

# RECOVER evidence and knowledge gap analysis on veterinary CPR.

## Part 7: Clinical guidelines

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- Preparedness and Prevention
  - 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)
  - Equipment and supply inaccessibility or failure has been implicated in delays in initiation of CPR in up to 18% of CPA cases
  - The location, storage, and content of resuscitation equipment should be standardized and regularly audited
  - The presence of cognitive aids such as checklists, algorithm charts, and dosing charts has been shown to improve compliance with CPR guidelines
  - CPR training
    - Include both didactic components targeted at cognitive performance and opportunities to practice hands-on skills with quality feedback
    - Refresher training at least every 6 months is recommended to reduce the risk of the decay of skills
    - Improved learning outcomes have been documented when CPR training culminates in performance testing
      - Regardless of the methods used for initial and refresher training, structured assessment after CPR training is recommended
  - Open, honest discussion about opportunities for improvement immediately after a CPR attempt can lead to significant enhancement in CPR performance
  - There does not appear to be a beneficial effect on outcome of CPR from the presence of a physician acting as team leader
    - Veterinarians or technicians may be considered as leaders of a CPR team

- Communication and team skills training can improve the effectiveness of a CPR attempt
  - Specific leadership training is recommended for individuals who may need to lead in a CPR attempt
- Crucial roles of the team leader include
  - Distributing tasks to other team members
  - 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
  - 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
- Enhanced team performance with closed loop communication
  - Closed loop communication is accomplished by a clear, directed order being given to one team member by another
  - The receiving team member repeats the order back to the requestor to verify the accuracy of the receiver's perception
  - This 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
    - 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
  - Chest compressions
    - Initiated ASAP
    - Airway and ventilation management should not delay commencement of chest compressions
    - Lateral recumbency
      - Experimental evidence suggesting higher left ventricular pressures and aortic flow in dogs in lateral recumbency as compared to dorsal recumbency
      - Clinical data in dogs and cats showing higher rates of ROSC associated with compressions performed in lateral recumbency
    - 2 main theories describing the mechanism by which external chest compressions lead to blood flow during CPR
      - Due to variation in chest conformation in veterinary patients
      - The cardiac pump theory

- Cardiac ventricles are directly compressed between the sternum and the spine in patients in dorsal recumbency or between the ribs in patients in lateral recumbency
- In 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
  - In dogs with this conformation, chest compressions with the hands positioned directly over the heart is reasonable
- The thoracic pump theory
  - 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
  - Majority of medium, large, and giant breed dogs with rounded chests
    - Direct compression of the heart with external chest compressions is unlikely
    - Chest compressions over the widest portion of the chest will allow maximal increases in intrathoracic pressure
- In dogs with barrel-chested conformations, such as English bulldogs, sternal compressions in dorsal recumbency, directed at the cardiac pump theory, may be considered
- Increased rates of ROSC and 24-hour survival with compression rates of 100–120/min in cats and dogs
- Deep chest compressions of 1/3–1/2 the width of the thorax in most patients
- Observational studies in people have shown a high prevalence of leaning during CPR
  - Recommended that full chest wall recoil is allowed between compressions
  - Reduced coronary and cerebral perfusion when full elastic recoil between chest compressions is not permitted
- Ventilation
  - Both hypoxia and hypercapnia reduce the likelihood of ROSC
    - Securing a patent airway and providing ventilation are essential during CPR
  - 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

- 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
- Higher respiratory rates, longer inspiratory times, and higher tidal volumes lead to
  - Impaired venous return due to increased mean intrathoracic pressure
  - Decreased cerebral and coronary perfusion due to vasoconstriction
  - Have been documented to lead to poorer outcomes in people during CPR
- Reduced cardiac output achieved during CPR (approximately 25–30% or normal) -> decreased pulmonary blood flow -> lead to low arterial CO<sub>2</sub> tension
- Lower respiratory rates are associated with elevated arterial CO<sub>2</sub> tension and can cause peripheral vasodilation, worsening perfusion to the core, and cerebral vasodilation, potentially increasing intracranial pressure
- Ventilation rate of 10 breaths/min with a tidal volume of 10mL/kg and a short inspiratory time of 1 second are recommended
- Mouth to snout ventilation:
  - Compression-to-ventilation (C:V) ratio during CPR in nonintubated
    - C:V ratios of at least 30:2 should be maintained
- Tight fitting face masks
- Cycles of CPR
  - Uninterrupted cycles of BLS lasting 2 minutes result in better survival and neurological outcomes than shorter cycles with more frequent interruptions to chest compressions
  - If only 1 rescuer present: 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
  - After each 2-minute cycle of compressions, the compressor should rotate to reduce lean and compromise of compression efficacy due to fatigue
- 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
  - Poor sensitivity of pulse palpation for diagnosis of CPA
  - Common for agonal breaths to be misidentified as spontaneous breathing in people in CPA

- Strong evidence in the human literature that less than 2% of patients NOT in CPA experience any serious harm when BLS is started, likely because patients will commonly respond to the stimulation associated with CPR
- 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
- 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
  - Facilitates venous return from the abdomen and improves cardiac output interposed with chest compressions has been extensively studied in experimental canine and porcine models as well as in human clinical trials
  - Minimal evidence of abdominal trauma due to the use of interposed abdominal compressions when rescuers are trained in the technique
    - The use of interposed abdominal compressions in dogs and cats with CPA is reasonable when sufficient personnel trained in its use are available
- ALS
  - Encompasses the components of veterinary CPR performed after BLS has been initiated and until ROSC is achieved
  - Includes therapy with vasopressors, positive inotropes, and anticholinergics, correction of electrolyte and acid-base disturbances and volume deficits, and prompt defibrillation
  - Vasopressors are an essential component of ALS drug therapy
    - Generate adequate coronary and cerebral perfusion pressures during CPR by creating high peripheral vascular resistance
    - Directs more of the circulating volume to the central circulation
  - Epinephrine
    - Catecholamine that acts as a nonspecific adrenergic agonist
    - Also has  $\alpha_1$  adrenergic activity
      - Inotropic and chronotropic effects of which are likely less crucial and may be harmful when treating CPA due to increased myocardial oxygen demand, exacerbating myocardial ischemia, and predisposing to arrhythmias once ROSC is achieved
    - Higher doses (0.1 mg/kg IV) of epinephrine have been associated with increased rates of ROSC, they have not been associated with increased survival to discharge, possibly due to the exaggerated adrenergic effects
    - Use of low-dose (0.01 mg/kg IV) epinephrine administered every 3–5 minutes early in CPR is recommended, but high-dose (0.1mg/kg IV) epinephrine may be considered after prolonged CPR

- To minimize underdosing or overdosing during CPR, this drug should be administered during every other cycle of BLS
  - Vasopressin
    - Vasopressor effects are mediated through the peripheral V1 receptor located on vascular smooth muscle
    - MOA is completely independent of the  $\alpha_1$  effects of epinephrine
    - Unlike  $\alpha_1$  receptors, V1 receptors remain responsive in the face of an acidic pH, and vasopressin has no inotropic or chronotropic effects that could worsen myocardial ischemia
    - Evidence of the efficacy of vasopressin compared to epinephrine in dogs and cats during CPR is limited
    - The use of vasopressin (0.8 U/kg IV) as a substitute or in combination with epinephrine every 3–5 minutes may be considered
  - Atropine
    - Parasympatholytic agent that has been used widely in patients with CPR
    - Many studies have largely shown no beneficial or detrimental effect of its use at standard dosing (0.04 mg/kg) in CPR
    - Higher doses (0.1, 0.2, 0.4 mg/kg) have been associated with worse outcomes in an experimental study in dogs
    - Although not strongly supported by the literature, atropine is most likely to be of use in dogs and cats with asystole or PEA associated with high vagal tone
    - Due to the lack of any clear detrimental effect, routine use of atropine (0.04 mg/kg IV) during CPR in dogs and cats may be considered
- Defibrillation
  - Electrical defibrillation is the most effective therapy for ventricular fibrillation
  - Current guidelines in human medicine recommend that “shockable” rhythms (VF and pulseless VT) be promptly treated with electrical defibrillation if available
  - VF and VT are the result of abnormal pacing of groups of ventricular myocardial cells by the myocardial cells themselves rather than the pacemakers, the goal of electrical defibrillation is to depolarize as many of these cells as possible, driving them into their refractory period, and stopping the random electrical and uncoordinated mechanical activity
  - If this is successful, the pacemakers may then begin driving the myocardial cells (establishing a sinus rhythm), or the patient may develop asystole
    - Either of these outcomes is considered a successful defibrillation
  - In the absence of an electrical defibrillator, mechanical defibrillation may be accomplished with a precordial thump, but the efficacy of this intervention is likely poor
  - Electrical defibrillation
    - Modern defibrillators are monophasic (a unidirectional current flows from one electrode to the other) or biphasic (current initially flows in one direction, then reverses and flows in the other direction)

- Biphasic defibrillators have been shown to more effectively terminate VF at lower defibrillation energy than monophasic defibrillators, in turn leading to less myocardial injury
  - If the first shock is unsuccessful, there is some evidence from experimental and clinical human studies that increasing the defibrillation energy may increase the rate of success
    - No studies have shown a direct detrimental effect of dose escalation, there is a risk of increased myocardial damage with increasing defibrillation dose
    - In dogs and cats with VF/pulseless VT, defibrillation energy escalation (eg, 50% dose increase) is reasonable if the first countershock is unsuccessful
  - To maximize current through the ventricles, the paddles should be placed on opposite sides of the thorax approximately over the costochondral junction directly over the heart
  - Defibrillator paste or gel should be liberally applied to the paddles, which must be pressed firmly against the chest to establish contact with the skin
  - Once the defibrillator is charged, the operator must ensure that no personnel are making any contact with the patient or the table
    - Electrical defibrillation should not be attempted if alcohol is on the fur due to the high risk of fire
- Timing of electrical defibrillation
  - After a loss of perfusion, the ischemic heart passes through 3 phases
    - The electrical phase during which minimal ischemic damage occurs, lasting 4 minutes
    - The circulatory phase during which reversible ischemic damage occurs, lasting 6 minutes
    - The metabolic phase during which potentially irreversible ischemic damage begins to occur, and which may necessitate more advanced techniques such as therapeutic hypothermia and cardiopulmonary by-pass to reverse
  - Immediate defibrillation is recommended in cases of CPA due to VF/pulseless VT of duration of 4 minutes or less or if VF is diagnosed during a rhythm check between cycles of CPR
  - If the patient is known or suspected to have been in VF/pulseless VT for greater than 4 minutes and is beyond the electrical phase, energy substrates are likely depleted, and the patient will most likely benefit from a 2-minute cycle of BLS before defibrillation
  - A single shock was followed by a full 2-minute cycle of CPR before reevaluating the ECG and defibrillating again is recommended (vs older recommendation of three stacked shocks)
- Precordial thump

- A method of mechanical defibrillation, accomplished by striking the patient with the heel of the hand directly over the heart
  - More recent studies have documented minimal efficacy of this technique for treatment of VF
  - A precordial thump should only be considered if an electrical defibrillator is not available
- Antiarrhythmic drug therapy
  - Only amiodarone has shown consistent benefit and may be considered in cases of VF/pulseless VT resistant to electrical defibrillation
  - Some studies have also shown a beneficial effect of lidocaine in patients with refractory VF/pulseless VT, although one experimental study showed an increase in the energy required to successfully defibrillate dogs with induced VF
    - Occurs when using monophasic defibrillators, but not when using biphasic defibrillators
  - Given the uniformly grave prognosis for patients in refractory VF/pulseless VT, when amiodarone is not available, lidocaine may be considered in cases of pulseless VT/VF resistant to defibrillation, especially when a biphasic defibrillator is used
  - Routine use of magnesium sulfate is not recommended for cardiac arrhythmias during CPR, although it may be considered for treatment of torsades de pointes
  - Use of antiarrhythmic agents may be considered as adjunctive therapy in refractory cases, but electrical defibrillation is the recommended primary treatment for VF/pulseless VT
- Reversal agents
  - Only naloxone has been evaluated for use in patients in CPA
  - Evidence of a beneficial effect is limited, though in cases of opioid toxicity, naloxone should be used during CPR
    - Even in the absence of opioid toxicity, the data available suggest that in cases of recent opioid administration, the use of naloxone during CPR may be considered
    - No specific studies have evaluated the use of other reversal agents, in dogs and cats that have received reversible anesthetic/sedative medication, administering reversal agents during CPR may be considered
- Electrolyte therapy
  - Calcium
    - Although hypocalcemia commonly develops in patients with prolonged CPA, the majority of studies investigating the utility of routine calcium administration during CPR demonstrated no effect on outcome or worse outcomes, suggesting that IV calcium should not be used routinely during CPR
    - Given the importance of calcium for skeletal and smooth muscle contraction, intravenous calcium may be considered in dogs and cats with documented moderate to severe hypocalcemia during CPR
  - Potassium



- Hyperkalemia develops commonly in patients with prolonged CPA, and treatment of hyperkalemia during CPR using hemodialysis is associated with improved outcomes
  - Documented hyperkalemia should be treated during CPR
- Corticosteroids
  - Lack of compelling evidence of a beneficial effect and the potential for deleterious side effects from corticosteroids, especially in animals with poor perfusion, the routine use of corticosteroids during CPR is not recommended
- Impedance threshold device
  - Have been shown to improve hemodynamics in anesthetized dogs by increasing venous return due to decreased intrathoracic pressure
  - Studies have failed to demonstrate any improvement in ROSC or survival to discharge in people in CPA with the use of an ITD
  - The device requires chest wall recoil to generate a “cracking pressure” of at least –12 cm H<sub>2</sub>O, and use is not feasible in small dogs or cats weighing less than 10 kg because they are unlikely to be capable of generating those types of pressures from elastic recoil alone
  - Use of an ITD to enhance circulation is reasonable in animals > 10 kg, but studies to date have not demonstrated a survival advantage with their use
- Alkalinization therapy
  - Severe acidemia due to metabolic acidosis is common in patients with CPA, and this acid-base disturbance can lead to detrimental metabolic dysfunction
  - Beneficial with prolonged (>10 min) duration of CPA?
  - Worse outcome and metabolic derangements in early CPA
  - Given the evidence available, bicarbonate therapy after prolonged CPA of greater than 10–15 minutes with administration of 1 mEq/kg of sodium bicarbonate may be considered
- Intratracheal drug administration
  - IV and IO administration of resuscitation drugs is preferred over intratracheal administration, and is associated with improved survival from CPA
  - Use of the intratracheal route for epinephrine, vasopressin, or atropine may be considered
  - The optimal location within the respiratory tract for administration of these drugs is not fully understood, nor is the optimal drug dose, or volume and type of diluent  
There is some evidence that use of a long catheter advanced to or beyond the level of the carina results in higher plasma concentrations of drug than shorter catheters or direct instillation of drug into the ETT
  - If the intratracheal route is used for drug administration during CPR, drugs should be diluted with saline or sterile water and administered via a catheter longer than the ETT
  - Increased doses of up to 10× standard doses (in the case of epinephrine) have been recommended, but data regarding optimal dosing are lacking
- Supplemental oxygen administration

- Presence of hyperoxia may predispose patients to increased concentrations of reactive oxygen species, worsening tissue damage during CPR
- Evidence suggests decreased neurologic injury when oxygen supplementation is titrated to achieve normoxemia (PaO<sub>2</sub> of 80–105mmHg) compared to animals that are hyperoxemic
- In the absence of arterial blood gas data, the risks of hypoxemia likely outweigh the risks of hyperoxemia, and the use of an FiO<sub>2</sub> of 100% is reasonable
- IV fluid administration
  - Multiple experimental studies in animals have shown that fluid administration during CPR in animals that are euvolemic is associated with decreased coronary perfusion pressure
    - Likely due to the fact that the administration of IV fluids predominantly increases central venous pressure, opposing blood flow to the coronary and cerebral circulation
    - Patients with preexisting hypovolemia are likely to benefit from increased circulating volume during CPR, and administration of intravenous fluids in these patients is reasonable
- Open-chest CPR
  - Open-chest CPR is more effective than closed-chest CPR in restoring ROSC and promoting a good outcome in canine models of VF
    - Requires significant resources, is a procedure that requires a skillful veterinary team, and demands advanced PCA supportive care
    - In cases of significant intrathoracic disease, such as tension pneumothorax or pericardial effusion, promptly performing open-chest CPR may be considered
- Diagnosing CPA
  - Early initiation of CPR in patients that have experienced CPA is crucial for a successful outcome
    - Rapid initial airway, breathing, and circulation (ABC) assessment of any unresponsive, apneic patient to rule out CPA is essential
  - Pulse palpation is widely employed by veterinary practitioners as part of their initial assessment of any acutely presenting patient
  - Many human studies have shown that pulse palpation is an unreliable technique to confirm CPA, and that only 2% of rescuers correctly recognize the lack of a pulse within 10 seconds
  - The specificity of pulse palpation for diagnosis of CPA is approximately 65%, meaning that in 35% of cases, rescuers believed a pulse was present when one was not
  - The use of pulse palpation to support a diagnosis of CPA before initiating CPR is not recommended
  - Evidence that Doppler blood pressure monitoring may be useful for early recognition of CPA in patients at risk of arrest
    - Given the time associated with placing a Doppler sensor and acquiring a signal, in unresponsive, apneic dogs and cats, the use of Doppler to support a diagnosis of CPA before initiating CPR is not recommended

- Some ECG rhythms (eg, PEA, pulseless VT) may appear as perfusing rhythms despite the presence of CPA, and thus have the potential to delay the start of BLS
  - In unresponsive, apneic dogs and cats, the use of ECG as the sole parameter to accept or reject a diagnosis of CPA before initiating CPR is not recommended
- Initial EtCO<sub>2</sub> values (ie, the first values obtained after endotracheal intubation) have been shown to be unreliable for diagnosing CPA in dogs, pigs, and humans
  - In dogs with asphyxial cardiac arrest, initial EtCO<sub>2</sub> can be higher than the prearrest mean value
- Verification of endotracheal intubation
  - RECOVER guidelines recommend early intubation and ventilation in dogs and cats in CPA because of the ease with which most dogs and cats may be intubated and the higher prevalence of asphyxial arrest in these species
  - Verification that the ETT is correctly placed into the trachea as opposed to the esophagus is crucial
  - EtCO<sub>2</sub> monitoring has been used to assist in this verification process because CO<sub>2</sub> will not be consistently measured if the esophagus has been intubated
    - EtCO<sub>2</sub> monitoring is likely a valuable adjunct for verification of correct ETT placement in conjunction with direct visualization, auscultation, or observation of chest excursions in dogs and cats with CPA to verify correct ETT placement, but should not be used as a sole measure of correct placement
- Electrocardiogram
  - Susceptible to artifact during chest compressions
  - Evaluation of the ECG during intercycle pauses is recommended to obtain an accurate rhythm diagnosis and to guide ALS therapy
  - ECG evaluation must be done rapidly, and should not significantly delay resumption of chest compressions
  - Chest compressions should not be stopped during a complete 2-minute cycle of CPR to allow ECG interpretation
  - For patients in VF, rapid assessment of the ECG to determine if VF has resolved immediately after defibrillation is reasonable, but should minimally delay resumption of chest compressions for another cycle
    - Several studies have demonstrated no harm in these short delays in chest compressions
    - There is also evidence that 72% of patients will develop recurrent VF within 60 seconds of defibrillation while only 20% have evidence of recurrence within 6 seconds, suggesting that an ECG rhythm diagnosis immediately after defibrillation may not be an accurate reflection of sustained defibrillation success
- End tidal CO<sub>2</sub>
  - There is strong evidence supporting the use of EtCO<sub>2</sub> monitoring during CPR as an early indicator of ROSC and as a measure of efficacy of CPR

- May allow rescuers to adjust their treatment to maximize perfusion during CPR
- As EtCO<sub>2</sub> is affected by both pulmonary perfusion and minute ventilation, rescuers should be cautious to maintain constant minute ventilation when using EtCO<sub>2</sub> measurement for these purposes
- Multiple high-quality studies support the conclusion that sudden increases in EtCO<sub>2</sub> occur rapidly with ROSC due to an increase in pulmonary blood flow
- Limited data in dogs and cats suggesting that higher EtCO<sub>2</sub> values during CPR (>15 mm Hg in dogs, >20mmHg in cats) may be associated with an increased rate of ROSC

## Review

### The role of Levosimendan in cardiopulmonary resuscitation



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- Levosimendan is a unique inodilator with cardioprotective and neuroprotective effects
  - Treatment of choice in acute and decompensated chronic heart failure states
  - May be beneficial in the treatment of post-operative myocardial dysfunction following cardiac surgery, right ventricular failure and sepsis
  - Several studies suggest that the administration of Levosimendan during CPR and the post-resuscitation phase is associated with increased rates of ROSC as well as improved post-resuscitation myocardial function and neurological outcome
- Levosimendan's actions
  - Non-adrenergic inotropic calcium sensitizer that exerts its inotropic effect principally via binding to the Ca<sup>2+</sup> saturated troponin C of the myocardial thin filament
  - Enhance calcium responsiveness of the myofilaments potentiates cross-bridge formation, thereby augmenting contractility and enhancing relaxation
  - It has anti-stunning effects and reduces post-resuscitation myocardial dysfunction
  - Vasodilatory and anti-ischemic effects mediated by the opening of ATP-sensitive potassium channels in the sarcolemmal membrane of vascular smooth muscle cells
    - Induces vasodilation in systemic circulation and lowers both preload and afterload, improving tissue perfusion
    - Exerts some vasodilator effects on the coronary and cerebral circulation
    - Protect mitochondria from ischemia–reperfusion injury
    - Exerts some anti-inflammatory effects
- Use has been associated with both hypotension and hypokalemia, and has been associated with increased frequency of both atrial fibrillation and ventricular tachycardia
- Levosimendan during CPR

- In contrast to classic inotropic agents, Levosimendan elevates the oxygen availability to the myocardium during CPR, reducing the pressure of the right atrium due to its peripheral vasodilatory effect, which leads to higher CPP
- The enhanced myocardial contractility produced by Levosimendan along with the higher CPP allows the maintenance of an adequate cardiac output during resuscitation
- Direct vasodilator effect on coronary arteries and enhances coronary blood flow
- Prolonged CPA is accompanied with global hypoxia and severe acidosis that depresses myocardial function by impairing the responsiveness of myofilaments to  $\text{Ca}^{2+}$
- Although catecholamines remain the mainstay of treatment in the setting of prolonged CPA, studies have shown that acidosis limits their effectiveness to reverse acidosis-induced myocardial contractile impairment
  - Prolonged CPA leads to beta-adrenergic receptor down-regulation, reduction of formation of cAMP and inhibition of  $\text{Ca}^{2+}$  exchange
  - Catecholamine resistant CA lead to the false need for multiple repetitive doses of, which is an independent predictor of poor neurologic outcome

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## **Randomized, Blinded Comparison of Epinephrine and Vasopressin for Treatment of Naturally Occurring Cardiopulmonary Arrest in Dogs**

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- **Background:**
  - Administration of epinephrine during CPR is recommended for treatment of CPA in dogs. Administration of epinephrine during CPR might be associated with deleterious adverse effects. Vasopressin has been studied for use in CPR as an alternative.
- **Hypothesis:**
  - That administration of vasopressin instead of epinephrine with standard CPR techniques will result in improved outcome.
- **Animals:**
  - Seventy-seven client-owned dogs identified in the ER/ICU with CPA were eligible for inclusion.
- **Methods:**
  - Randomized, prospective clinical study. Dogs were randomized to receive epinephrine (0.01–0.02mg/kg) or vasopressin (0.5–1 U/kg) in a blinded fashion. Attending veterinarians were asked to adhere to standardized CPR protocol for the 1st 6 minutes of CPR, during which time doses of the study drug were administered at 3-minute intervals.
- **Results:**

- A total of 60 dogs completed this study with 31 receiving epinephrine and 29 receiving vasopressin. Overall rate of return of spontaneous circulation (ROSC) was 60% (36/60), 32% (19/60) of dogs survived to 20 minutes, 18% (11/60) survived to 1 hour. No difference was seen in rates of ROSC between the 2 groups ( $P = .20$ ). Dogs receiving epinephrine were more likely to survive to 1 hour (odds ratio 5.86; 95% CI: 1.19–28.95) than those receiving vasopressin ( $P = .027$ ).
- Conclusions and Clinical Importance:
  - ROSC was similar in dogs receiving epinephrine or vasopressin. In this study, a survival advantage at 1 hour was seen in those animals receiving epinephrine. No advantage of routine use of vasopressin over epinephrine was detected. Further studies are required to examine subgroups of dogs that might benefit from specific interventions.

## Original Study

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# Comparison of time to obtain intraosseous versus jugular venous catheterization on canine cadavers

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- Objective
  - To compare the time required and the success rate of personnel with 4 different levels of experience to place a humeral intraosseous (IO) catheter versus a jugular venous catheter (IV) in cadaver dogs
- Design
  - Prospective study
- Setting
  - Veterinary university teaching hospital
- Interventions
  - Canine cadavers from recently euthanized dogs were obtained from the cadaver donation program between May and December 2014. Catheter placers (CPs) with varying clinical experience, including a first year emergency and critical care resident, a senior emergency veterinary technician (VTS certified), a final year veterinary student, and an ACVECC diplomate, participated in the study. Each CP catheterized a total of 6 dogs so that there was a total of 6 IO and 6 IV catheters placed, by automatic rotary insertion device (with an EZ-IO gun) and vascular cut-down technique, respectively, for each CP. Time for IO catheterization and IV catheterization

was recorded and compared. The success of IO catheterization and IV catheterization was verified by visualization of an injection of iodinated contrast material under fluoroscopy within the medullary cavity or vessel.

- Animals
  - Twenty-four canine cadavers.
- Measurements and Main Results
  - Outcomes were analyzed using the Wilcoxon rank-sum test and the Kruskal–Wallis one-way analysis of variance. The median time for all IO catheterization operators was faster at 55.4 seconds (range 15.0–153.0 s) compared to the median time for all IV catheterization operators at 217.3 seconds (range 55.6–614 s). The success rate for IO and IV was equal at 87.5%.
- Conclusion –IO catheterization using an automatic rotary insertion device was performed more rapidly and successfully than jugular venous catheterization using a cut-down technique in canine cadaver. These findings suggest IO catheterization may be more efficient for gaining vascular access in the appropriate emergency clinical situations when preexisting IV access does not exist.

## Case Report

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# Ultrasound-guided intracardiac xenotransfusion of canine packed red blood cells and epinephrine to the left ventricle of a severely anemic cat during cardiopulmonary resuscitation

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- Objective
  - To describe the use of an ultrasound-guided intracardiac xenotransfusion of canine packed red blood cells (pRBC) to the left ventricle of a severely anemic cat during cardiopulmonary resuscitation (CPR).
- Case Summary
  - An 8-year-old previously healthy neutered female cat was presented with severe weakness after she had disappeared for 1 month. On presentation, the cat was in hypovolemic shock, laterally recumbent, and severely anemic with massive flea infestation. Within minutes of admission, the cat became agonal and suffered cardiopulmonary arrest. CPR was immediately initiated; however,

attempts to gain IV access during CPR were unsuccessful. As the cat's blood type was yet unknown, 10 mL of canine pRBC was transfused directly into the left ventricular chamber using ultrasound guidance, as well as 0.02 mg/kg of epinephrine using a similar technique. The cat regained cardiac activity and once the jugular vein was cannulated it received 20 additional mL of canine pRBC intravenously. The packed cell volume and total plasma protein following the intracardiac transfusion were 0.09 L/L [9%] and 30 g/L [3.0 g/dL], respectively. Subsequent blood typing revealed the cat had type B blood. The cat was discharged 3 days post-CPR and was alive and doing well 3 months following discharge.

- New or Unique Information Provided
  - This is the first reported case of ultrasound-guided intracardiac canine-to-feline xenotransfusion during CPR
- Although first-time xenotransfusion of canine blood appears to be safe in cats, it is important to note that the lifespan of canine whole blood in the cat is significantly shorter than that of feline blood (4 versus 30 days).
- Bovens et al 2012 reviewed 62 reported cases in the literature describing xenotransfusion ranging from 5–130 mL of canine whole blood administered to cats
  - Published evidence in a limited number of cases (62 cats) indicates that cats do not appear to have naturally-occurring antibodies against canine red blood cell antigens: compatibility tests prior to the first transfusion did not demonstrate any evidence of agglutination or haemolysis of canine red cells in feline serum or plasma.
  - No severe acute adverse reactions have been reported in cats receiving a single transfusion with canine whole blood.
  - Anaemic cats receiving canine blood are reported to improve clinically within hours.
  - However, antibodies against canine red blood cells are produced rapidly and can be detected within 4-7 days of the transfusion, leading to the destruction of the transfused canine red cells in a delayed haemolytic reaction.
  - The average lifespan of the transfused canine red cells is less than 4 days.
  - Any repeated transfusion with canine blood later than 4-6 days after the first transfusion causes anaphylaxis, which is frequently fatal.
- We conclude that intraventricular canine-to-feline xenotransfusion is feasible, and injection of canine pRBC and epinephrine into the left ventricle of the heart could be considered during CPR in cases of severe anemia when no intravenous access, a matched feline pRBC unit or HBOC are available. In addition, this case highlights the important contribution of ultrasound use in the emergency setting.



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

Robin L. McIntyre, DVM, DACVECC; Kate Hopper, BVSc, PhD, DACVECC and Steven E. Epstein, DVM, DACVECC

- Objective
  - To prospectively describe cardiopulmonary resuscitation (CPR) and evaluate factors associated with outcome in dogs and cats with cardiopulmonary arrest (CPA).
- Design
  - Prospective observational study.
- Setting
  - University teaching hospital.
- Animals
  - One hundred twenty-one dogs and 30 cats that underwent CPR.
- Interventions
  - None.
- Measurements and Main Results
  - Supervising clinicians completed a data form immediately following completion of CPR. Eighty-seven (58%) animals attained return of spontaneous circulation (ROSC), 49 (32%) had ROSC >20 minutes, 15 (10%) were alive at 24 hours, and 8 (5%) were discharged alive. Cardiovascular abnormalities were the most common suspected precipitating cause of CPA (51/151, 34%). Presence of an IV catheter before CPA ( $P=0.01$ ) and the presence of palpable pulses during CPR ( $P=0.007$ ) were both associated with ROSC. Increased time from CPA to CPR ( $P=0.04$ ), longer duration of CPR ( $P < 0.0001$ ), and neurologic cause of arrest ( $P=0.02$ ) were associated with not achieving ROSC. There was no association between ROSC and the initial arrest rhythm identified on ECG, animal weight, number of people present, and ventilation or compression rate. In patients achieving ROSC, those with a “survived event” were more likely to be euthanized and less likely to experience a second CPA than those with ROSC less than/equal to 20 minutes. Thirty-four percent of patients submitted for necropsy had gross and histological lesions considered secondary to CPR.
- Conclusions
  - Early CPR interventions were associated with a greater likelihood of ROSC, emphasizing the importance of prompt recognition, and initiation of CPR efforts. Although ROSC rates in this study were comparable or higher than previous human and veterinary studies, the rate of “survived events” was lower than that

reported in human patients. This may suggest that advances in post CPR care could have benefits to the veterinary CPR patient in the future.

## Retrospective Study

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# Acid base, electrolyte, glucose, and lactate values during cardiopulmonary resuscitation in dogs and cats

Kate Hopper, BVSc, PhD, DACVECC; Angela Borchers, DVM, DACVIM, DACVECC and Steven E. Epstein, DVM, DACVECC

- Objective
  - To report acid base, electrolyte, glucose, and lactate values collected during or immediately after cardiopulmonary resuscitation (CPR) in dogs and cats.
- Design
  - Retrospective study.
- Setting
  - University Teaching Hospital.
- Animals
  - Thirty-two dogs and 10 cats.
- Interventions
  - None.
- Measurements and Main Results
  - Blood gas, electrolyte, glucose, and lactate values measured during CPR or within 5 minutes of return of spontaneous circulation (ROSC) were retrospectively evaluated. The time of blood collection with respect to the occurrence of cardiopulmonary arrest (CPA), the initiation of CPR or ROSC was noted. Forty-two venous blood samples were analyzed, 24 collected during CPR and 18 samples were collected within 5 minutes of ROSC. Metabolic acidosis and hyperlactatemia were evident in all samples in the study while an increased PvCO<sub>2</sub> occurred in 88% of samples collected during CPR and in 61% of samples collected following ROSC. Hyperkalemia occurred in 65% of all cases, decreased ionized calcium was evident in 18%, hypoglycemia was evident in 21% while hyperglycemia was evident in 62%. There was no significant difference in any parameter evaluated between dogs and cats during CPR. There was no significant difference of any variable measured during the first 15 minutes of CPA versus those measured more than 15 minutes following CPA. When the values measured during the first 5 minutes of ROSC were compared to those measured during CPR, the pH and PvO<sub>2</sub> were significantly lower in the CPR group.
- Conclusions

- Biochemical abnormalities including metabolic acidosis, hyperkalemia, ionized hypocalcemia, hypoglycemia, and hyperglycemia can be identified during CPR and immediately following ROSC. The therapeutic and prognostic relevance of these changes are yet to be defined and may prove to be useful to guide patient management in the future.

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REVIEW

Open Access



# Extracorporeal membrane oxygenation (ECMO) for critically ill adults in the emergency department: history, current applications, and future directions

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- Extracorporeal life support (ECLS) is a general term used to describe temporary support of cardiac or pulmonary function using mechanical devices. When using the “heart–lung machine” to completely bypass the cardiopulmonary circulation, it is referred to as cardiopulmonary bypass. When ECLS is used in the intensive care unit (ICU) or emergency department (ED) to augment oxygenation, ventilation, or cardiac output it is generally referred to as extracorporeal membrane oxygenation (ECMO)
- Venous-arterial ECMO for cardiac arrest
  - Despite advances in management, outcomes for both in-hospital and out-of-hospital cardiac arrest remain poor. In-hospital cardiac arrest treated with conventional cardiopulmonary resuscitation (CPR) typically has a survival rate of 15–17 % and out-of-hospital cardiac arrest (OHCA) survival is even lower at only 8–10 %
  - The worst outcomes are in patients with prolonged time to return of spontaneous circulation. Prolonged cerebral hypoperfusion leads to significantly worse neurologic sequelae and early initiation of ECPR with venous-arterial (VA) ECMO may be a useful adjunct to reducing the interval time from arrest to restoration of cerebral perfusion. Data for in-hospital arrest are the most promising, likely due to the shorter interval from the onset of arrest to initiation of ECMO flow. While there are no randomized trials to date, observational studies have reported an association between ECPR and improved survival. A retrospective, single-center, propensity-matched analysis showed improved survival with favorable neurologic outcome for patients with in-hospital arrest treated with ECPR versus conventional CPR

