Cardiopulmonary resuscitation (CPR) is challenging at the best of times; knowing how to properly intervene in a timely fashion will markedly improve overall survival. It is very difficult to determine if the interventions we perform routinely during CPR are effective or indicated because of low survival rates and few randomized controlled clinical trials on the topic. Every five years the American Heart Association (AHA) releases International Liaison Committee on Resuscitation (ILCOR) based updates on CPR – this information is a review of the previous 5 years of research to determine if there is any new evidence that impacts guidelines for CPR; the AHA guidelines are available free online through the medical journal Circulation (most recent print 2015). This information is primarily based on human research, and application in veterinary medicine may be impossible or inappropriate. The American College of Veterinary Emergency and Critical Care (ACVECC) recently published Reassessment Campaign on Veterinary Resuscitation (RECOVER) initiative in the June 2012 supplemental issue of the Journal of Veterinary Emergency and Critical Care (JVECCS), available free online, www.acvecc-recover.org. The goals of this project were to review the published evidence available on CPR, create consensus guidelines for veterinary CPR based on available evidence, incorporate feedback and distribute the information as well as identify knowledge gaps. The chair-persons of the RECOVER project (Daniel Fletcher and Manuel Boller) began with more than 80 clinical questions; they called on Diplomats of ACVECC and other specialists to investigate those questions, and develop a statement for each question based on current literature that was available; each “answer” also comes with a ranking in terms of the level of evidence that was available to answer that question. Much of this information is based on RECOVER recommendations along with some opinion from the author (who is a contributor to the RECOVER initiative). Since then, several peer-reviewed journal articles have added to our knowledge on veterinary CPR.

There are five basic portions of CPR: preparedness/prevention, basic cardiac life support (BCLS), advanced cardiac life support (ACLS), CPR monitoring and post cardiac-arrest care.

Preparedness/prevention. It is vitally important for your veterinary team to have regular drills and refreshers on CPR. This has been shown in humans to improve response time and subsequent outcome. Performing drills, particularly with feedback dummies and having a ready area makes everyone aware of where to go and what to do. The “crash cart” should be fully stocked, remain in the same location and should have regular audits to ensure all supplies are present. All staff should be familiar with the equipment that is available and their roles in CPR so effective communication can result in efficient intervention. It is recommended to have leadership and team training along with refresher drills every 6 months; in addition, after every drill or CPR that is performed on a patient, it is important to have a post-resuscitation evaluation or debriefing session to; the team should examine how they performed. Performing closed loop communication during CPR (and practicing this skill on a regular basis) will help avoid errors and ensure proper technique.

An active triage system to help identify patients that need rapid intervention and recognize emergency medical problems may help prevent cardiopulmonary arrest (CPA) from occurring. Adequate monitoring during anesthetic procedures will also help early recognition of trends and may help prevent CPA.

Recognition of CPA should be adequate and rapid. Gasping motions may indicate an impending arrest. An unconscious patient with no palpebral or corneal reflex is that most rapid way to assess loss of life. Other measures (checking for pulses, auscultation and watching for respirations) may take several seconds longer resulting in delay of treatment, however no ideal method has been determined. Starting with chest compressions in a patient that is not deceased is likely to cause little harm.

Once an arrest has been identified, all staff should be alerted to come to the area, a team leader should be immediately identified and orders directed to specific individuals (i.e., David, start compression over the widest part of the chest at 100 compressions per minute; Julie get an endotracheal tube and laryngoscope for intubation, then start breathing at 10 breaths per minute, etc.)

BCLS. AHA has changed their guidelines from ABC (airway, breathing and circulation) to CAB, emphasizing the importance of circulation prior to breathing and clearing the airway. This has occurred for
several reasons: ease of intervention (it’s simple for a lay-person to provide chest compressions compared to delivering breaths); humans commonly have CPAs due to ventricular fibrillation, secondary to myocardial infarctions (this is less common in veterinary medicine); and oxygen can remained dissolved in the blood for even several minutes after arrest; there is also concerns for transmission of infectious disease in people and many lay persons are reluctant to deliver breaths. However, trained medical professionals are encouraged to tailor their CPR efforts to the patient. The AHA currently have a “push hard and push fast” motto to emphasize their recommendations of at least 100 beats per minute and depressing the sternum at least 2 inches (the optimal depth has not been investigated in dogs and cats), but 1/3 the depth of the chest is recommended (similar to pediatric recommendations). Faster rates of compression have been associated with higher survival rates, and survival rates in people have been shown to be similar whether or not ventilation was administered. In dogs and cats, a rate of 100-120 beats per minute is beneficial compared to lower rates. In addition, there should be time for complete chest recoil, minimized interruptions to cardiac compression efforts and a compression-to-ventilation ratio of 30:2 is recommended if there is a sole provider.

The body position in which compressions should be delivered to the patient has not been determined, however it is often logistically/physically easier to perform CPR with the patient in lateral recumbency; the ideal position may depend on body size and shape. Interposed abdominal compressions may increase venous return, but should be avoided in patients with abdominal disease. One must avoid leaning on the patient between compressions, emphasized in the 2015 guidelines. Alternating compressors every 2 minutes (considered ‘one cycle’) of CPR is considered appropriate to avoid exhausting a single person and gives timing for medications to be given (every 4 min). Compressions should be administered over the widest part of the chest (thoracic pump technique) in large or ‘barrel-chested’ animals and over the heart directly (3rd-5th intercostal space) for cats, and ‘keel-chested’ animals (i.e. greyhounds).

Airways in dog are relatively simple to obtain but cats can be a bit more challenging; practicing intubation in all different positions (and for cats, in dorsal) may improve speed and ease of intubation and can be performed with minimal assistance. Having tools available to clear an airway (suction or sponge forceps) and a variety of stylets and entotracheal tubes will ensure rapid and adequate intubation. Once the airway is obtained, it must be secured and maintained as motion of the CPR patient may dislodge the tube. Breathing should be performed with 100% oxygen and an AMBU bag or anesthetic machine, at a rate of 10 breaths per minute, 1 sec inspiratory time, approximately 10 mL/kg (although this is difficult to gauge). There is a tendency to over-ventilate patients which may worsen hemodynamic parameters and blood flow to the brain. Suction or postural drainage may help clear the airway and pulmonary system of fluid.

Open chest CPR can dramatically improve blood flow and is indicated as follows: patients > 10 kg, un-witnessed arrest, arrest from trauma, suspect or known pericardial disease or pleural space disease, no response to CPR for 10 minutes, thoracic wall disease and recent surgery. Practice on cadavers will optimize entry time. A modified Rommel tourniquet (aortic cross clamping) can be maintained for 10-15 minutes to improve blood flow to the heart and brain. It should be released every 10-15 min for 2 minutes to maintain blood flow to the spinal cord.

New devices such as automated compression devices (ACD) and impedance threshold devices (ITD, ResQPod) have been shown to mildly improve perfusions pressures and ROSC in people in some studies – ITD should only be considered in patient > 10 kg and avoided in patients with lung or thoracic wall disease. These have NOT been evaluated in veterinary patients and are not currently recommended.

ACLS. This involves recognition of predisposing factors and EKG analysis for administration of drugs. Anesthetic or analgesic drugs should be reversed if possible, and inhalants discontinued. Drugs are preferentially administered IV or IO. If those are not available, IT (intratracheal) administration of some drugs can be performed (naloxone, atropine, vasopressin, epinephrine and lidocaine; - Navel); although optimal doses are not determined for drugs delivered via the IT method, doubling the IV dose is used as convention, epinephrine should be considered at 10X the dose). AHA has emphasized that devices, drugs and other distracters should not interfere with quality CPR efforts.

Fluids should ONLY be administered if there is a known or precipitating events or disease that may result in hypovolemia. One bolus may be administered to euvolemic patients; excessive amounts of fluids may increase venous pressures and subsequently decrease cerebral and cardiac perfusion. Epinephrine may be used for asystole, pulseless electrical activity (PEA), refractory ventricular fibrillation (Vfib) and ventricular tachycardia (Vtach); there is little evidence supporting any dose range however because of potential negative effects of high dose, general consensus is lower dose epinephrine (0.01 mg/kg IV q 3-5 min) is generally
Accepted. There is little evidence to support or refute the use of atropine during CPR outside of bradycardia; the author administers atropine with asystole or bradyarrhythmias. There is little evidence for the use of other antiarrhythmics during CPR with the exception of vasopressin. Vasopressin may be used for asystole, PEA, defibrillator-resistant Vfib and pulseless Vtach. Vasopressin, as a CPR drug has had controversial results and has demonstrated no worse compared to epinephrine. It currently is recommended every 2nd cycle of ACLS. Vasopressin has become cost-prohibitive for veterinary patients in the US. The author has used vasopressin for years and anecdotally this drug seems particularly effective in cats. Na-bicarbonate can be used for CPR lasting > 10 minutes as well as calcium gluconate, insulin and glucose in prolonged CPR efforts or known or suspected hyperkalemia (renal failure, blocked cats, Addison’s, etc).

Electrical defibrillation should be used for Vfib (fine or course); unstable (arresting) Vtach may also be defibrillated; cardioversion (synchronized defibrillation) may be used for unstable supraventricular tachycardia, however this is rare in veterinary medicine. New defibrillators (biphasic) use lower energy with the same or better outcome than monophasic defibrillators – these are likely to decrease morbidity and improve outcome. It is recommended to administer one shock, and resume CPR efforts for 2 min. Escalating energy may or may not be considered. Precordial thump may be considered ONLY if electrical and chemical defibrillation is not available. Amiodarone is considered better than lidocaine for defibrillation-resistant VF or VTach.

Most drugs have little evidence to support their use; but there are specific indications for some:
Calcium gluconate for known or suspected hyperkalemia (the author also uses in prolonged arrest, > 10 minutes) and calcium channel blocker toxicity; glucocorticoids ONLY in patient who may have glucocorticoid deficiency (hypoadrenocorticism), otherwise there are NO DEMONSTRATED BENEFITS OF STEROIDS; insulin and dextrose for hyperkalemia (or dextrose for known or suspected hypoglycemia), and reversal agents if it is suspected the arrest was related to drug administration (flumazenil for benzodiazepines; naloxone for opioids, atipamezole for dexmedetomidine) and magnesium sulfate for a specific arrhythmia, Torsade de pointes.

CPR monitoring. One of the most effective and under-utilized tools in CPR is End-Tidal CO2 monitoring. It can provide immediate feedback confirming and monitoring intubation as well as the effectiveness of CPR efforts and when ROSC occurs. Normal ETCO2 is 35-45 mmHg, and is rarely achieved during CPR due to diminished blood flow through the lungs. An absent reading (0 mmHg) may indicate esophageal intubation, inadequate CPR efforts or a massive pulmonary embolism; however it should not be used as a sole mechanism to diagnose CPA (nor should any tool, as ECG may be normal with no pulses). Placement of the ET tube should be confirmed visually and also watching (and auscultation) the chest with breaths. A reading of 8-12 mmHg is indicative of adequate CPR efforts, and return of spontaneous circulation (ROSC) is usually indicated by an increase in ETCO2 >20 mmHg or a rapid increase. Ventilation should be held constant for this to be an effective tool. Electrocardiogram monitoring is essential for ACLS and discussed above. Other monitoring such as blood pressure (Doppler, oscillometric) and pulse-oximetry are inappropriate during CPR.

Standard monitoring sheets were recently investigated and published in JVECCS in 2016 and are available. These sheets should standardize recording during CPR so information can be collected from them for future investigations.

Post cardiac arrest care. One should immediately search for the underlying reason for the arrest, and it should be treated or corrected. Normalizing what is abnormal is essential (oxygenation, fluid status/blood pressure, electrolytes, blood glucose, blood gas, thoracocentesis, etc.). If open chest CPR was performed, this should be converted to a clean contaminated wound, a chest tube placed and the chest closed and bleeding controlled. Intensive monitoring of EKG, blood pressure, SpO2, etc. is essential. Often it is recommended to administer mannitol for neuro-protection. AHA recommends temperature control to optimize neurological recovery and transfer to an appropriate critical care unit. Non-rapid (< 1 °C/hr) warming is appropriate in veterinary patients. The use of steroids in the post arrest patient remains controversial; the author does not recommend them.

Readers are encouraged to visit www.acvecc-recover.org for further information.
CPR Algorithm

Unresponsive, apneic patient

CPR (1 cycle = 2 minutes)
Compressions: 100-120/min, lateral, 1/3-1/2 chest width
Ventilate: 10/min, \( V_t = 10 \text{ml/kg} \), I-Time = 1sec
Initiate Monitoring: ECG and ETCO\(_2\)

ROSC → Post-CPA Algorithm

Evaluate Patient
Check ECG

Vfib
• Continue CPR while charging defibrillator
• Give 1 shock
• Resume CPR immediately for 1 cycle

Asystole / PEA
• Resume CPR immediately for 1 cycle
• Low dose epinephrine or vasopressin q 3-5 mins
• Consider atropine if ↑ vagal tone
• Consider high dose epinephrine after 10 mins

ROSC → Post-CPA Algorithm

Evaluate Patient
Check ECG

Vfib
• Continue CPR while charging defibrillator
• Give 1 shock
• Resume CPR immediately for 1 cycle
• Give epinephrine or vasopressin q 3-5 mins
• Consider amiodarone or lidocaine if refractory

Asystole / PEA
# CPR Emergency Drugs and Doses

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Post-Cardiac Arrest Hemodynamic Optimization

1. Use 10 ml/kg IVF over 5 min q20 min until CVP > 8
2. If no CHF, continue IVF to get MAP>80, CVP* > 8, but < 15

*CATS: CVP goal is > 5 but < 10

1. If EF is normal, use NE (0.1-0.5 mcg/kg/min)
2. If EF ↓, start Dobutamine (5-20 mcg/kg/min); if MAP ↓, add NE
3. Ongoing hypotension, consider 2nd vasopressor

If evidence of shock is present:
1. Optimize CVP up to 15
2. Transfuse PRBC if hematocrit < 25%
3. Dobutamine if not already started
4. IPPV +/- neuromuscular block

MAP and CVP are in mm Hg; PRBC=packed red blood cells; NE=norepinephrine; EF=Ejection Fraction; IPPV=intermittent positive pressure ventilation