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# RECOVER evidence and knowledge gap analysis on veterinary CPR. Part 7: Clinical guidelines

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***Abstract***

**Objective** – To present a series of evidence-based, consensus guidelines for veterinary CPR in dogs and cats.
**Design** – Standardized, systematic evaluation of the literature, categorization of relevant articles according to level of evidence and quality, and development of consensus on conclusions for application of the concepts to clinical practice. Questions in five domains were examined: Preparedness and Prevention, Basic Life Support, Advanced Life Support, Monitoring, and Post-Cardiac Arrest Care. Standardized worksheet templates were used for each question, and the results reviewed by the domain members, by the RECOVER committee, and opened for comments by veterinary professionals for 4 weeks. Clinical guidelines were devised from these findings and again reviewed and commented on by the different entities within RECOVER as well as by veterinary professionals.
**Setting** – Academia, referral practice and general practice.
**Results** – A total of 74 worksheets were prepared to evaluate questions across the five domains. A series of 101 individual clinical guidelines were generated. In addition, a CPR algorithm, resuscitation drug-dosing scheme, and postcardiac arrest care algorithm were developed.
**Conclusions** – Although many knowledge gaps were identified, specific clinical guidelines for small animal veterinary CPR were generated from this evidence-based process. Future work is needed to objectively evaluate the effects of these new clinical guidelines on CPR outcome, and to address the knowledge gaps identified through this process.

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**Abbreviations**

| | |
|---|---|
| ABC | airway, breathing, circulation |
| ALS | advanced life support |
| BLS | basic life support |
| CPA | cardiopulmonary arrest |
| CPR | cardiopulmonary resuscitation |
| $EtCO_2$ | end tidal $CO_2$ |
| ETT | endotracheal tube |
| ILCOR | International Liaison Committee on Resuscitation |
| LOE | level of evidence |
| PEA | pulseless electrical activity |
| PICO | population, intervention, control group, outcome |

| | |
|---|---|
| RECOVER | Reassessment Campaign on Veterinary Resuscitation |
| VF | ventricular fibrillation |
| VT | ventricular tachycardia |

## Introduction

The development of specific, evidence-based clinical guidelines for human cardiopulmonary resuscitation (CPR), based upon extensive surveys of the literature by the International Liaison Committee on Resuscitation (ILCOR) has allowed consistent training for human healthcare professionals and the lay public, leading directly to improved outcomes.[1–3] No comparable evidence-based guidelines have been available in veterinary medicine, although recommendations on practical execution of CPR in small animals have been published.[4–8] The absence of standardized, comprehensive training coupled with a lack of consensus on the content of the published recommendations has led to significant variability in the approach to veterinary CPR, likely to the detriment of our patients.[9]

The main goal of the Reassessment Campaign on Veterinary Resuscitation (RECOVER) initiative was to develop a set of clinical consensus guidelines for the practice of CPR in dogs and cats based upon an extensive, systematic review of the literature in the context of our target species. Although there is overlap between the literature examined by ILCOR and RECOVER, the science was interpreted based upon applicability to dogs and cats. This has led to conclusions that diverge, in some areas, from those reached by ILCOR. Based upon the results of the evidence worksheet process used in RECOVER,[10] a total of 101 clinical guidelines were developed and made available for review for a period of 4 weeks to members of the veterinary community (see Appendix I). This feedback was used to modify and refine the recommendations, yielding the final set of consensus guidelines presented in this manuscript.

In order to reflect the variability in the quality and quantity of evidence examined, each guideline developed through the RECOVER consensus process has been assigned two descriptors: (1) Class – this categorizes the risk-benefit ratio of the intervention described in the guideline, and (2) Level – this categorizes the strength of the evidence available to support the recommendation. This scheme was adapted from that used by ILCOR.[11] The individual class and level categories are detailed in Tables 1 and 2, and each guideline is labeled (Class-Level).

**Table 1:** Class descriptors for the clinical guidelines, categorizing the risk-benefit ratio associated with the intervention

| Class | Risk:benefit ratio | Clinical recommendation |
|---|---|---|
| I | Benefit >>> Risk | Should be performed |
| IIa | Benefit >> Risk | Reasonable to perform |
| IIb | Benefit ≥ Risk | May be considered |
| III | Risk > Benefit | Should not be performed |

**Table 2:** Level descriptors for the clinical guidelines, categorizing the strength of the evidence available for the recommendation

| Level | Populations studied | Criteria for recommendation |
|---|---|---|
| A | Multiple populations | Multiple high quality and/or high level of evidence studies |
| B | Limited populations | Few to no high quality and/or high level of evidence studies. |
| C | Very limited populations | Consensus opinion, expert opinion, guideline based on physiologic/ anatomic principles, standard of care |

## Small Animal Veterinary CPR Algorithm

The guidelines presented in this document cover a wide variety of CPR-related topics in 5 domains: Preparedness and Prevention, Basic Life Support (BLS), Advanced Life Support (ALS), Monitoring, and Post-Cardiac Arrest Care. The main elements of CPR and their temporal sequence have been summarized in a CPR algorithm chart (Figure 1). This algorithm was designed to deliver step-by-step prompts to the veterinary rescuer engaged in CPR and stresses the importance of early BLS interventions. The evidence reviewed strongly reinforced the importance of early delivery of high-quality chest compressions with minimal interruption. High-quality chest compressions should be delivered in uninterrupted cycles of 2 minutes with most patients in lateral recumbency, at a compression rate of 100–120/min and a compression depth of 1/3–1/2 the width of the chest while allowing for full elastic recoil of the chest between individual compressions. In addition, it is likely that early intubation and ventilation in veterinary CPR is highly valuable, with a ventilation rate of approximately 10 breaths/min, a tidal volume of 10 mL/kg, and an inspiratory time of 1 second delivered simultaneously with compressions. If intubation supplies are not available, mouth-to-snout ventilation is an acceptable alternative, and should be delivered in repeated rounds of 30 chest compressions followed by 2 rapid breaths in cycles of 2 minutes. After each 2-minute cycle of BLS, the compressor should be rotated to prevent fatigue, which may decrease the quality of chest compressions. Every effort should be made to minimize the duration of chest compression interruptions between cycles. ALS

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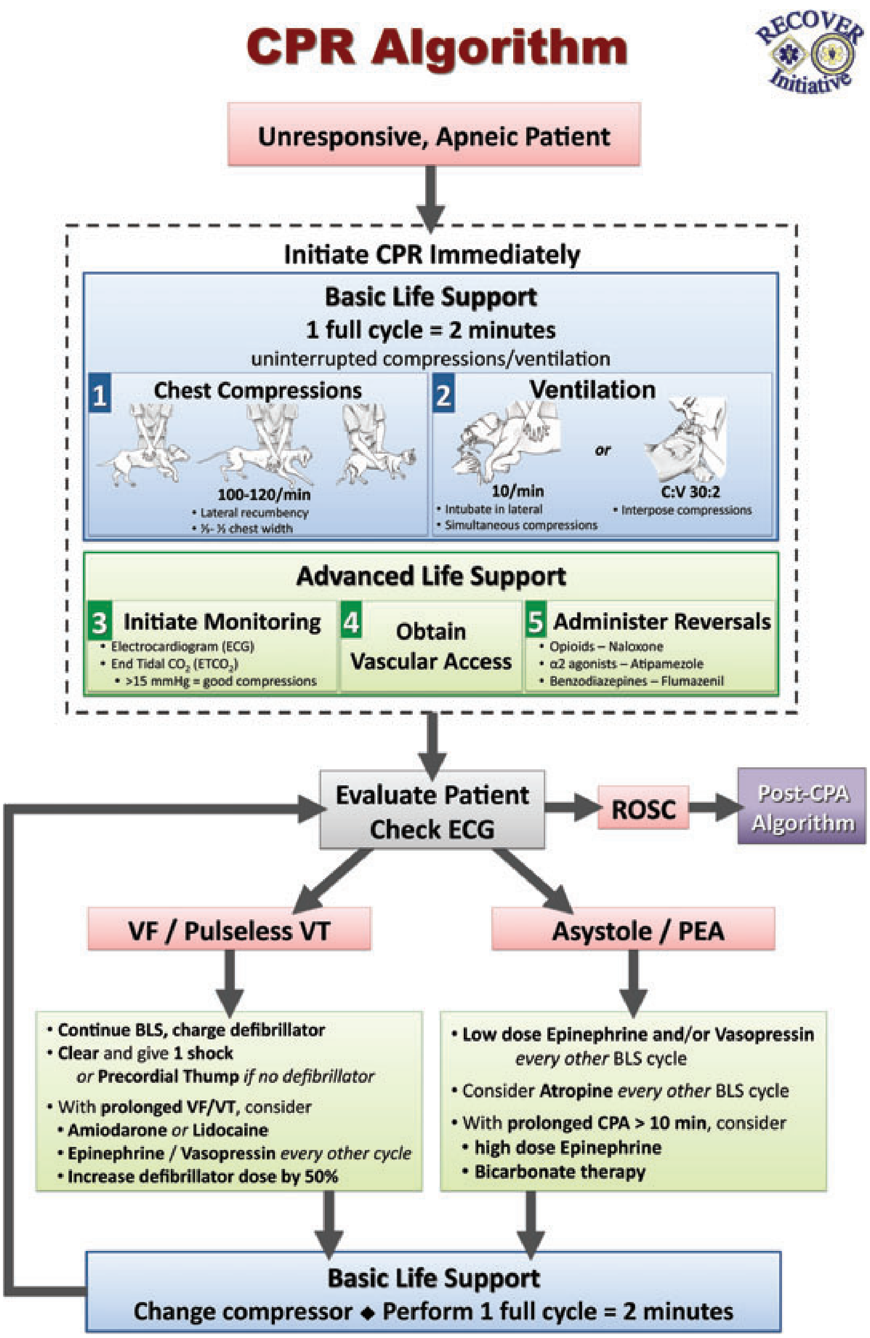


**Figure 1:** CPR algorithm chart. This chart summarizes the clinical guidelines most relevant to the patient presenting acutely in CPA. The box surrounded by the grey dashed line contains, in order, the initial BLS and ALS actions to be taken when a patient is diagnosed with CPA: (1) administration of chest compressions, (2) ventilation support, (3) initiation of ECG and $EtCO_2$ monitoring, (4) obtaining vascular access for drug administration, and (5) administration of reversal agents if any anesthetic/sedative agents have been administered. The algorithm then enters a loop of 2-minute cycles of CPR with brief pauses between to rotate compressors, to evaluate the patient for signs of ROSC, and to evaluate the ECG for a rhythm diagnosis. Patients in PEA or asystole should be treated with vasopressors and, potentially, anticholinergic drugs. These drugs should be administered no more often than every other cycle of CPR. Patients in VF or pulseless VT should be electrically defibrillated if a defibrillator is available, or mechanically defibrillated with a precordial thump if an electrical defibrillator is not available. Immediately after defibrillation, another 2-minute cycle of BLS should be started immediately. BLS, basic life support; CPA, cardiopulmonary arrest; CPR, cardiopulmomary resuscitation; C:V, compression to ventilation ratio; $EtCO_2$, end tidal $CO_2$; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

 

interventions, including initiation of monitoring, establishment of vascular access, administration of reversal agents, vasopressor and vagolytic therapy, and defibrillation are also included in the algorithm. Recommended dosing and indications for common CPR-related drugs are included in Appendix II.

A post-cardiac arrest (PCA) algorithm chart, designed to summarize the major interventions recommended in the guidelines for patients that achieve return of spontaneous circulation (ROSC), is shown in Figure 2. The algorithm is focused on initial respiratory optimization that includes normalizing ventilation to achieve normocapnia and titration of oxygen supplementation to maintain normoxemia while avoiding both hypoxemia and hyperoxemia. Once the patient's respiratory status is assessed and a treatment plan is initiated, cardiovascular concerns are addressed. The hemodynamic optimization component is based on the concept of early goal-directed therapy, first described for patients in septic shock.[12] Arterial blood pressure is first assessed, and IV fluids, vasopressors, and positive inotropes are administered as needed to achieve normotension or mild hypertension. Severe hypertension is addressed with adjustment of vasopressors, pain management, and antihypertensives. Once arterial blood pressure targets are met, central venous oxygen saturation ($ScvO_2$) or blood lactate concentration is assessed to determine if oxygen delivery to tissues is adequate. If a deficit in oxygen delivery is noted, hemodynamic optimization is revisited and guided by oxygen delivery targets rather than arterial blood pressure targets. If oxygen delivery targets are still not met, red blood cell transfusions are administered if indicated. A PCV target of 25% is suggested, a departure from traditional early goal-directed therapy due to more recent data in humans documenting improved outcomes with more restrictive transfusion triggers.[13] Once hemodynamic optimization strategies have been initiated, neuroprotective interventions and intensive monitoring are considered based on the neurologic status of the patient. Recommended doses for common PCA-related drugs are included in Appendix II. It should be noted that this comprehensive treatment protocol is based in part on evidence specific to the PCA condition and in part on general critical care principles. Studies on the effects of these types of optimization strategies during PCA care are needed.

## *Preparedness and Prevention*

The guidelines developed through the evidence collected by this domain are based on the premise that resuscitation attempts that are organized, cohesive, and led by a well-functioning knowledgeable team adhering to evidence-based CPR guidelines should improve survival from cardiopulmonary arrest (CPA). Strengthening the links in the chain of survival, the time-sensitive, coordinated actions necessary to maximize survival from CPA, has the potential to lead to improved outcomes.[4] The guidelines derived from this domain focus on interventions involving both environmental and personnel factors that strengthen the chain of survival for dogs and cats with CPA.

### Equipment organization and cognitive aids

An organized and efficient response to an acute medical or surgical crisis is crucial. The effects of ready access to organized and consistently audited crash carts on outcomes for patients receiving CPR have been well studied in human medicine.[14] Equipment and supply inaccessibility or failure has been implicated in delays in initiation of CPR in up to 18% of CPA cases.[15] Therefore, it is recommended that the location, storage, and content of resuscitation equipment should be standardized and regularly audited (I-A). In addition, the presence of cognitive aids such as checklists, algorithm charts, and dosing charts has been shown to improve compliance with CPR guidelines.[16] Formal training of personnel in the use of these cognitive aids is also crucial to effective utilization during a crisis.[17] Figure 1 shows an example of a CPR algorithm chart, and Figure 3 shows an example of an emergency drug and dosing chart, containing only the most commonly used drugs, separated into categories based upon indication, and provided in volume of drug to be administered by body weight to reduce dose calculation errors. Availability and clear visibility of these charts in areas in which CPA may occur, such as procedure areas, anesthesia induction rooms, and surgery suites is recommended (I-B).

### CPR training

Adherence to CPR guidelines can only be accomplished if personnel receive effective, standardized training and regular opportunities to refresh their skills. Because high-quality CPR requires both cognitive skills to correctly perform all indicated steps in an orderly, rapid fashion as well as psychomotor skills to provide effective manual interventions such as chest compressions and ventilation, CPR training should include both didactic components targeted at cognitive performance and opportunities to practice hands-on skills with quality feedback (I-A). Effective options for psychomotor skill training include high-fidelity simulation technologies, low-fidelity task trainers, and auditory and visual feedback devices.[18–20] Regardless of the type of technology used for initial training, refresher training at least every 6 months is recommended to reduce the risk of the decay of skills (I-A). There is some evidence that the use of simulation methodologies may be most beneficial for

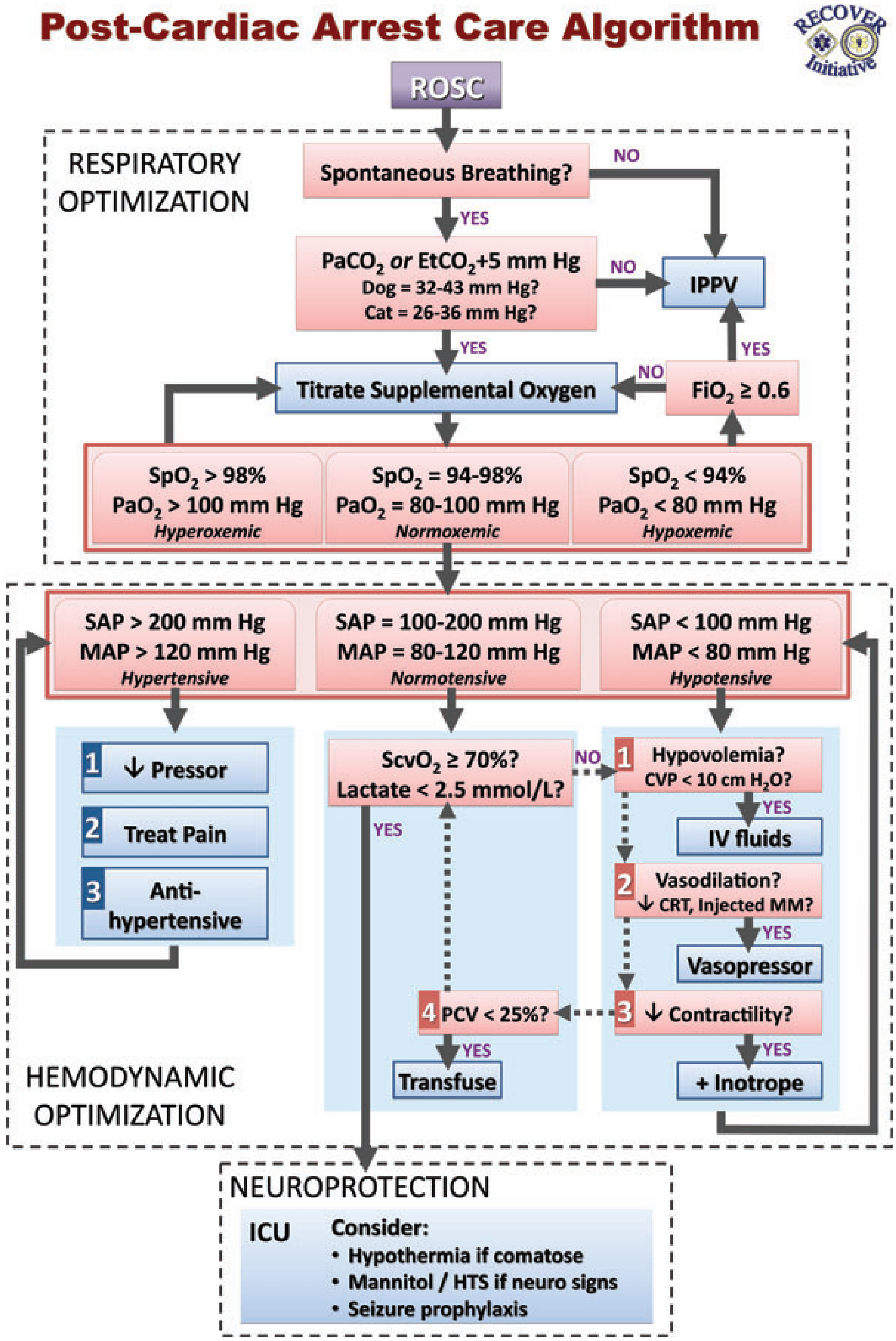


**Figure 2:** Post-cardiac arrest (PCA) care algorithm. This chart summarizes a comprehensive treatment protocol for PCA care that includes components of controlled ventilation and oxygenation, goal-directed hemodynamic optimization, and neuroprotective strategies. The sequence shown reflects the order in which each component should be assessed and treatment initiated. Assessment and initiation of treatment for the subsequent component will likely commence before the endpoints of the previous component have been completely met. Thus respiratory, hemodynamic, and neuroprotective treatment strategies will be initiated in parallel in most cases. CRT, capillary refill time; CVP, central venous pressure; $EtCO_2$, end-tidal carbon dioxide; HTS, hypertonic saline; IPPV, intermittent positive pressure ventilation; MAP, mean arterial pressure; MM, mucous membrane color; ROSC, return of spontaneous circulation; SAP, systolic arterial pressure; $ScvO_2$, central venous oxygen saturation.

## CPR Emergency Drugs and Doses

| | | Weight (kg) | 2.5 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weight (lb) | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| | DRUG | DOSE | ml | ml | ml | ml | ml | ml | ml | ml | ml | ml | ml |
| Arrest | Epi Low (1:1000; 1mg/ml) every other BLS cycle x3 | 0.01 mg/kg | 0.03 | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 | 0.45 | 0.5 |
| Arrest | Epi High (1:1000; 1 mg/ml) for prolonged CPR | 0.1 mg/kg | 0.25 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| Arrest | Vasopressin (20 U/ml) | 0.8 U/kg | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1 | 1.2 | 1.4 | 1.6 | 1.8 | 2 |
| Arrest | Atropine (0.54 mg/ml) | 0.04 mg/kg | 0.2 | 0.4 | 0.8 | 1.1 | 1.5 | 1.9 | 2.2 | 2.6 | 3 | 3.3 | 3.7 |
| Anti-Arrhyth | Amiodarone (50 mg/ml) | 5 mg/kg | 0.25 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| Anti-Arrhyth | Lidocaine (20 mg/ml) | 2 mg/kg | 0.25 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| Reversal | Naloxone (0.4 mg/ml) | 0.04 mg/kg | 0.25 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| Reversal | Flumazenil (0.1 mg/ml) | 0.01 mg/kg | 0.25 | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| Reversal | Atipamezole (5 mg/ml) | 100 ug/kg | 0.06 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1 |
| Defib Monophasic | External Defib (J) | 4-6 J/kg | 10 | 20 | 40 | 60 | 80 | 100 | 120 | 140 | 160 | 180 | 200 |
| Defib Monophasic | Internal Defib (J) | 0.5-1 J/kg | 2 | 3 | 5 | 8 | 10 | 15 | 15 | 20 | 20 | 20 | 25 |

**Figure 3:** CPR drug dosing chart. Drugs are separated by indication and volumes are provided by body weight to reduce calculation errors. Defibrillator dosing is for a monphasic electrical defibrillator. Anti-arrhyth, antiarrhythmic drugs; CPR, cardiopulmonary resuscitation; Epi, epinephrine; Defib, electrical defibrillation.

this booster training.[21] Although high-fidelity simulators may carry some advantage in this type of training, simple mock codes run every 3–6 months on low-fidelity manikins are likely to improve awareness of CPR guidelines and are achievable in most small animal practice settings.

Improved learning outcomes have been documented when CPR training culminates in performance testing.[22] Therefore, regardless of the methods used for initial and refresher training, structured assessment after CPR training is recommended (I-A). In addition to assessment after didactic and psychomotor skills training, structured debriefing after a real resuscitation effort or simulated CPR, allowing participants to review and critique their performance and the performance of the team as a whole is recommended (I-A). During the debriefing, the participants should be encouraged to drive the discussion and identify for themselves the strengths and weaknesses of the team's performance. Facilitation by a team member trained in debriefing technique is useful, and care must be taken to prevent focusing on blaming individuals for poor performance. Open, honest discussion about opportunities for improvement immediately after a CPR attempt can lead to significant enhancement in CPR performance.[23–25]

**Team dynamics**

Several studies in human medicine have investigated the effect of the presence of a physician on outcomes in out-of-hospital CPA, and taken as a whole, there does not appear to be a beneficial effect on outcome of CPR from the presence of a physician acting as team leader.[26,27] Although there have been no studies investigating this question in veterinary medicine, based on the data available in human medicine, veterinarians or technicians may be considered as leaders of a CPR team (IIb-B).

Regardless of the status of the team leader, there is strong evidence in the literature that communication and team skills training can improve the effectiveness of a CPR attempt,[28] and specific leadership training is recommended for individuals who may need to lead in a CPR attempt (I-A). Crucial roles of the team leader include distributing tasks to other team members and enforcing rules and procedures. Important leadership behaviors that can improve CPR team performance include intermittently summarizing the code to ensure a shared mental model among team members, actively soliciting input from team members to encourage situation awareness and identify issues and ideas from all members of the team, and assigning individual tasks to team members rather than performing them personally to allow better attention to the global status of the code rather than a specific task. Team performance can also be enhanced by using focused, clear communication directed at individuals when tasks are assigned, and utilization of closed loop communication.[29] Closed loop communication is accomplished by a clear, directed order being given to one team member by another, after which the receiving team member repeats the order back to the requestor to verify the accuracy of the receiver's perception. This simple technique drastically reduces medical errors, especially in an emergency situation, due to misunderstanding of orders and prevents the possibility of an order not being carried out because the receiver did not hear the request.

## *BLS*

In veterinary CPR, BLS includes the recognition of CPA, administration of chest compressions, airway management, and provision of ventilation. It is imperative that BLS is provided immediately upon diagnosis or suspicion of CPA, and lay rescuers and medical professionals alike may accomplish most aspects. Numerous human and animal experimental studies have shown that the rapidity of initiation and quality of BLS performed is associated with ROSC and survival in victims of CPA.[30–32] Although BLS is considered separately from ALS and monitoring in this consensus statement, in clinical practice, the intent is that BLS will be performed simultaneously with ALS and monitoring, or that ALS and monitoring will occur as soon after initiation of BLS as possible.

**Chest compressions**

Chest compressions should be initiated as soon as possible upon recognition of CPA and if multiple rescuers are present, airway and ventilation management should not delay commencement of chest compressions.

Patient position and compressor hand placement

Due to experimental evidence suggesting higher left ventricular pressures and aortic flow in dogs in lateral recumbency compared to dorsal recumbency, and clinical data in dogs and cats showing higher rates of ROSC associated with compressions performed in lateral recumbency,[33,34] chest compressions should be done in lateral recumbency in both dogs and cats (I-B). Either left or right lateral recumbency is acceptable. However, the profound variations in chest conformation among dogs and cats suggest that a single, identical approach to chest compressions is unlikely to be optimal in all patients with CPA. There are 2 main theories describing the mechanism by which external chest compressions lead to blood flow during CPR.[35] The cardiac pump theory postulates that the cardiac ventricles are directly compressed between the sternum and the spine in patients

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in dorsal recumbency or between the ribs in patients in lateral recumbency. The thoracic pump theory proposes that chest compressions increase overall intrathoracic pressure, secondarily compressing the aorta and collapsing the vena cava leading to blood flow out of the thorax. During elastic recoil of the chest, subatmospheric intrathoracic pressure provides a pressure gradient that favors the flow of blood from the periphery back into the thorax and into the lungs where oxygen and carbon dioxide exchange occurs. Although minimally studied, it is believed that the predominant mechanism in any patient will be dependent upon thoracic conformation, and it is likely that both mechanisms contribute to blood flow in most patients.

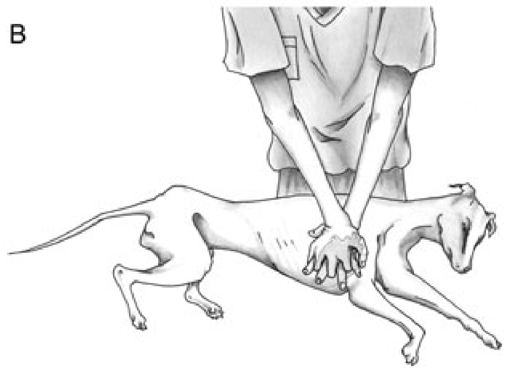
In the majority of medium, large, and giant breed dogs with rounded chests, direct compression of the heart with external chest compressions is unlikely. Therefore, the thoracic pump mechanism is likely to predominate in these patients, and chest compressions over the widest portion of the chest will allow maximal increases in intrathoracic pressure (see Figure 4a). It is therefore reasonable in most large and giant breed dogs, to deliver chest compressions with the hands placed over the widest portion of the chest (IIa-C). Conversely, in more keel-chested (narrow, deep chested) dogs such as greyhounds, the cardiac pump theory may be more easily employed with external chest compressions in lateral recumbency; therefore, in dogs with this conformation, chest compressions with the hands positioned directly over the heart is reasonable (IIa-C). (Figure 4b). In dogs with barrel-chested conformations, such as English bulldogs, sternal compressions in dorsal recumbency, directed at the cardiac pump theory, may be considered (IIb-C) (Figure 4c). Cats and small dogs tend to have higher thoracic wall compliance, and effective chest compressions using the cardiac pump mechanism can likely be achieved with a 1-hand technique with the compressor's fingers wrapped around the sternum at the level of the heart (see Figure 5a). Thus, circumferential compressions rather than lateral compressions may be considered (IIb-C). However, if the compressor becomes fatigued or an individual patient's thoracic wall compliance is lower due to age, obesity, or conformation, a 2-handed technique employing the cardiac pump mechanism can be used (Figure 5b).

### Chest compression technique

There is strong evidence, including an experimental study in dogs documenting increased rates of ROSC and 24-hour survival, supporting a recommendation for compression rates of 100–120/min in cats and dogs (I-A).[36] However, there is also some evidence that higher compression rates of up to 150/min may be even more advantageous, and further work in this area is needed.

A

B



C

**Figure 4:** Chest compression techniques for medium, large, and giant breed dogs. (A) For most dogs, it is reasonable to do chest compressions over the widest portion of the chest to maximally employ the thoracic pump theory. Either left or right lateral recumbency are acceptable. (B) In keel-chested (ie, deep, narrow chested) dogs like greyhounds, it is reasonable to do chest compressions with the hands directly over the heart to employ the cardiac pump theory, again in either recumbency. (C) For barrel-chested dogs like English Bulldogs, sternal compressions directly over the heart with the patient in dorsal recumbency may be considered to employ the cardiac pump mechanism.

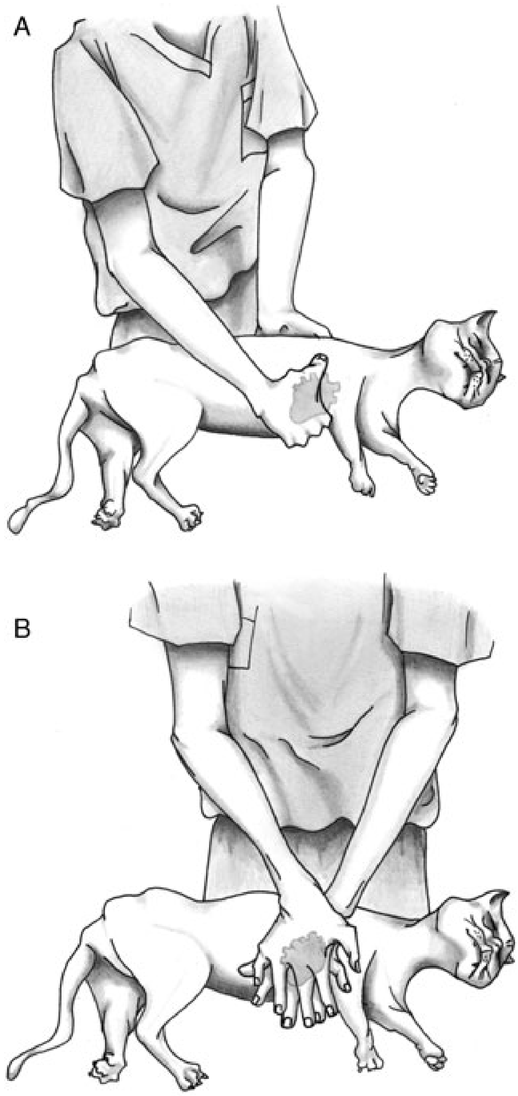



**Figure 5:** Chest compression techniques for small dogs and cats. (A) For most cats and small dogs (<10 kg) with compliant chests, the use of a 1-handed technique to accomplish circumferential chest compressions with the hand wrapped around the sternum directly over the heart may be considered. (B) An alternative chest compression method for cats and small dogs is the 2-handed technique directly over the heart to employ the cardiac pump mechanism. This method may be considered in larger cats and small dogs with lower thoracic compliance, or in situations in which the compressor is becoming fatigued while doing 1-handed compressions.

There is also good evidence to support deep chest compressions of 1/3–1/2 the width of the thorax in most patients (IIa-A), with an experimental canine study showing a linear relationship between compression depth and mean arterial pressure, and multiple human clinical trials and experimental animal studies supporting these compression depths.[37–39] Finally, experimental studies in pigs have documented reduced coronary and cerebral perfusion when full elastic recoil between chest compressions is not permitted (ie, leaning). Observational studies in people have shown a high prevalence of leaning during CPR. It is recommended that full chest wall recoil is allowed between compressions (I-A).[40,41]

**Ventilation**

Both hypoxia and hypercapnia reduce the likelihood of ROSC; therefore, securing a patent airway and providing ventilation are essential during CPR.[42,43] Although human CPR algorithms emphasize the importance of chest compressions over ventilation in BLS, there is evidence in human pediatric patients that ventilation is more important in patients with CPA not of primary cardiac origin.[44] Because the majority of canine and feline cardiac arrests are due to noncardiac root causes, early endotracheal intubation and provision of ventilation in CPR is likely to be of benefit.

Ventilation technique for intubated patients

Given the documented detrimental effects of pauses in chest compressions and the ease with which dogs and cats can be intubated, if equipment and personnel are available, rapid intubation of dogs and cats in CPA is recommended. This should be accomplished with the animal in lateral recumbency so that chest compressions may be continued during the procedure. Once the endotracheal tube (ETT) is in place, the cuff should be inflated so that ventilation and chest compressions can occur simultaneously (I-A). The ETT should be secured to the muzzle or mandible to prevent dislodgement. It may be useful for veterinarians and technicians to practice lateral endotracheal intubation in patients undergoing routine anesthetic procedures to develop and maintain these skills.

Although there are very limited data in dogs and none in cats evaluating optimal ventilation strategies for intubated patients during CPR, there are several well-controlled experimental studies in pigs as well as clinical studies in people supporting these recommendations. Higher respiratory rates, longer inspiratory times, and higher tidal volumes can lead to impaired venous return due to increased mean intrathoracic pressure as well as decreased cerebral and coronary perfusion due to vasoconstriction, and have been documented to lead to poorer outcomes in people during CPR.[45] Due to decreased pulmonary blood flow resulting from the reduced cardiac output achievable during CPR (approximately 25–30% or normal), physiologically "normal" ventilation rates are likely to lead to low arterial $CO_2$ tension. Lower respiratory rates are associated with elevated arterial $CO_2$ tension and can cause

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peripheral vasodilation, worsening perfusion to the core, and cerebral vasodilation, potentially increasing intracranial pressure. Therefore, a ventilation rate of 10 breaths/min with a tidal volume of 10 mL/kg and a short inspiratory time of 1 second are recommended (I-A).

Ventilation technique for nonintubated patients

There have been no studies examining the efficacy of mouth-to-snout ventilation in dogs and cats, although there is a case report describing successful application of this technique in a dog with traumatic cervical spinal cord injury during transport to a veterinary hospital, suggesting that it can effectively maintain oxygenation and ventilation in this species.[46] In addition, there is some evidence that effective ventilation can be accomplished in dogs using noninvasive techniques such as tight-fitting masks, but obtaining an appropriate fit and seal can be challenging.[47,48] To accomplish mouth-to-snout ventilation, the rescuer holds the patient's mouth tightly closed, places his or her mouth over the patient's nares making a seal with the snout, and blows into the nares (see Figure 6). There have been no studies investigating the optimal compression-to-ventilation (C:V) ratio during CPR in nonintubated dogs and cats and the results of studies in other species are somewhat conflicting. The preponderance of the evidence suggests C:V ratios of at least 30:2 should be maintained. Until further studies are done evaluating higher C:V ratios, a C:V ratio of 30:2 in nonintubated dogs is recommended (I-B). To accomplish this, a series of 30 chest compressions at a rate of 100–120/min is performed, followed by a brief interruption of chest compressions during which 2 breaths are delivered quickly, after which another series of 30 chest compressions are delivered.

**Figure 6:** Mouth-to-snout breathing technique. The rescuer holds the patient's mouth closed with one hand, creates a seal over the patient's nares with his or her mouth, and blows into both nares to achieve a normal chest rise.

**Cycles of CPR**

Although there have been no studies in dogs and cats evaluating the optimal timing of CPR cycles, there are several high-quality prospective and retrospective studies in human medicine suggesting that uninterrupted cycles of BLS lasting 2 minutes result in better survival and neurological outcomes than shorter cycles with more frequent interruptions to chest compressions.[49,50] Therefore, chest compressions should be performed in 2-minute cycles without interruption in intubated patients when several rescuers are present, or in 2-minute cycles with brief interruptions after every 30 chest compressions to allow 2 quick breaths to be delivered using the mouth-to-snout technique if only 1 rescuer is present or the animal is not intubated (I-A). After each 2-minute cycle of compressions, the compressor should rotate to reduce lean and compromise of compression efficacy due to fatigue (I-B).

**Delay in starting CPR**

Rapid diagnosis of CPA is crucial because the deleterious effects of delaying the start of BLS are significant, with reductions in survival to discharge and neurologic status reported in numerous studies.[51–53] Although not examined in veterinary medicine, several human studies have documented the poor sensitivity of pulse palpation for diagnosis of CPA.[54,55] In addition, it is common for agonal breaths to be misidentified as spontaneous breathing in people in CPA.[56] There is also strong evidence in the human literature that less than 2% of patients in CPA experience any serious harm when BLS is started, likely because patients will commonly respond to the stimulation associated with CPR.[57] Therefore, aggressive administration of CPR in patients suspected of being in CPA is recommended, as the risk of injury due to CPR in patients not in CPA is low (I-B). When assessing patients that are apneic and unresponsive, a rapid airway, breathing, circulation (ABC) assessment lasting no more than 5–10 seconds is recommended. If there is any doubt as to whether the patient has experienced CPA, CPR should be initiated immediately while further assessment to support the diagnosis of CPA is accomplished simultaneously by other personnel or after an initial cycle (2 min) of CPR.

**Interposed abdominal compressions**

To facilitate venous return from the abdomen and improve cardiac output, the use of abdominal compressions