Everything You Need to Know about Intensive Care Mini Series

Session Three: The Septic Patient

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Cardio-pulmonary Resuscitation

Cardio-pulmonary resuscitation (CPR) is defined as an attempt to restore spontaneous circulation and respiration in a patient which has undergone cardio-pulmonary arrest (CPA). In a retrospective study (Hofmeister et al. 2009) CPR was successful in 35% of dogs and 44% of cats but only 6% of these were discharged from the hospital. Also, when considering only dogs, the proportion of these that survived and were discharged from the hospital was significantly higher in patients which were anaesthetised at the time of the CPA (50%) compared to those that were not (2%).
Recently the RECOVER study (Reassessment campaign on Veterinary Resuscitation) was published (Fletcher et al., 2012). This study addresses all steps of the CPR process and provides a series of evidence based consensus guidelines for veterinary CPR in dogs and cats.

Preparedness and Prevention

This is paramount for a successful return of spontaneous circulation (ROSC) following CPR.
Training of personnel and communication during CPR is essential. The team (if it is possible to have one) should have a leader who assigns tasks and clearly gives orders, these must be repeated by the team member receiving it (closed loop communication). Also ideally the team should consist of at least a person performing chest compressions, a breather (these two should alternate every 2 minutes), a drug pusher (who injects drugs) and a recorder (who records the events and is also a time keeper).
Every structure should have an easily accessible and well organised crash trolley (or box) where the essential drugs and equipment should be in order. The presence of algorithms and emergency drugs dose charts can have an important role in avoiding delays (see end of notes).

Basic life support (BSL)

BSL should absolutely not be delayed and early recognition of CPA is crucial. The most common way of recognizing CPA is by pulse palpation, however the specificity of pulse palpation for diagnosis of CPA is of only 65%. It has been shown that if a pulse cannot readily be identified then CPR should be started immediately as less than 2% of patients with CPA experience serious harm when BLS is started. A basic ABC assessment should be rapidly performed and CPR should be started immediately after.
High quality studies concluded that CPR performed in 2 uninterrupted minutes cycles results in better survival rates. After each 2 minutes cycle the compressor must rotate to avoid fatigue and compromise the quality of chest compressions.

<u>Chest compressions</u>
Chest compressions represent the first step to an adequate attempt to CPR and should be initiated as soon as possible. Studies have shown that these are more effective with the patient in lateral recumbency. According to the size and chest conformation of the patient chest compressions will be performed in different manners.
Cardiac pump theory
With hands positioned directly onto the heart. The cardiac ventricles are directly pressed. In small dogs and cats this can be achieved with one hand wrapped around the sternum at the level of the heart.
In deep chested dogs (greyhounds) the cardiac pump theory is be the way of choice of performing CPR. The animal is placed in lateral recumbency (left or right) and both hands are used to apply compressions directly onto the heart.
In barrel chested dogs (bulldogs) some recommend to position the animal in dorsal recumbency and apply compressions with both hands on the sternum at the level of the heart.
Thoracic pump theory
In all other dogs the thoracic pump theory should be applied. Compressions are performed over the widest portion of the chest with the animal in lateral recumbency. Chest compressions will increase intrathoracic pressure which will compress the aorta and the vena cava pushing blood out of the chest. During elastic recoil of the chest negative pressure will be produced favouring blood return to the heart and lungs.
Several rates have been suggested but there is strong evidence that a rate of 100-120 compressions/min (or higher) in both dogs and cats is the most adequate. A study performed for human CPR actually demonstrated that, when performing chest compressions at the rhythm of the song “Staying alive” the compressors regularly delivered 100-120 chest compressions Also compressions should be very deep (1/3 to 1/2 of the width of the chest) and a full chest recoil must be allowed in between compressions.

Ventilation

Although this is very important, the placement of an endotracheal tube (ETT) should not interfere with chest compressions.
When more than one rescuer is present, intubation of the trachea should be performed in lateral recumbency without interrupting chest compressions. After securing the tube with a tie, the cuff should be inflated.
Because of the importance in minimising delays, the most experienced person should intubate the trachea, preferably with the use of a laryngoscope. Sometimes when secretions are present a suction unit can be useful. Usually capnography confirming the presence of an end tidal carbon dioxide ($EtCO_2$) is the best way to confirm the correct placement of an ETT in a patient. Unfortunately during CPA and unsuccessful CPR sometimes $EtCO_2$ is low or zero and cannot be used for this purpose.
Correct tube placement can also be confirmed by observing chest expansion when ventilating or by palpating the neck and not feeling two “trachea-like” structures.
Because during CPR there is reduced pulmonary blood flow, and because high respiratory rates and tidal volumes can lead to decrease venous return, a ventilation rate if 10 breaths/ minute with a tidal volume of 10 ml/kg over a short inspiratory time (1 s) is recommended and sufficient to ventilate the patient.
If the patient cannot be intubated or only one rescuer is present mouth to snout ventilation can be performed. In this case it is recommended to perform 30 chest compressions at a rate of 100-120 compressions/minute followed by a brief interruption in chest compressions to deliver 2 breaths after which chest compressions are immediately resumed. Another alternative, albeit sub-optimal is to deliver oxygen via a face mask or flow by at very high oxygen flows should be used.

Interposed abdominal compressions

If enough staff is available, abdominal compressions, interposed to the chest compressions can be performed to improve venous return to the heart.

Advanced life support (ALS)

This includes drug therapy, fluid resuscitation, defibrillation and correction of any electrolyte disturbance where this can be identified.

Route of administration

The preferred route of administration of “crash drugs” is the IV route. If fluids are not administered it is important to follow the drug bolus with an adequate bolus of saline.
If it is impossible to provide a venous access, the intra-osseous route can be used, mostly in young patients. In this case a needle is inserted in the medulla of the femoral greater trocanter, the lateral humeral tuberosity or less frequently in the sternum or the iliac crest. The absorption into the blood stream through this route is considered to be close to 100%.
Finally, the intra-tracheal route can be considered, although with a less favourable outcome. Adrenaline, atropine and vasopressin can be administered via this route. Ideally a urinary catheter should be advanced in the ETT to the level of the carina, and again drug administration should be followed by a small amount of saline or sterile water. The recommended doses need yet to be confirmed and can be up to ten times the IV dose.

Drugs

Adrenaline

This cathecolamine acts as a vasopressor via □1 receptors and as a positive inotrope and chronotrope via the β1 receptors. In a study the number of doses of adrenaline administered decrease the likelihood of ROSC (Hofmeister et al. 2009) possibly because this drug increases myocardial oxygen demand in a moment where oxygen delivery is poor, leading to cardiac hypoxia and ischaemia. To improve myocardial oxygenation it is recommendable to perform a first 2 minutes cycle of CPR before administering adrenaline. Adrenaline is less effective in the presence of acidosis and this is a common feature in patients who have undergone CPA.
The recommended dose of adrenaline is of 0.01 mg/kg IV administered every 3-5 minutes. After prolonged CPR (10-15 min) a high dose (0.1 mg/kg IV) of adrenaline can be considered.

Vasopressin
This drug is another vasopressor which acts on V1 receptors on the vessels smooth muscles. Unlike adrenaline the effects of vasopressin are not affected by acidosis. There is mixed evidence on the superiority of vasopressin compared to adrenaline, but, vasopressin (0.8 U/kg IV) can be used in combination or as a replacement to adrenaline every 3-5 minutes of CPR.

Atropine
Atropine is an anticholinergic drug. There is no evidence that atropine (0.04 mg/kg IV) has any beneficial or detrimental effects during CPR. However when asystole or pulseless electrical activity (PEA) is associated with high vagal tone atropine at the dose of 0.04 mg/kg IV is the drug of choice. Unlike in human medicine, small animals tend to arrest following profound bradycardia and in these cases atropine is highly recommended.

Antiarrhythmic drugs
The most commonly used drugs belonging to this category are lidocaine and amiodarone. The latter (5 mg/kg IV) has been shown to improve outcome in patients undergoing CPA with ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) resistant to electrical defibrillation. In dogs with induced VF, lidocaine has been shown to actually increase the energy required for a successful defibrillation, but only when using monophasic defibrillators.
As amiordarone is not often available in practice, lidocaine (2 mg/kg IV) can be used in case of VT, VF, pulseless VT resistant to electrical defibrillation (mostly if a biphasic defibrillator is used) or if a defibrillator is not available.

Other treatments

Defibrillation
This is not commonly available in practice. There are two types of defibrillator and the biphasic type where (the current initially flows in one direction then in the other) is recommended. Defibrillation of the patient (2-4 J/kg) is recommended in dogs and cats with VF or pulseless VT. If the duration of this arrhythmia is of less than 4 minutes then immediate defibrillation is recommended. After 4 minutes, because of the likelihood of ischaemic damage, then a 2 minutes cycle of CPR is recommended before defibrillation.
If a defibrillator is not available, mechanical defibrillation with a precordial thump can be attempted, although the likelihood of success is way lower compared to electrical defibrillation. This precordial thump is achieved by strongly striking the patient’s chest over the heart with the heel of the hand.

Electrolyte and acid-base correction
Although several patients develop hypocalcaemia, hyperkalaemia and acidaemia during CPA, it is dangerous to correct these disturbances without actually having measured electrolytes and pH. However bicarbonate therapy (1 mEq/kg IV very slow) after prolonged CPA (10-15 minutes) is advisable. Remember that bicarbonate therapy will increase the production of CO_2 and this will be reflected in the $EtCO_2$.

Fluid-therapy
The amount of fluid (and type) to be administered depends on the patient and the underlying disease. In the case of hypovolaemic patients boluses of fluids are recommended, but on the other side these are contraindicated in euvolaemic or hypervolaemic patients, mostly cats.
During CPA circulation is compromised and the administration of fluids will help “push” the drugs from the peripheral compartment to the central one where their action takes place.

Oxygen therapy
Usually once intubated, most patients are ventilated with 100% oxygen. However, hyperoxaemia can worsen tissue damage by increasing the concentration of free radicals. Where it is possible to perform arterial blood gas analysis, oxygen supplementation should be titrated to achieve a PaO_2 of ~ 100 mmHg. If arterial blood gases cannot be performed, then a 100% concentration of inspired O_2 is recommended as the risks of hyperoxaemia outweigh the risks of hypoxaemia.

Open chest CPR
Evidence shows that open chest CPR is more effective than closed chest CPR but this should never be performed in a practice which hasn’t got the means to provide appropriate post CPR care to the patient.

Open chest CPR is highly recommended in cases with significant intrathoracic disease (pleural, pericardial effusion, tension pneumothorax)

Hypothermia

Mild induced hypothermia is beneficial in that it has protective effects in patients which have undergone PCA but it is not recommended if the structure hasn't got advanced critical care capabilities.
During CPA, mild accidental hypothermia can be allowed and, in this case, slow patient rewarming (0.25 to 0.5 □C/h) is advised.

Corticosteroids

Several studies in both humans and small animal patients have led to controversial results, however there is evidence in human medicine that if PCA is caused by shock, treatment with low dose hydrocortisone actually improved survival to discharge. On these lines, in dogs and cats which remain haemodynamically unstable in spite of administration of fluids/drugs, low dose hydrocortisone (1 mg/kg followed by 1 mg/kg q 6hr or an infusion of 0.15 mg/kg/hr) can be considered, unless contraindicated from the patients' underlying disease.

Mannitol / hypertonic saline

It is recommended that one of these hyperosmotic fluids is administered post CPR to minimise the development of cerebral oedema and to improve neurological outcome.

CPR in a patient under general anaesthesia

Because of the higher success rate of ROSC of patients undergoing CPA under general anaesthesia, there should be no hesitation in performing prompt CPR in this category of patients.
Usually anaesthetised patients are closely monitored and their trachea is already intubated, which will help both with the early recognition of CPA and the performance of BLS.
The inhalational anaesthetic should be turned off immediately and the breathing system (circuit) flushed (by briefly disconnecting the breathing system from the patient, occluding the patient's end and pushing the emergency oxygen button with the APL valve open).
BLS and ALS should be started as soon as possible.
Drugs which can be antagonised should be antagonised. Atipamezole can be used if medetomidine was administered. Although expensive and usually not normally stocked, naloxone and flumazenil can be used to antagonise opioids and benzodiazepines respectively.

Monitoring of the patient during and after CPR

Pulse

Pulse palpation is fundamental but as mentioned earlier it is not very specific. During CPR, movement of the patient will interfere further with pulse palpation. In no circumstance a 2 minutes cycle of chest compressions should be interrupted to verify the presence of pulses.
Sometimes the Doppler can be used to assess the presence of a pulse and some authors advice to place he probe on the eye. However, in the authors experience, because of interference from movement during chest compressions and because of the possibility f ocular damage, this method of diagnosing the presence of pulse is not superior to femoral pulse palpation.

Electrocardiogram (ECG)

It is important to remember that this indicates the electrical activity of the heart and does not its mechanical contraction. Sometimes a perfect ECG can be present but no mechanical activity occurs (PEA). However an ECG is important to identify treatable rhythms (severe atrio ventricular blocks, ventricular tachycardia ..). The ECG can very briefly be assessed, together with the presence of a pulse, at the end of each 2 minutes CPR cycle. Chest compression should be resumed very quickly.

EtCO2

In the authors opinion, this is the gold standard in monitoring the success/failure of ROSC.
CO2 is produced by cellular metabolism, and transported to the lungs by circulating blood, from which it is exhaled by ventilation. If ventilation is constant, as it should be during CPR, then any increase in EtCO2 will be an indication of the efficacy of CPR.
EtCO2 can therefore be used to assess the adequacy of chest compressions. If, when the compressor rotates, EtCO2 drops, the CPR leader should prompt for stronger chest compressions.

A retrospective study has demonstrated that higher EtCO2 (>15 mmHg in dogs and > 20 mmHg in cats) may be associated with a increased rate of ROSC.

What should a crash box contain?

A crash box should contain only necessary equipment. Crash carts are sold and these allow an organised and practical stocking of crash equipment. If a crash cart is not available a tool box can be used.
As a minumum syringes, needles, IV cannulas, tape, drugs (adrenaline, atropine, lidocaine) and ETT of different size should be contained in the box. Ideally a laryngoscope, material to tie the ETT, drug labels should be available too.
As mentioned previously, the crash box should be easily reachable, every member of staff should be familiar with its contents and these should be checked on a regular basis. After each CPR attempt, the box should be immediately restocked.
Drug charts and CPR algorithms can be attached on the box to avoid any delays during CPR.

Who should we resuscitate?

When looking at the causes of cardiac arrest in dogs and the success of ROSC following CPR, it has been shown that when the patient had a suspected cause other than haemorrhage or anaemia, shock, hypoxaemia, multiple organ dysfunction syndrome, malignant arrhythmia or anaphylactic reaction then they were more likely to be successfully resuscitated. Also dogs with multiple disease conditions were approximately 20% as likely to be successfully resuscitated compared to dogs without multiple disease conditions.
As mentioned earlier in dogs, the proportion that survived and was discharged from the hospital was significantly higher in patients which were anaesthetised at the time of the CPA (50%) compared to those that were not (2%).
Cats with higher CPR success were those who were less likely to have had shock as a cause of CPA.
These facts suggest that aggressive CPR efforts should be undertaken in animals under general anaesthesia at the moment of CPR or in dogs which did not arrest due to one of the aforementioned cause or cats which were not in shock at the moment of CPA.

Conclusions

It is important to keep in mind that at all time the most successful CPR is the one avoided. Therefore close monitoring of the most critically ill patients if fundamental. However, when a patient undergoes CPA, good team organisation and training can make the difference between a successful and an unsuccessful CPR.
Major CPR efforts should be used on patients with a better prognosis and finally the decision to undertake CPR should be discussed with the owners and these should be made aware of the poor prognosis associated with it.