, in which invitations are not sent to specific addressees as in postal surveys but are distributed via a general link.³³ The distribution of individualized survey links to specific email addresses, rather than mailing lists, would have mitigated this issue but would have violated privacy policies. While we cannot determine the response rate, it is likely that those that responded to each survey represented a relatively small sample (<20%) of each study's target population (ie, BCS and GPE clinicians in the United States and Canada). Although a small sample size decreases the precision of the measures of association between each of the exposure variables and the outcome of interest, of greater importance is that those who did respond to each survey provided responses that were typical (ie, unbiased) for their respective source population.¹⁴ The data presented in Figure 1 show that the age and gender distribution of respondents were reasonably similar for the 2008 and 2017 surveys and consistent with recent reports of the age and gender composition of the US veterinary profession. We also found that differences in clinical practice between GPE and BCS were consistently and across both year levels, indicating a higher compliance with RECOVER guidelines in

BCS. As a higher skill level in BCS is expected, this further supports the survey sample's representativeness of the population of interest.

Compared to 2008, current self-reported practices in small animal CPR in the North American emergency and critical care community shifted toward those recommended in the RECOVER guidelines across all CPR domains. This supports the notion that the uptake of the RECOVER guidelines among veterinary emergency and critical care clinicians was sufficient to promote a partial, but consistent, change in the practice of CPR. Studies examining the effect of widespread guideline implementation on clinically relevant outcomes need to be conducted to better understand the impact of this set of evidence-based treatment recommendations on dogs and cats suffering from CPA.

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Footnotes

^a Microsoft Excel, version 14.0, Microsoft, Redmond, WA.

^b R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: <https://www.R-project.org/>

^c JMP 12.2.0, SAS Institute, Cary, NC.

^d Dr. Daniel L Chan, personal communication, March 3, 2017.

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Guidelines domain	Compliance criteria
Preparedness	<p>Regularly maintained crash cart or crash station is in place in respondent's practice.</p> <p>Emergency drug dosing chart is displayed in respondent's practice.</p> <p>Respondent participated in some form of veterinary CPR training within the last 6 months.</p>
Basic life support (BLS)	<p>External chest compressions in dogs are performed at 100 to 120/min.</p>

Table 1. Criteria for assessing compliance in three CPR guidelines domains

External chest compressions in cats are performed at 100 to 120/min.

In dogs, the generally targeted ventilation rate is 6 to 15/min.

In cats, the generally targeted ventilation rate is 6 to 15/min.

Breaths are delivered independent of chest compressions to achieve target respiratory rate.

Routine use of ECG during CPR.

Routine use of a capnography during CPR.

No routine administration of intravascular volume expansion therapy (eg, crystalloid or colloid bolus or boluses) as part of CPR strategy.

Atropine readily available during CPR.

Epinephrine or vasopressin is readily available during CPR.

Amiodarone or lidocaine is readily available during CPR.

Sodium bicarbonate is readily available during CPR.

Table 2. Comparison of age (in years) and the number of veterinarians in the workplace for veterinarians that took part in the surveys carried out in 2008 and 2017

Characteristic	Year of survey				Total	
		2008		2017		
	<i>n</i>	Median (IQR)	<i>n</i>	Median (IQR)	<i>n</i>	Median (IQR)
Age (y)						
BCS	44	40 (10)	158	39 (11)	202	39 (11)
GPE	127	37 (14)	162	36 (14)	289	36 (13)
Number of veterinarians in workplace						
BCS	44	32 (36)	158	25 (26)	202	25 (34)
GPE	127	7 (10)	162	10 (13)	289	9 (10)

BCS, board-certified specialists; GPE, general practitioners in emergency practices. IQR, interquartile range

Table 3. Comparison of characteristics of veterinarians that took part in the surveys carried out in 2008 and 2017

Characteristic	Year of survey				Total	
	<i>n</i>	2008 % (95% CI)	<i>n</i>	2017 % (95% CI)	<i>n</i>	% (95% CI)
Gender (male)						
BCS	18	41 (28, 56)	38	24 (18, 31)	56	28 (22, 34)
GPE	43	34 (26, 42)	33	20 (15, 27)	76	26 (22, 32)
Country of work (United States)						
BCS	42	95 (85, 99)	140	89 (83, 93)	182	90 (85, 93)
GPE	117	92 (86, 96)	152	94 (89, 97)	269	93 (90, 95)
Emergency clinic (OOH)						
BCS	0	0 (0, 8)	1	1 (0, 4)	1	1 (0, 3)
GPE	46	36 (28, 45)	21	13 (9, 19)	67	23 (19, 28)
Emergency clinic (24/7)						
BCS	9	20 (11, 35)	14	9 (5, 14)	23	11 (8, 17)
GPE	56	44 (36, 53)	87	54 (46, 61)	143	49 (44, 55)
ECC center with BCS						
BCS	32	73 (58, 84)	138	87 (81, 92)	170	84 (78, 89)
GPE	25	20 (14, 27)	53	33 (26, 40)	78	27 (22, 32)
University practice						
BCS	24	55 (40, 68)	49	31 (24, 39)	73	36 (30, 43)
GPE	1	1 (0, 4)	2	1 (0, 4)	3	1 (0, 3)
Practice with interns or residents						
BCS	15	34 (22, 49)	63	40 (33, 48)	78	39 (32, 45)
GPE	30	24 (17, 32)	60	37 (30, 45)	90	31 (26, 37)
100% emergencies						
BCS	6	14 (6, 27)	43	27 (21, 35)	49	24 (19, 31)
GPE	76	60 (51, 68)	104	64 (57, 71)	180	62 (57, 68)
Team size during CPR ≥ 4						
BCS	35	81 (67, 90)	141	89 (83, 93)	176	88 (82, 91)
GPE	64	50 (42, 59)	112	69 (62, 76)	176	61 (55, 66)
CPR carried out ≥ 6 times per year						
BCS	29	66 (51, 78)	130	82 (76, 87)	159	79 (73-84)
GPE	103	81 (73, 87)	141	87 (81, 91)	244	84 (80-88)

Data presented as counts and percentages and their 95% CIs. BCS, board-certified specialists; GPE, general practitioners in emergency practices; OOH, emergency clinic or service open after regular business hours only; 100% emergencies, entire case load seen by respondent consists in emergencies.

Table 4. Comparison of CPR preparedness scores in 2008 and 2017

Characteristic	Year of survey				Total	
	2008		2017			
	<i>n</i>	% (95% CI)	<i>n</i>	% (95% CI)	<i>n</i>	% (95% CI)
Access to a crash cart						
BCS	42	98 (88, 100)	155	98 (95, 99)	197	98 (95, 99)
GPE	113	90 (83, 94)	157	97 (93, 99)	270	94 (90, 96)
Access to emergency drug dosage chart						
BCS	37	86 (73, 93)	154	97 (94, 99)	191	95 (91, 97)
GPE	96	76 (68, 83)	155	96 (91, 98)	251	87 (83, 91)
CPR training carried out in the previous 6 months						
BCS	17	39 (26, 53)	67	42 (35, 50)	84	42 (35, 48)
GPE	33	26 (19, 34)	56	35 (28, 42)	89	31 (26, 36)
Complete compliance (score = 3)						
BCS	15	34 (22, 49)	66	42 (34, 50)	81	40 (34, 47)
GPE	23	18 (12, 26)	51	31 (25, 39)	74	26 (21, 31)

Data presented as counts and percentages and their 95% CIs. BCS, board-certified specialists; GPE, general practitioners in emergency practices.

Table 5. Comparison of BLS compliance scores in 2008 and 2017

Characteristic	Year of survey				Total	
	2008		2017		<i>n</i>	% (95% CI)
	<i>n</i>	% (95% CI)	<i>n</i>	% (95% CI)		
Target compression rate in dog (100-120/min)						
BCS	17	40 (26, 54)	115	73 (65, 79)	132	66 (59, 72)
GPE	28	22 (16, 30)	90	56 (48, 63)	118	41 (35, 47)
Target compression rate in cat (100-120/min)						
BCS	11	28 (16, 43)	96	61 (53, 68)	107	54 (47, 61)
GPE	30	25 (18, 33)	72	44 (37, 52)	102	36 (31, 42)
Target respiratory rate in dog (6-15/min)						
BCS	25	58 (43, 72)	139	88 (82, 92)	164	82 (76, 86)
GPE	54	44 (35, 52)	131	81 (74, 86)	185	65 (59, 70)
Target respiratory rate in cat (6-15/min)						
BCS	23	53 (39, 67)	139	88 (82, 92)	162	81 (75, 85)
GPE	50	39 (31, 48)	128	79 (72, 85)	178	62 (56, 67)
Breath delivery independent of compressions						
BCS	25	58 (43, 72)	130	82 (76, 87)	155	77 (71, 82)
GPE	53	42 (34, 51)	102	63 (55, 70)	155	54 (48, 59)
Complete BLS compliance (score = 5)						
BCS	3	8 (3, 20)	61	39 (31, 46)	64	32 (26, 39)
GPE	1	1 (0, 5)	34	21 (15, 28)	35	13 (9, 17)

Data presented as counts and percentages and their 95% CIs. BCS, board-certified specialists; GPE, general practitioners in emergency practices.

Table 6. Comparison of ALS compliance scores in 2008 and 2017

Characteristic	Year of survey				Total	
		2008		2017		
	<i>n</i>	% (95% CI)	<i>n</i>	% (95% CI)	<i>n</i>	% (95% CI)
Routine use of ECG						
BCS	43	98 (88, 100)	157	99 (97, 100)	200	99 (96, 100)
GPE	107	84 (77, 90)	154	95 (91, 97)	261	90 (86, 93)
Routine use of capnograph						
BCS	34	77 (63, 87)	151	96 (91, 98)	185	92 (87, 95)
GPE	24	19 (13, 27)	102	63 (55, 70)	126	44 (38, 49)
Access to atropine						
BCS	43	98 (88, 100)	158	100 (98, 100)	201	100 (97, 100)
GPE	127	100 (97, 100)	162	100 (98, 100)	289	100 (99, 100)
Access to vasopressor						
BCS	43	98 (88, 100)	158	100 (98, 100)	201	100 (97, 100)
GPE	127	100 (97, 100)	162	100 (98, 100)	289	100 (99, 100)
Access to antiarrhythmic drugs						
BCS	43	98 (88, 100)	153	97 (93, 99)	196	97 (94, 99)
GPE	125	98 (94, 100)	161	99 (97, 100)	286	99 (97, 100)
Access to bicarbonate						
BCS	41	93 (82, 98)	143	91 (85, 94)	184	91 (86, 94)
GPE	115	91 (84, 95)	138	85 (79, 90)	253	88 (83, 91)
No routine use of vascular volume expansion therapy during CPR						
BCS	14	33 (20, 47)	90	57 (49, 64)	104	52 (45, 59)
GPE	14	11 (7, 18)	52	32 (25, 40)	66	23 (18, 28)
Complete ALS compliance (score = 7)						
BCS	11	25 (15, 39)	76	48 (40, 56)	87	43 (36, 50)
GPE	3	2 (1, 7)	33	20 (15, 27)	36	12 (9, 17)

Data presented as counts and percentages and their 95% CIs. BCS, board-certified specialists; GPE, general practitioners in emergency practices.

Table 7. Estimated regression coefficients and their standard errors from a fixed-effects logistic regression model of factors influencing CPR preparedness compliant responses to an online questionnaire on small animal CPR

Variable	Correct ^a	Total ^b	Coefficient (SE)	z	P-value	OR (95% CI)
Intercept	1,082	1,473	0.2610 (0.9836)	0.27	0.79	-
Year of survey						
2008	338	513	Reference			1.0
2017	744	960	0.5203 (0.1284)	4.05	< 0.01	1.7 (1.3 to 2.2) ^c
Professional group						
GPE	610	867	Reference	-	-	1.0
BCS	472	606	0.3091 (0.1325)	2.33	0.02	1.4 (1.0 to 1.8)
Gender						
Female	787	1074	Reference	-	-	1.0
Male	293	396	0.0980 (0.1415)	0.69	0.49	1.1 (0.84 to 1.5)
Age	1082	1473	0.0017 (0.0072)	0.24	0.81	1.0 (0.99 to 1.0)
Country of work						
Canada	92	120	Reference	-	-	1.0
United States	990	1353	-0.1878 (0.2393)	-0.78	0.43	0.83 (0.51 to 1.3)
Number of cardiopulmonary resuscitations per year						
None	4	6	Reference	-	-	1.0
1	16	30	-0.4458 (0.9630)	-0.46	0.64	0.64 (0.08 to 4.0)
2 to 5	163	228	0.3260 (0.9082)	0.36	0.72	1.4 (0.18 to 7.8)
6 to 10	201	276	0.4226 (0.9125)	0.46	0.64	1.5 (0.20 to 8.6)
11 to 20	236	315	0.4884 (0.9102)	0.54	0.59	1.6 (0.21 to 9.2)
>20	462	618	0.4530 (0.9075)	0.50	0.62	1.6 (0.21 to 8.8)

BCS, board-certified specialists ; GPE, general practitioners in emergency practice.

^aNumber of “correct” responses.

^bTotal number of responses.

^cInterpretation: After adjusting for the effect of professional group, gender, age, country of work, and the number of cardiopulmonary resuscitations carried out per year, the odds of a survey respondent

recording a correct response to questions about CPR preparedness in 2017 was 1.7 (95% CI, 1.3 to 2.2) times the odds of recording a correct response to questions about CPR preparedness in 2008.

Table 8. Estimated regression coefficients and their standard errors from a fixed-effects logistic regression model of factors influencing BLS compliant responses to an online questionnaire on small animal CPR

Variable	Correct ^a	Total ^b	Coefficient (SE)	<i>z</i>	<i>P</i> -value	OR (95% CI)
Intercept	1,458	2,455	-0.8379 (0.8117)	-1.0	0.30	
Year of survey						
2008	316	855	Reference	-	-	1.0
2017	1,142	1,600	1.3055 (0.0946)	13.8	< 0.01	3.7 (3.1 to 4.4)
Professional group						
GPE	738	1,445	Reference	-	-	1.0
BCS	720	1,010	0.7168 (0.0964)	7.4	< 0.01	2.0 (1.7 to 2.5)
Gender						
Female	1,104	1,790	Reference	-	-	1.0
Male	349	660	-0.1087 (0.1030)	-1.1	0.29	0.80 (0.73 to 1.1)
Age	1,458	2,455	-0.0214 (0.0052)	-4.1	< 0.01	0.98 (0.97 to 0.99)
Country of work						
Canada	117	200	Reference	-	-	1.0
United States	1,341	2,255	0.1449 (0.1708)	0.8	0.40	1.2 (0.83 to 1.6)
Number of cardiopulmonary resuscitations per year						
None	3	10	Reference			1.0
1	21	50	0.6632 (0.8239)	0.8	0.42	1.9 (0.41 to 11)
2 to 5	208	380	0.7839 (0.7733)	1.0	0.31	2.2 (0.51 to 11)
6 to 10	289	460	1.0281 (0.7761)	1.3	0.19	2.8 (0.65 to 15)
11 to 20	310	525	0.8533 (0.7747)	1.1	0.27	2.3 (0.54 to 12)
>20	627	1,030	0.8493 (0.7734)	1.1	0.27	2.3 (0.54 to 12)

BCS, board-certified specialists; GPE, general practitioners in emergency practice.

^aNumber of “correct” responses.

^bTotal number of responses.

TABLE 9. Estimated regression coefficients and their standard errors from a fixed-effects logistic regression model of factors influencing ALS compliant responses to an online questionnaire on small animal CPR

Variable	Correct ^a	Total ^b	Coefficient (SE)	<i>z</i>	<i>P</i> -value	OR (95% CI)
Intercept	2,841	3,437	2.4147 (-1.1126)	2.17	0.03	-
Year of survey						
2008	900	1,197	Reference	-	-	1.0
2017	1,941	2,240	0.5834 (0.0967)	6.03	< 0.01	1.8 (1.5 to 2.2)
Professional group						
GPE	1,570	2,023	Reference	-	-	1.0
BCS	1,271	1,414	0.8499 (0.1101)	7.72	< 0.01	2.3 (1.9 to 2.9)
Gender						
Female	2,072	2,506	Reference	-	-	1.0
Male	763	924	0.0633 (0.1089)	0.58	0.56	1.1 (0.86 to 1.3)
Age	2,841	3,437	-0.0011 (0.0054)	-0.21	0.84	1.0 (0.99 to 1.0)
Country of work						
Canada	245	280	Reference	-	-	1.0
United States	2,596	3,157	-0.4260 (0.2002)	-2.13	0.03	0.65 (0.43 to 0.95)
Number of cardiopulmonary resuscitations per year						
None	13	14	Reference	-	-	1.0
1	51	70	-1.5796 (1.0946)	-1.44	0.15	0.21 (0.01 to 1.2)
2 to 5	430	532	-1.2169 (1.0675)	-1.14	0.25	0.30 (0.02 to 1.6)
6 to 10	524	644	-1.1094 (1.0696)	-1.04	0.30	0.33 (0.02 to 1.8)
11 to 20	613	735	-0.9817 (1.0681)	-0.92	0.36	0.37 (0.02 to 2.1)
>20	1,210	1,442	-0.9769 (1.0668)	-0.92	0.36	0.38 (0.02 to 2.1)

BCS, board-certified specialists; GPE, general practitioners in emergency practice.

^aNumber of “correct” responses.

^bTotal number of responses.

Figure 1. Vertical bar plot showing the percentage of veterinarians that responded to the survey in 2008 and 2017 as a function of age at the time of completion of the survey, conditioned by gender and country of work.

Figure 2. CPR preparedness scores in board-certified specialists (BCS) and general practitioners in emergency practices (GPE) in 2008 and 2017. Error bars represent 95% confidence intervals.

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Figure 3. Basic life support (BLS) scores in board-certified specialists (BCS) and general practitioners in emergency practices (GPE) in 2008 and 2017. Error bars represent 95% confidence intervals.

Figure 4. Advanced life support (ALS) scores in board-certified specialists (BCS) and general practitioners in emergency practices (GPE) in 2008 and 2017. Error bars represent 95% confidence intervals.

Figure 5. Error bar plot showing the adjusted proportions (and their 95% confidence intervals) of correct responses to questions related to CPR preparation, basic life support and advanced life support for board-certified specialists (BCS) and general practitioners in emergency practices (GPE) in 2008 and 2017. Proportions have been calculated for a 35-year old female veterinarian from Canada who carries out between 2 and 5 cardiopulmonary resuscitations per year using the regression coefficients presented in Tables 6, 7 and 8.

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