Cardiopulmonary Resuscitation
The RECOVER Guidelines

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Management of cardiopulmonary arrest (CPA) requires rapid patient assessment, with immediate institution of cardiopulmonary resuscitation (CPR).

Despite amazing advances in veterinary medicine over the last several years, over 90% of dogs and cats do not survive CPA.1 Human and veterinary CPA patients had similar outcomes before the institution of evidence-based guidelines and mandatory comprehensive training of human health care professionals.1 Now approximately 20% of humans survive in-hospital CPA.1

The improved outcomes in human survival are largely considered to be a product of the guidelines and standardized training mentioned above. With this in mind, the Reassessment Campaign on Veterinary Resuscitation (RECOVER) was developed. The RECOVER initiative had 2 goals:

• Develop evidence-based guidelines for dogs and cats experiencing CPA
• Identify knowledge gaps, or areas of CPA management that require further investigation.1

Both goals have the same ultimate objective: to improve the quality and outcomes of veterinary resuscitation efforts. The RECOVER initiative is an ongoing process, combining evaluation of available evidence to develop current best practices and reevaluation in the future.1

This article provides an overview of the guidelines; however, readers are encouraged to read the original manuscript (see Read the RECOVER Guidelines).

RECOVER GUIDELINES
The RECOVER guidelines are divided into 5 major topics, or domains, which provided structure for the development process:1

RECOVER Classes & Levels
Each guideline was assigned a class and level based on the initiative’s findings (Table).1 For example, the recommendation to perform chest compressions at 100 to 120 compressions per minute is a Class I, Level A recommendation, which means:2,4

• The benefit of performing chest compressions at 100 to 120 compressions per minute greatly outweighs the risk of performing them at another rate (Class)
• There are multiple, high-quality studies in multiple populations that support this recommendation (Level).

<table>
<thead>
<tr>
<th>Class</th>
<th>Benefit greatly outweighs the risk, and the intervention should be performed.</th>
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<tbody>
<tr>
<td>Class Ia</td>
<td>Benefit outweighs the risk, and the intervention is reasonable to perform.</td>
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<tr>
<td>Class IIb</td>
<td>Benefit is less clear, but unlikely to cause harm, and intervention may be considered.</td>
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<tr>
<td>Class III</td>
<td>Risk outweighs the benefit, and the intervention should not be performed.</td>
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<tr>
<th>Level</th>
<th>Multiple high quality studies in multiple populations support recommendation.</th>
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<tr>
<td>Level A</td>
<td>Few or no high quality studies in limited populations support recommendation.</td>
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<tr>
<td>Level C</td>
<td>Expert opinion or physiologic principle in very limited populations.</td>
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1. Preparedness and prevention
2. Basic life support (BLS)
3. Advanced life support (ALS)
4. Monitoring
5. Post cardiac arrest (PCA) care.

A total of 101 clinical guidelines were developed and published, with the guidelines organized by domain.1,2 The guidelines are further categorized by Class and Level (see RECOVER Classes & Levels).

DOMAIN 1: PREVENTION & PREPAREDNESS

Equipment & Training
The prevention and preparedness guidelines are directed at improving CPA equipment availability, training, and teamwork, and include ensuring:
• Staff are familiar with and utilize a standardized crash cart (Figure 1) or pre-stocked arrest stations (I-A)
• Cognitive aids are available for review during a CPR event (I-B)
• Staff receive comprehensive multimodal training, including simulations, followed by structured assessment to determine comprehension (I-A).2,3

Education & Leadership
Refresher training every 6 months is also recommended (I-A).2,3 The RECOVER authors developed a comprehensive, standardized online CPR course offered through Veritas (veritasdvm.com) and endorsed by the Veterinary Emergency and Critical Care Society and American College of Veterinary Emergency and Critical Care. ALS certification is currently in development.

Specific leadership training for those who may be leading a CPR (I-A) is recommended; both veterinarians and technicians are capable of leading such a team (IIb-B).2,3

Regular debriefing after a CPR event should take place to discuss what went well or wrong (I-A).2,3

CPR & Anesthesia
Prompt, high quality CPR should be provided for anesthetic-related CPA patients due to their significantly higher survival rate of 47% (I-B).2,3 Planning ahead for “worst case scenario” situation—by calculating emergency drug dosages and ensuring easy access to emergency equipment—before the anesthetic procedure can shave off precious seconds, allowing for rapid diagnosis of CPA and initiation of CPR.

DOMAIN 2: BASIC LIFE SUPPORT

The BLS domain focused on the importance of providing high-quality BLS to patients and, therefore, increasing the likelihood of return of spontaneous circulation (ROSC).1 For the RECOVER guidelines, BLS includes:

• Recognition of CPA
• Ventilation
• Chest compressions
• Airway management.

Recognition of CPA
If a patient is unresponsive and apneic, CPR should be initiated aggressively and immediately (I-B); wasting time for confirmation of CPA by pulse palpation or ECG is not recommended (III-B).2,4,5

Read the RECOVER Guidelines
The RECOVER initiative’s evidence-based guidelines were published in a special issue of the Journal of Veterinary Emergency and Critical Care in 2012; these guidelines can be downloaded for free at veccs.org.

The RECOVER initiative also developed 3 posters for use in clinical practice—CPR Emergency Drugs and Doses, CPR Algorithm, and PCA Algorithm.1,2 These posters are available for purchase at veccs.org. The Veterinary Emergency and Critical Care Society kindly granted permission for adapted versions of the CPR Emergency Drugs and Doses (page 32) and the CPR Algorithm (page 30) to be published in this article.

Chest Compressions
Chest compressions should be (Figure 2, page 26):
• Initiated in lateral recumbency (I-B)
• At a rate of 100 to 120 compressions per minute for both dogs and cats (I-A)
• Performed with chest compression depth being to ½ the width of the chest (IIa-A)
• Performed without leaning on the patient, allowing for full chest-wall recoil (I-A).2,4

CPR should be performed without interruption in 2-minute cycles to maximize coronary perfusion (I-A), with a change in compressor after each cycle in order to minimize fatigue (I-B).2,4

Ventilation & Airway Management
Regardless of compression technique, simultaneous ventilation should be provided via a cuffed endotracheal tube (with cuff inflated) at a rate of 10 breaths per minute, with a tidal volume of 10 mL/kg and an inspiratory time of 1 second (I-A).2,4

• Endotracheal intubation and ventilation should be performed simultaneously during chest compressions in lateral recumbency.2,4
• A laryngoscope should always be used and tube placement confirmed by visualization (tube passing through the arytenoids), auscultation, observing chest wall movement, and capnometry.2,4

Figure 1. A stocked crash cart
VENTILATION WITH 100% OXYGEN IS REASONABLE (IIa-B); however, use of room air may also be considered (IIb-B).2,4

In single-rescuer CPR, or if endotracheal intubation is unavailable, mouth-to-snout ventilation is recommended, with 2 breaths delivered after every 30 compressions (I-B).2,4 On the other hand, if sufficient trained personnel are available, interposed abdominal compressions may increase venous return and should be considered (IIa-B).2,4

**Vasopressor Therapy**

Vasopressor therapy is directed at increasing systemic vascular resistance in an effort to increase coronary and cerebral blood flow.6 Epinephrine, a nonselective adrenergic agonist, is the most commonly used vasopressor for CPR therapy; it affects both alpha and beta adrenergic receptors. Alpha adrenergic stimulation causes peripheral vasoconstriction. Beta adrenergic stimulation has positive inotropic and chronotropic effects, which increase myocardial oxygen demand and, therefore, may be detrimental in CPA patients.6

**Epinephrine**

- Low-dose epinephrine (0.01 mg/kg) is recommended for routine use every other BLS cycle (I-B) or every 3 to 5 minutes.2,6
- High-dose epinephrine (0.1 mg/kg) may be considered after prolonged CPR (IIb-B).

Experimental data in dogs demonstrated no benefit or reduced survival with use of high-dose epinephrine.2,6 Additionally, some research argues that high-dose epinephrine may resuscitate patients with irreversible, ischemic damage, which leads to ethical questions regarding use of high-dose epinephrine.6

**Vasopressin**

Unlike epinephrine, vasopressin does not affect heart rate or contractility and, therefore, does not increase myocardial oxygen demand. Vasopressin (0.8 U/kg) may be considered as a substitute or in combination with epinephrine (IIb-B) per the RECOVER guidelines.2,6 While vasopressin is advocated for use in CPR,2,6 research regarding its benefits is mixed. The only prospective veterinary study showed no benefit over epinephrine use.6,7

**Vagolytic Therapy**

During CPR, vagolytic therapy is usually provided by atropine.6 Limited data is available on atropine use in CPR, with no high-quality data available for dogs or cats.6

Current best-evidence suggests that:
- Atropine can be used in patients with CPA related to increased vagal tone and associated asystole or pulseless electrical activity (IIb-B).
- Routine use of atropine may be considered (IIb-C).2,6

In experimental studies in dogs, high-dose atropine is associated with poor outcomes; therefore, doses above 0.04 mg/kg should be avoided.6

**Electrical Cardioversion**

Electrical defibrillation is indicated in patients suffering from ventricular fibrillation (VF) (Figure 5) or pulseless ven-
tricular tachycardia (VT), and has been shown to significantly improve ROSC in these patients.6

RECOVER guidelines recommend:

• **Use of a biphasic defibrillator** (I-A) has been shown to be more effective than monophasic current.2–6
• **Single-shock therapy versus stacked-shock therapy** in order to minimize interruption of chest compressions (I-B) (However, evidence on stacked shocks versus single shocks in dogs and cats is lacking.6)

**Immediate defibrillation** for pulseless VT/VF of less than 4 minutes duration as there is minimal ischemia during this time (I-B).2–6

**Two-minute BLS cycle before defibrillation** for pulseless VT/VF of greater than 4 minutes duration in order to maximize coronary perfusion (I-B).2–6

**Immediate defibrillation** may be considered if VF or pulseless VT is diagnosed during an intercycle pause (IIb-B).2–6

If defibrillation is unsuccessful, escalation of defibrillation energy is reasonable (IIa-B).2–6 Readers with electrical defibrillators should view the RECOVER drug dosage chart specific to their defibrillator type for recommendations on energy selection (see veccs.org).2–6

### Additional ALS Therapies

**Medications**

Routine use of IV fluids, magnesium, corticosteroids, or calcium is not recommended (III-B, IIb-B, III-C, III-B, respectively), but these drugs may be beneficial in specific patient populations.2–6 Use of these drugs, as well as amiodarone, lidocaine, sodium bicarbonate, reversal agents, and impedance threshold devices are thoroughly covered in the RECOVER guidelines.2–6

Of note, naloxone should be administered to CPA patients with suspected opioid toxicity (I-B), and may be considered in all patients that recently received opioids (IIb-B).2–6 If IV access is unavailable, intraosseous access is obtained; if intraosseous access is unavailable, intratracheal administration may be performed (IIb-B) (see Intratracheal Administration & Drugs).2–6

**Procedures**

Open-chest CPR may be considered in cases of intrathoracic disease if appropriate resources are available for the intensive PCA care these patients will require (IIb-C).2–6

### DOMAIN 4: CPR MONITORING

Proper monitoring plays a critical role in patients at risk for, suffering from, or recovering from CPA. Monitoring involves understanding the monitor’s limitations, and correctly interpreting the information obtained. Monitoring is further subdivided into:

• **Diagnosing CPA and confirmation of endotracheal intubation**
• **Monitoring during CPR**
• **PCA monitoring**

**Diagnosing CPA**

Rapid identification of a patient requiring CPR allows more rapid institution of BLS and ALS, which increases the chance of ROSC.

**Pulse Palpation**

Pulse palpation to diagnose CPA in unresponsive, apneic patients is not recommended (III-B) given that:2–5

• Lack of a palpable pulse does not always indicate CPA

• Length of time it takes to determine if a patient is pulseless can delay initiation of CPR.

Human research has shown that diagnosis of CPA by pulse palpation is not reliable, with only 2% of professionals diagnosing a pulseless patient in less than 10 seconds.2–5 For this reason, current human guidelines limit pulse palpation by health care professionals to less than 10 seconds before BLS measures are initiated.2–5

**Electrocardiography & Blood Pressure Measurement**

Electrocardiography (ECG) or Doppler blood pressure measurement to diagnose CPA in unresponsive, apneic patients is not recommended (III-C) due to the reasons listed above for pulse palpation.2–5

However, ECG or Doppler blood pressure measurement to detect impending CPA is reasonable to perform in at-risk patients (IIa-C) (Figure 6). Evidence of an ECG rhythm does not always indicate a perfusing rhythm; absence of a Doppler signal does not always indicate CPA.2–5

In patients with VF, waveform analysis may provide prognostic information, with coarse VF (high amplitude) associated with better outcomes than fine VF (low amplitude) (IIb-B).2–4

**End-Tidal Carbon Dioxide Monitoring**

End-tidal carbon dioxide (EtCO₂) monitoring is recommended for intubated patients at risk of CPA (I-A).2–5 EtCO₂ correlates well with cardiac output and rapidly drops to zero at CPA onset.19 Additional reasons for rapid decreases include:

• Leaking anesthetic circuit
• Airway obstruction
• Massive pulmonary thromboembolism
• Severe hypotension (may indicate impending CPA).

EtCO₂ readings should be interpreted cautiously and in conjunction with other monitoring parameters. Additionally, many arrests in dogs and cats are asphyxial in nature (due to respiratory failure, hypoxemia, or hypercarbia), which may cause elevated EtCO₂ readings immediately following endotracheal intubation and manual ventilation.2–5
Therefore, immediate post-intubation EtCO₂ readings should not be used to diagnose CPA because elevated values may lead to the incorrect conclusion that the patient is not in CPA (II-B).²,⁵ Similarly, an EtCO₂ reading may not be obtained (or a reading of zero may be obtained) immediately following endotracheal intubation in a patient suffering from CPA.⁵

**Confirmation of Endotracheal Intubation**

For the reasons stated above, use of EtCO₂ alone to verify endotracheal intubation is not recommended (II-B).²,⁵ Verification should be accomplished by all 3 of the following (IIa-B):²,⁵

- Laryngoscopy
- Bilateral lung sounds and chest movement
- EtCO₂ readings.

**Monitoring during CPR**

**Electrocardiography**

ECG use during CPR is recommended for rhythm evaluation, but should (I-C):²,⁵

- Only be evaluated during intercycle pauses
- Not delay resumption of chest compressions.

**End-Tidal Carbon Dioxide Monitoring**

Since EtCO₂ correlates well with cardiac output, EtCO₂ monitoring during CPR to evaluate efficacy of chest compressions is reasonable if minute ventilation is held constant (IIa-B).²,⁵ Additionally, ROSC will cause a sharp increase in EtCO₂, and EtCO₂ monitoring should be used as an indicator of ROSC during CPR (I-A).²,⁵
Blood Gas & Electrolyte Analysis

Blood gas and electrolyte analysis may be helpful in evaluating CPR effectiveness and identifying underlying causes.5

- Mixed-venous or central-venous blood gas analysis may more accurately reflect tissue acid–base status during CPA; use of such values to evaluate CPR effectiveness may be considered (IIb-B). Increased PCO2, increasing lactate, or decreasing pH may indicate inadequate compression or ventilation technique; a change in technique should be considered.

- Because CPA causes poor peripheral perfusion, peripheral venous or arterial blood gas analysis is not recommended to evaluate CPR effectiveness (III-A). CPA may be caused by significant electrolyte derangements.2,5 If underlying electrolyte derangements are suspected or known, electrolyte analysis to guide therapy is recommended (I-C). If underlying electrolyte derangements are suspected or known, electrolyte analysis to guide therapy is recommended (I-C).

- Treatment of documented hypokalemia may be considered but clear benefit has not been shown (IIb-C).2,6

Real-Time CPR Feedback

While widely used in human medicine but not in veterinary medicine, real-time CPR feedback devices that improve CPR effectiveness may be useful in veterinary CPR (IIa-C).2

PCA Monitoring

While limited data is available regarding PCA monitoring, the RECOVER authors recommend use of monitoring appropriate for a critically-ill patient.2,5 This monitoring should detect impending recurrence of CPA as well as guide therapy to avoid its recurrence (I-C).2,5

Minimum monitoring should consist of (I-B):2,5

- Continuous ECG
- Arterial blood pressure measurement
- Body temperature
- Oxygenation/ventilation status.

Additional clinicopathologic monitoring, which is dependent on patient comorbidities, may include blood glucose and lactate concentrations, although the benefit of monitoring these parameters in all PCA patients is not clear (IIb-B).2,5

DOMAIN 5: POST CARDIAC ARREST CARE

Excellent PCA care is required to minimize the likelihood of CPA recurrence and maximize the chance of a patient returning home with its owners. One study showed that over 50% of dogs and cats will suffer another CPA event while in the hospital, which correlates with human data on the subject.5 Patients with CPA who experience ROSC are likely to have:

- Some degree of hemodynamic instability related to vasopressor therapy during CPR or the underlying cause of CPA
- Cardiac ischemia
- Systemic inflammatory response syndrome (hallmarked by inflammatory system activation and excess circulating cytokines)
- Anoxic brain injury.

Fluid Therapy

When titrating IV fluids and vasopressors, the primary endpoints of central venous oxygen saturation (> 70%) and lactate (< 2.5 mmol/L) coupled with the following secondary endpoints may be considered (IIb-B):2,10,11

- Arterial blood pressure (systolic, 100–200 mm Hg; mean arterial pressure, 80–120 mm Hg)
- Central venous pressure (10 cm H2O)
- Packed cell volume (> 25%)
- Arterial oxygen saturation (SpO2 94–98%; PaO2, 80–100 mm Hg).

However, routine large-volume IV fluid administration is not recommended unless hypovolemia is strongly suspected or documented (III-C).2,10

Oxygen Supplementation

Oxygen supplementation should be titrated to produce normoxia (PaO2, 80–100 mmHg, or SpO2, 94%–98%), but
hyperoxia should be avoided (I-A). While routine, mechanical ventilation of all PCA patients is not recommended (II-B). Mechanical ventilation of hypoventilating CPA patients is reasonable (IIa-C).

**Referral to Specialty Center**

Several human studies demonstrate improved survival of patients treated by highly-trained professionals with experience in PCA care and in facilities with higher staff-to-patient ratios.

Veterinary research on the subject is lacking; however, research has indicated that patients were more likely to survive when drugs, such as dopamine and vasopressin, were available and more staff were involved in resuscitation efforts.

For these reasons, it is reasonable to refer a PCA patient to a facility with (IIa-B).

- 24-hour care
- Higher staff-to-patient ratios
- Advanced critical care capabilities.

Many facilities have critical care transportation available. Contact your local emergency/referral center for critical care transportation options.

**Other Recommendations**

The RECOVER guidelines outline several other recommendations for PCA care, including:

- Therapeutic hypothermia
- PCA hypertension
- Corticosteroids
- Seizure prophylaxis
- Osmotic agents

**REFERENCES**


**FIGURE CREDITS**

Figures 2 through 4 courtesy David Liss, AS, BA, RVT, VTS (Emergency Critical Care & Small Animal Internal Medicine), CVPM

ALS = advanced life support; BLS = basic life support; CPA = cardiopulmonary arrest; CPR = cardiopulmonary resuscitation; ECG = electrocardiography; EGDT = early goal-directed therapy; EtCO2 = end-tidal carbon dioxide; ILCOR = International Liaison Committee on Resuscitation; PCA = post cardiac arrest; RECOVER = Reassessment Campaign on Veterinary Resuscitation; ROSC = return of spontaneous circulation; VF = ventricular fibrillation; VT = ventricular tachycardia

See Read the RECOVER Guidelines, page 25, to access more information on these recommendations.

**IN SUMMARY**

The RECOVER initiative created the first consensus guidelines on veterinary resuscitation, which provide an in-depth look at the available evidence on veterinary resuscitation. Readers are encouraged to review these guidelines in their entirety as well as seek standardized training in the area of veterinary resuscitation. These consensus guidelines combined with standardized training allow veterinary professionals to provide the best standard of care for CPA patients.

**EARLY GOAL DIRECTED THERAPY**

Most PCA care recommended by the RECOVER initiative pertains to early goal-directed therapy (EGDT). It has been shown to improve outcomes in human patients, though veterinary data on the subject is lacking.

EGDT is directed at:
- Optimizing hemodynamics to maximize perfusion to organs
- Minimizing the likelihood of multiple-organ dysfunction syndrome.

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