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RECOVER evidence and knowledge gap analysis on veterinary CPR. Part 3: Basic life support

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Abstract

Objective – To systematically examine the evidence on basic life support (BLS) in veterinary CPR and to determine knowledge gaps.
Design – Standardized, systematic evaluation of the literature, categorization of relevant articles according to level of evidence and quality, and development of consensus on conclusions for application of the concepts to clinical practice. Relevant questions were answered on a worksheet template and reviewed by the Reassessment Campaign on Veterinary Resuscitation (RECOVER) BLS domain members, by the RECOVER committee and opened for comments by veterinary professionals for 30 days.
Setting – Academia, referral practice, and general practice.
Results – Sixteen worksheets were prepared to evaluate techniques for chest compression and ventilation strategies as well as identification of cardiopulmonary arrest (CPA). Major recommendations arising from this evidence review include performing chest compressions at a rate of at least 100/min at a compression depth of one-third to half the width of the chest with minimal pauses, and early instigation of ventilation at a rate of 8–10 breaths/min in intubated patients, or using a 30:2 compression/ventilation ratio in nonintubated patients.
Conclusions – Although veterinary clinical trials are lacking, much of the experimental literature on BLS utilized canine models. The major conclusions from this analysis of the literature are the importance of early identification of CPA, and immediate initiation of BLS in these patients. Many knowledge gaps exist, most importantly in our understanding of the optimal hand placement and technique for chest compressions, warranting coordinated future studies targeted at questions of relevance to differences between veterinary species and humans.

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Abbreviations

ABC	airway, breathing, circulation
ALS	advanced life support
BLS	basic life support
CAB	circulation, airway, breathing
CPA	cardiopulmonary arrest
CPP	coronary perfusion pressure
C:V	compression to ventilation ratio
IAC	intraabdominal compressions
LOE	level of evidence
PICO	population, intervention, control group, outcome
RECOVER	Reassessment Campaign on Veterinary Resuscitation

ROSC	return of spontaneous circulation
VF	ventricular fibrillation

Introduction

In the context of veterinary CPR, basic life support (BLS) includes the recognition of cardiopulmonary arrest (CPA), airway management, provision of ventilation, and chest compressions. BLS is the immediate response to CPA, and lay rescuers and medical professionals alike may accomplish most aspects. Numerous human and animal experimental studies have shown that the quality of BLS performed is associated with return of spontaneous circulation (ROSC) and survival in arrest victims.[1] BLS is considered separately from advanced life support (ALS) and monitoring in this consensus statement as it requires minimal equipment and can be initiated immediately at the onset of arrest. In clinical practice, the intent is that BLS will be performed in conjunction with ALS and appropriate monitoring as possible. The key BLS recommendations made in this consensus statement for canine and feline CPR are as follows:

- Emphasis on rapid recognition of CPA and rapid initiation of CPR.
- Immediate initiation of chest compressions with intubation and ventilation being performed simultaneously.
- Ventilation rate of 10 breaths/min without interruption to chest compressions.
- Chest compressions should aim to compress the chest by one-third to half its width in lateral recumbency, at a rate of at least 100 compressions/min, allowing full recoil between compressions (Push hard and push fast).
- Utilization of 2-minute cycles of uninterrupted chest compressions with alternation of compressors between cycles. Intercycle interruptions in compressions should be kept to a minimum; only as long as required for rhythm diagnosis.

This report is focused on 16 BLS questions specific to the population, intervention, control group, and outcome (PICO question) with a summary of the evidence and the consensus on treatment recommendations.

Epidemiology and Recognition of CPA

An understanding of the incidence and accurate recognition of CPA is critical to enable development of appropriate studies and the formulation of guidelines for rapid BLS intervention, an essential step toward improving the outcome for CPR in dogs and cats. This area has been poorly evaluated in veterinary medicine to date.

Although the incidence of CPA during anesthesia or sedation has been reported as 0.17% in dogs and 0.24% in cats, the overall incidence of CPA in veterinary patients is unknown.[2] A prospective study performed at a veterinary teaching hospital reported 204 CPA episodes (161 dogs and 43 cats) in a 60-month period.[3] Nineteen of these animals were anesthetized at the time of arrest. This may over estimate the rate of CPA in general veterinary practice as a teaching hospital may have a greater proportion of critically ill and injured patients. In addition, the incidence of out-of-hospital CPA in veterinary medicine is unknown. Further studies are needed to accurately determine the incidence of CPA in dogs and cats in various practice settings.

Identification of CPA (BLS13)

PICO question

In dogs and cats that are unresponsive (P), are there any factors (I), as opposed to standard assessment (C), that increase the likelihood of diagnosing cardiac arrest (as opposed to nonarrest conditions [eg, post seizures, hypoglycemia, intoxication]) (O)?

Conclusion

There are no studies addressing the identification of CPA in cats or dogs. It is reasonable for rescuers to rely on unresponsiveness, absence of breathing (ignoring agonal breaths) and absence of palpable pulses or heart beat to identify CPA. With serious adverse effects occurring in less than 2% of human patients not in CPA that receive chest compressions, and the potential benefits of early chest compressions in patients in cardiac arrest, chest compressions should be provided to dogs and cats as soon as possible if CPA cannot be definitively ruled out.

Summary of the evidence

Routine arrest identification consists of identifying a patient that is unconscious and unresponsive, with the absence of respirations or the presence of agonal respirations. Clinical human studies (level of evidence [LOE] 6) have revealed that improving the ability of first responders to correctly interpret agonal respirations, aids in correctly identifying whether to institute CPR efforts.[4] Clinical studies (LOE 6) have also revealed considerable inaccuracy among lay rescuers to correctly determine the presence or absence of pulses.[5,6] Inaccurate assessment may delay initiation of potentially life-saving CPR efforts or activate CPR efforts in a patient that is unlikely to benefit from such therapy. The relevance of this literature to clinical veterinary medicine is questionable given that CPR in animals is almost always initiated by trained veterinary personnel, not lay rescuers.

While many clinical studies in CPR inherently hinge on correctly identifying patients that are experiencing cardiac or pulmonary arrest, the vast majority fail to state what criteria were used to make this distinction. The current trend in the human literature has focused on identifying patients *at risk* of experiencing CPA in an attempt to correctly activate the Rapid Response Team or Emergency Medical Team. There is currently insufficient evidence to support the use of patient factors, other than standard assessment, to correctly differentiate CPA patients from patients that may be unconscious for reasons other than CPA (eg, syncope, hypoglycemia).

Knowledge gaps

The accuracy of identifying CPA using standard assessment criteria in cats and dogs is unknown. The advantage of defining populations of veterinary patients at risk of CPA needs to be investigated.

Harm from CPR to dogs or cats not in CPA (BLS11)

PICO Question: In dogs and cats that are *not* in cardiac arrest (P), how often does provision of chest compressions (I) lead to harm (eg, rib fracture) (O)?

Conclusion

There are no clinical veterinary studies and only 3 human clinical studies addressing this question. The human clinical studies suggest that the benefit of early provision of chest compression to subjects in CPA outweighs the risk of injury to subjects not in cardiac arrest.

Summary of the evidence

There are only 3 LOE 6 studies that evaluate whether bystander chest compressions in patients not in CPA cause harm. This was not the main objective in one paper, but it was reported.[7] In this study, no serious adverse sequelae were noted by attending emergency medical service (EMS) personnel or by telephone interview. Whether injury occurred from bystander chest compressions in patients not in cardiac arrest was a primary objective of the other 2 papers available. The largest study included 247 people that received chest compressions but were not in cardiac arrest, were examined by a physician, and had a medical record.[8] Rib fractures attributed to the chest compressions were noted in only 4 patients (1.6%). One patient (0.4%) had tracheal bleeding possibly resulting from the chest compressions. Additionally 29 of 247 patients (11.7%) experienced chest pain or discomfort as a probable or possible consequence of chest compressions. One smaller retrospective study had medical records available for 72 patients in whom chest compressions had been performed, but the patient deemed not to be in cardiac arrest.[9] Only 1 patient (1.4%) sustained a possible injury, which was rhabdomyolysis. No rib fractures were noted in this study.

Knowledge gaps

Given the differences in size and conformation of cats and dogs compared to humans, the risk of injury in chest compressions to animals not in CPA remains to be determined. Further, the injuries associated with CPR in dogs and cats that are in CPA are currently unknown.

Airway and Ventilation

Securing a patient's airway for the provision of ventilation is essential during CPR as both hypoxia and hypercapnia have been shown to reduce the likelihood of ROSC in experimental animal studies and human clinical patients.[10–12] The role of ventilation in the first few minutes of CPR is not clearly defined but there is evidence in human pediatric patients that ventilation is more important in patients with CPA not of primary cardiac origin.[13] As the majority of canine and feline cardiac arrests are due to noncardiac root causes, the provision of ventilation early in CPR is likely to be of benefit.

The questions in this section attempt to provide some guidelines for ventilation and highlight the major areas for future research.

Bag-mask or mouth-to-snout ventilation (BLS16)

PICO Question

In dogs and cats with cardiac arrest (P), does bag-mask/mouth-to-snout ventilation (I), compared to ventilation via endotracheal intubation (C), improve any outcomes (eg, ROSC, survival) (O)?

Conclusion

Although there are no veterinary studies addressing this question, there is a single veterinary case report documenting successful mouth-to-snout ventilation. From this, it is reasonable to recommend mouth-to-snout rescue breathing for dogs and cats with respiratory arrest or with CPA in a 30:2 ratio with chest compressions when endotracheal intubation is not available. Bag-mask ventilation may be an effective option in dogs and cats but equipment designed specifically for animals is required

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and its performance evaluated, before any recommendations can be made.

Summary of the evidence

The most recent human CPR guidelines recommend mouth-to-mouth rescue breathing initially as it is the quickest approach to establishing ventilation. Bag-mask rescue breathing can be used by trained personnel but is considered a challenging skill that requires significant training and practice to perform competently. Mouth-to-snout rescue breathing is commonly recommended in veterinary medicine for lay rescuers and when immediate endotracheal intubation is not possible. The effectiveness of mouth-to-snout rescue breathing in dogs and cats with CPA is unknown. No studies in any animal species could be identified in which mouth-to-snout breathing was studied. One case report (LOE 5) describes the successful use of mouth-to-snout ventilation by an owner in a dog with traumatic cervical spinal trauma and respiratory arrest until arrival at a veterinary facility, suggesting it can be an effective rescue breathing technique in animals.[14] The relative efficacy of mouth-to-snout ventilation compared to endotracheal intubation in dogs and cats is unknown. At this time, it is reasonable to recommend mouth-to-snout rescue breathing for dogs and cats with CPA or respiratory arrest when endotracheal intubation is not available.

Bag-mask breathing has not been well described in veterinary medicine. An experimental study in anesthetized cats (LOE 3) compared 2 bag-mask devices.[15] In this study, bag-mask ventilation could achieve adequate PCO_2 levels at acceptable airway pressures suggesting bag-mask ventilation may be effective in animals. No studies evaluating bag-mask ventilation for CPR in dogs or cats could be identified. One study of CPA in rabbits (LOE 6) showed that of 7 rabbits that experienced CPA and had bag-mask ventilation, 5 had ROSC.[16] The use of a tight-fitting face mask was emphasized in this study.

Knowledge gaps

The efficacy of mouth-to-snout ventilation in dogs and cats in providing adequate ventilation and oxygenation is unknown, as are the likelihood of adverse effects such as gastric distension. The practicality and effectiveness of bag-mask ventilation in dogs and cats needs to be determined.

Inspiratory time and tidal volume (BLS14)

PICO Question

In dogs and cats with cardiac arrest (P), does providing ventilation with a 1-second inspiratory time and tidal volume of about 10 mL/kg (I), compared with other inspiratory times and tidal volumes (C), improve any outcomes (eg, ventilation, oxygenation) (O)?

Conclusion

From 3 human clinical studies with various tidal volumes delivered at 12 breaths/min of 100% oxygen to patients in cardiac arrest, no definite conclusion can be drawn on the optimal tidal volume during CPR due to conflicting results. Investigations into inspiratory time utilizing laboratory models show that an inspiratory time between 0.5 and 2.0 seconds is needed to produce a 10 mL/kg tidal volume, but did not assess oxygenation nor ventilation. There is insufficient evidence to determine the optimal tidal volume and inspiratory time during CPR for dogs and cats. Given the current evidence available, it would appear acceptable to use a 10 mL/kg tidal volume with a 1-second inspiratory time.

Summary of the evidence

No study could be identified that addressed this question in dogs and cats. There are several LOE 6 studies that provide some insight on the optimal tidal volume and inspiratory time during CPR. It is critical to maintain normocapnia and normoxemia during CPR via ventilation, inspiratory time, and oxygen supplementation, as hypoxemia or hypercapnia have been shown to negatively impact outcome in LOE 6 CPR studies.[10–12] One LOE 3 and 1 LOE 6 study suggest that hyperoxia also has detrimental effects on CPR outcome.[17,18] No studies were identified that directly related tidal volume or inspiratory time to outcome in CPR, as there are an almost infinite number of variables that likely affect outcome. Consequently, the best one can aim for is to maintain normoxemia and normocapnia with ventilation. It is difficult to compare many of the studies, as there is inconsistent patient selection, inconsistent airway maintenance (some are intubated, some are mask ventilated), and inconsistent oxygen supplementation (21% versus 50% versus 100%).

One neutral study (LOE 6) indirectly suggests that 10 mL/kg of tidal volume may be the optimal target ventilation, as 7 mL/kg caused hypercapnia and 13 mL/kg caused hypocapnia.[19] Another LOE 6 study demonstrated that 10 mL/kg of tidal volume produced normocapnia and nonhypoxemia.[20] In contrast, yet another human clinical study (LOE 6) found that the same tidal volume produced hypercapnia and hypoxemia, although there were a small number of people included in this study and inconsistencies in the methodology.[21] There have been no studies evaluating the optimal tidal volume during CPR for dogs and cats.

During CPR with only a single rescuer present, 2 LOE 6 studies showed shorter inspiratory times were superior to increase the time available for, and consequently the actual number of, chest compressions during CPR without risking an excessive increase in stomach inflation.[22,23] In addition, an LOE 6 study demonstrated that extended duration of positive intrathoracic pressure may negatively impact hemodynamics during CPR and maintaining short inspiratory times will minimize this effect.[24] Furthermore, lower tidal volume will lead to lower mean intrathoracic pressure. Inspiratory times of 1 second were found to provide sufficient tidal volumes compared to 2 seconds in bench-top experiments (LOE 6) while shorter inspiratory times were insufficient to maintain adequate tidal volumes.[25,26]

Knowledge gaps

Given the conflicting information in human studies and lack of any study in veterinary medicine, the ideal tidal volume and inspiratory time in dogs and cats is yet to be determined. Further studies are necessary to evaluate the effect of tidal volume and inspiratory time on respiratory parameters and outcome after CPR.

Ventilation rate (BLS15)

PICO Question

In dogs and cats with cardiac arrest (P), does a ventilation rate of 10 breaths/min (I), as opposed to any other ventilation rate (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

Four experimental pig studies (LOE 6) supported a ventilation rate of 10 breaths/min, while 1 found worsening hemodynamics and ROSC rates with ventilation rates of 20 and 30 breaths/min. In the absence of evidence to support an alternative ventilation rate, it is reasonable to recommend a ventilation rate of 10 breaths/min during CPR in dogs and cats, targeting normocapnia while avoiding arterial hypoxemia.

Summary of the evidence

Four LOE 6 studies support the specific ventilation rate of 10 breaths/min during CPR in porcine ventricular fibrillation (VF) cardiac arrest models.[27–30] In a comparison between chest compressions only, or 10 breaths/min of positive pressure ventilation, the animals in the ventilated control group showed a statistically significantly improved 24-hour neurologic outcome.[27] All other studies demonstrated improved cerebral and coronary perfusion pressure (CPP) resulting in increased vital organ blood flow and achieving shorter duration to ROSC in the 10 breaths/min groups compared to other ventilation rates evaluated.

Two human studies (LOE 6) evaluated various ventilation rates other than 10 breaths/min compared to chest compressions alone and found ventilated patients to have significantly shorter time to ROSC, increased end tidal CO_2, and a significantly higher pH.[20,31] Comparison of several ventilation rates in experimental pig studies (LOE 6) consistently demonstrated inferiority of hyperventilation (20–30 breaths/min); however, extreme hypoventilation (about 3 breaths/min) resulted in impaired pulmonary gas exchange and poor neurologic outcome, suggesting that a successful ventilation strategy needs to balance the opposing effects of protecting vital organ blood flow versus arterial hypoxemia.[32,33] One neutral study in a canine model (LOE 3) mimicking witnessed VF-induced cardiac arrest showed no difference in hemodynamics between ventilation rates of 4 and 8 breaths/min.[34]

Another issue identified in 1 LOE 3 study and 1 LOE 6 study evaluating variable ventilation rates in CPR is that in a single-rescuer scenario, increasing respiratory rates is coupled with less time for chest compressions.[34,35] This may not be a relevant concern in veterinary clinical patients, in which CPR is most commonly performed with more than 1 rescuer and delivery of rescue breaths does not require interruption of chest compressions.

Knowledge gaps

Although there is limited evidence to support a ventilation rate of 10 breaths/min in pigs, no specific evidence exists in dogs and cats at this time. Studies designed to determine the optimal ventilation rate for dogs and cats in CPA undergoing CPR are needed.

Chest Compressions

Chest compressions aim to generate blood flow to vital organs during CPR. Ideal chest compressions may achieve a cardiac output of approximately 25–30% of normal, at most. As a result, it is essential to provide the highest possible quality of chest compressions in an effort to maximize vital organ blood flow during CPR. There are several factors that contribute to maximizing the effectiveness of chest compressions. This section reviews many of these factors.

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Chest compression only CPR (BLS01)

PICO Question

In dogs and cats with cardiac arrest (P), does compression only CPR (I), when compared with traditional CPR (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

No strong evidence-based recommendation can be made at this time. Nearly all the evidence to date is based on studies in other species (pig, humans) and is almost exclusively modeled in a setting of acute VF. Moreover, the quantity and quality of the evidence supporting 1 approach versus the other is roughly similar in its weight. The studies to date suggest that compression-only CPR often results in improved hemodynamics and results in generally acceptable blood gas values for at least the first 4 minutes following VF cardiac arrest. In cases of witnessed arrest of presumed primary cardiac origin, the immediate provision of chest compressions should be the priority. However, intubation and ventilation should be attempted as soon as possible, while compressions are being performed.

Summary of the evidence

Nearly all of the published evidence is not directly applicable to the veterinary clinical setting. While there is a moderate number of clinical trials in which human patients were randomly assigned to receive chest compressions with or without concurrent ventilation, the relevance of these studies to veterinary patients is questionable. Equally concerning is the disparity in results among the published trials regarding outcomes. The meta-analysis by Hupfl and colleagues[36] concluded that in 3 large published trials (LOE 6), there was evidence of improved outcomes with compression-only resuscitation techniques compared to compressions plus mouth-to-mouth ventilation. This same meta-analysis found that no such finding was supported by pooling data from the many more numerous small published trials. Unfortunately, this meta-analysis was published prior to several more large trials (LOE 6) reported from Japan,[13,37,38] all of which concluded that compression-only approaches resulted in outcomes that were inferior (or rarely equivalent) to standard methods. Such results have been echoed in smaller trials (LOE 6) from other parts of the world (eg, Singapore, Sweden, Norway) and do not seem to be inherent to the Japanese model of emergency medical provision.[39–41] Each of these 3 trials has concluded that compression-only or "hands-only" CPR does not result in improved outcomes. To date, no veterinary clinical trials have been published comparing outcomes with the 2 approaches.

The overwhelming majority of laboratory research has been performed in pigs (LOE 6) in VF CPA models and may not be directly translated to the resuscitation of canine and feline patients. A minority of the pig models have used a hypoxic or asphyxial cardiac arrest approach with varied results. The results from pig models of arrest regarding the superiority or inferiority of compression-only CPR are mixed. Five studies have reported worse outcomes (eg, ROSC, survival, neurologic outcomes) with compression-only CPR.[10,42–45] One study reported improved hemodynamics with compression-only resuscitation methods,[35] and 3 studies show no difference in hemodynamics when comparing compression-only and standard CPR.[46–48] Work by both Ewy and Kern utilizing swine out-of-hospital cardiac arrest model (LOE 6) documented superior outcomes (survival, neurologic recovery) in animals resuscitated with compression-only CPR.[49–52]

There are scarce published data using canine models that is relevant to the question at hand (and none whatsoever in feline models). A study by Bendixen et al using a dog model (LOE 3) demonstrated that respiratory acidosis blunts the cardiovascular effects of epinephrine suggesting that compression-only CPR in dogs for more than 4–5 minutes may reduce the effectiveness of one of the most widely used resuscitation drugs.[53] Yakaitis and colleagues demonstrated in a canine model (LOE 3) that respiratory acidosis does not alter the defibrillation threshold substantially, which suggests that in an arrest due to VF, the use of compression-only methods would not inherently alter energy requirements for defibrillation in dogs.[54] Chandra et al demonstrated in a canine sudden cardiac arrest model (LOE 3) that blood oxygenation can be maintained adequately for up to 4 minutes with a compression-only approach to initial resuscitation.[55]

Taken as a whole, both the clinical and experimental evidence provide conflicting results. In addition, these out-of-hospital scenarios with primary cardiac arrest that are examined in these studies are of limited relevance to in-hospital cardiac arrest events that predominate in veterinary medicine. Based on the data available and the ease with which dogs and cats can be intubated, prolonged chest-compression only CPR in dogs and cats is not recommended. Recommendations for resuscitation techniques with regard to compression-only or standard methodology will need to be based on consensus rather than superior evidence at this time.

Knowledge gaps

The relative merits and risks of compression only CPR versus conventional CPR in clinical small animal patients is unknown.

Compression depth (BLS02)

PICO Question

In dogs and cats with cardiac arrest (P), does any specific compression depth (I), as opposed to a comparator (C), improve outcome (O) (eg, ROSC, survival)?

Conclusion

One experimental dog study (LOE 3) and 7 pig or human studies documented (LOE 6) improvement in hemodynamic parameters, ROSC, or success in defibrillation when depth of compression was increased. The optimal compression depth in lateral recumbency in dogs and cats has not been examined, but a compression depth of between one-third and half the width of the chest is reasonable. It would appear that the current human recommendation to "push hard" is likely to be applicable to veterinary medicine.[56]

Summary of the evidence

The majority of research on the effect of compression depth on outcome is with compressions being performed in an anterior-posterior direction (sternal compressions). In a study performed in pigs (LOE 6) using a lateral chest compression technique, depth of compression, cardiac output, and mean aortic pressure were positively correlated.[57] The only canine study (LOE 3) showed that cardiac output and mean arterial pressure increased linearly with sternal chest compression depth between 25 and 60 mm.[58] Using a linear regression technique, cardiac output and mean arterial pressure would be zero with a compression depth of 23 and 18 mm, respectively. Increased depth of compression was associated with an increased rate of successful defibrillation and ROSC in human patients and in pig models (LOE 6).[59–64] Notably, 2 human studies (LOE 6) showed similar rates of ROSC and rates of hospital discharge with increasing depth of compressions.[61,65] Only 1 pig study (LOE 6) failed to demonstrate beneficial cardiac effects of increasing compression depth from 40 to 50 mm, representing an increase from 20% to 25% compression of anterior-posterior chest width, although carotid blood flow was increased.[66]

From these data, one can conclude that depth of compression is important for optimizing cardiac output during closed chest CPR. The ideal depth has not been determined, but is in excess of 38 mm in humans, approximately 16% the external diameter of the thorax, and likely less than 50% of the internal diameter. The risk for injury may limit the maximum beneficial compression depth. Two computed tomography based studies in pediatric patients (LOE 6) demonstrated that over compression, defined as a thoracic internal diameter of less than 10 mm at peak compression, would occur with greater frequency when a compression depth of half is used compared to one-third or one-fourth.[67,68]

Knowledge gaps

Although there is evidence for the ideal chest compression depth being >38 mm in human medicine, the optimal compression depth in lateral recumbency in different dog breeds and cats has yet to be determined.

Compression-to-ventilation ratio (BLS03)

PICO Question

In dogs and cats with cardiac arrest (P), does the use of a specific compression-to-ventilation ratio (C:V) ratio (I), compared with standard care (30:2) (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

The optimal C:V ratio for animals that are not intubated has yet to be determined. Continuous chest compressions have been shown to improve hemodynamics in CPR for intubated patients and are recommended. However, if compressions need to be stopped for ventilation to occur, there is substantial evidence from multiple human clinical studies to suggest that a C:V ratio of less than 30:2 should be avoided. For single-rescuer CPR, a C:V ratio of 30:2 is currently recommended, but continuous chest compressions should be performed for intubated patients.

Summary of the evidence

The optimal C:V ratio during single-rescuer CPR has not yet been determined for the human or veterinary patient. There is evidence that increased ventilation rates (ie, lower C:V ratios) during CPR can negatively impact outcome. One LOE 6 study showed that an increase in respiratory rates leads to extended duration of elevated intrathoracic pressure and is associated with decreased survival, likely due to decreased venous return during chest recoil.[33] Experimental pig studies (LOE 6) reported that continuous chest compressions were associated with higher CPP, PaO_2, and global ventilation/perfusion parameters when compared to chest compressions that are interrupted to allow ventilations.[35,69] Another pig study (LOE 6) reported that neurologic status at 24 hours was better when a C:V ratio of 100:2 was used rather than a 15:2 ratio or continuous chest compressions, although there was no difference in survival between the groups in this study.[70] These findings are further supported by a

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human randomized clinical study (LOE 6), which found that survival to hospital discharge was greater when bystanders were instructed to do continuous chest compressions instead of standard CPR (C:V of 15:2).[71] Utilizing mathematical analysis, oxygen delivery and oxygen delivery with blood flow were determined to be maximal at a C:V ratio near 60:2.[72] Overall, these studies suggest that minimizing ventilation rate (increasing C:V ratio) during single-rescuer CPR maybe of benefit.

Some studies have found no superiority of a C:V ratio of 30:2 over other ratios during CPR. Two experimental animal studies (LOE 3 and LOE 6) found no difference in ROSC between a C:V ratio of 30:2 compared to other C:V ratios.[29,34] In addition, a manikin study (LOE 6) found that rescuer fatigue was no different between a 15:1 and 30:2 C:V ratio.[73]

A C:V ratio of 30:2 has been found to be superior in several studies. More chest compressions per minute were received by human patients (LOE 6) when a C:V ratio of 30:2 was compared to a C:V ratio of 15:2.[74] In an experimental pig study (LOE 6), hemodynamics, blood gases, and ROSC rates were improved in the group resuscitated with a 30:2 ratio compared to a 15:2 ratio.[75] Comparing continuous chest compressions without ventilation to CPR with a C:V ratio of 30:2 in pigs (LOE 6), hemodynamic performance was similar but cerebral oxygen delivery was better when ventilations were included.[44] When a higher C:V ratio of 100:5 was compared to a C:V ratio of 30:2, there was no difference in ROSC or arterial blood gases in another experimental pig study (LOE 6). Continuous chest compressions or a C:V ratio of 100:2 had lower rates of ROSC and poorer blood gas parameters compared to the 30:2 or 100:5 groups in this study.[76]

Knowledge gaps

Although there is substantial evidence that avoidance of C:V ratios of less than 30:2 is beneficial, there is no conclusive evidence that higher ratios improve outcome in single-rescuer CPR in humans. The ideal C:V for single-rescuer CPR in dogs and cats is undetermined at this time.

Compression first versus ventilation first CPR (BLS04)

PICO Question

In dogs and cats with cardiac arrest (P), does the use of compressions first (circulation, airway, breathing [CAB]) (I), compared with ventilations first (airway, breathing, circulation [ABC]) (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

No direct evidence comparing the efficacy of the CAB versus ABC resuscitation techniques exists in veterinary patients. Human studies have shown that delayed initiation of chest compressions due to prolonged intubation times have a potential negative impact on ROSC. Therefore, when multiple rescuers are available, chest compressions, securing an airway and ventilation should all be initiated as soon as possible. In dogs and cats with unwitnessed CPA or CPA not due to primary cardiac arrest where only 1 rescuer is present, traditional ventilation first (ABC) CPR is recommended as long as this does not significantly delay the initiation of chest compressions. In witnessed CPA due to primary cardiac disease, compression first (CAB) CPR is recommended.

Summary of the evidence

No studies have directly addressed the question of whether chest compressions should be initiated prior to endotracheal intubation during CPR (CAB versus ABC) in veterinary patients. Review of the literature reemphasized the importance of uninterrupted chest compressions during CPR in order to improve chances of ROSC. Three LOE 6 studies addressed the negative impact on ROSC caused by the delay in initiation of chest compressions due to either prolonged intubation time or misinterpretation of agonal breaths.[77–79] The American Heart Association 2010 guidelines justified the change from ABC to CAB with the following statement: "While no published human or animal evidence demonstrates that starting CPR with 30 compressions rather than 2 ventilations leads to improved outcomes, it is clear that blood flow depends on chest compressions. Therefore, delays in, and interruptions of, chest compressions should be minimized throughout the entire resuscitation. Moreover, chest compressions can be started almost immediately, while positioning the head, achieving a seal for mouth-to-mouth rescue breathing, and getting a bag-mask apparatus for rescue breathing all take time. Beginning CPR with 30 compressions rather than 2 ventilations leads to a shorter delay to first compression."[56] It is important to note that most of these studies have been conducted in the setting of VF CPA with nonhypoxemic patients and the American Heart Association recommendation is directed toward the lone rescuer scenario in particular.

Knowledge gaps

There are no veterinary studies comparing compression first versus ventilation/intubation first CPR in patients with CPA.

Hand Placement (BLS05)

Circumferential chest compressions (BLS05A)

PICO Question

In small dogs and cats with cardiac arrest (P), do circumferential chest compressions (I), compared to lateral chest compressions (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

Two experimental dog studies (LOE 3) of circumferential compressions versus sternal chest compressions show improved hemodynamics and short-term survival while 2 experimental dog (LOE 3), 1 pig, and 2 human clinical trials (LOE 6) showed neither superiority nor inferiority of this technique. One study in cats (LOE 3) showed ROSC is possible with circumferential compressions. There is insufficient evidence to recommend circumferential chest compressions in dogs and cats at this time over lateral chest compressions.

Summary of the evidence

Circumferential chest compressions can be achieved by manual techniques in small patients, or alternatively automated systems can be used. Two LOE 6 studies were found that evaluated manual chest compression techniques in the form of a "2-thumb" technique for human infants. In this technique, the rescuer places both hands around the chest with their thumbs meeting at the sternum. There is some similarity between this approach and the hand position that can be used in cats and small dogs. These 2 studies used human infant manikins and reported higher compression pressures, greater compression depth, and higher arterial pressures with the 2-thumb technique compared to the more usual 2-finger technique for chest compressions.[80,81]

Automated approaches to external chest compressions have been utilized in animal models and human clinical trials. Circumferential chest compressions are achieved by use of a pneumatic vest (ie, vest CPR) that encircles the thorax and is rhythmically inflated to a specific pressure then deflated. This generates blood flow via the thoracic pump mechanism. All of the studies comparing circumferential chest compressions with regular external compressions perform the regular compressions in the anterior posterior (sternal) direction.

Two experimental studies in dogs (LOE 3) found vest CPR generated greater CPP and was associated with greater 24-hour survival when compared to sternal compressions.[82,83] Comparison of external compression techniques is difficult due to variations in the force or pressure and compression rate used. Vest CPR has been shown to generate far greater cerebral blood flow in dogs than conventional CPR when a compression force of 300 N was used for manual compressions and a vest pressure of 280 mm Hg for vest CPR.[83] However, when conventional CPR was performed with a force of 430 N, similar coronary and cerebral perfusion pressures to vest CPR at a vest pressure of 280 mm Hg could be generated. The higher compression force was associated with more severe rib and liver trauma, and 24-hour survival remained superior in the vest CPR group. In the second study, the vest device was pressurized to 200 mm Hg during inflation and this device also generated abdominal pressures of 100 mm Hg, so it is difficult to directly compare these 2 studies.[82]

The majority of identified studies evaluating circumferential CPR did not find it to be superior or inferior compared to conventional sternal chest compressions. In 1 experimental dog study (LOE 3), no significant difference in the CPP was achieved between vest CPR and sternal compressions, with compressions maintained at equal force (400 N) and rate in both techniques.[84] In a second experimental dog study (LOE 3), vest CPR pressurized to 200 mm Hg found no difference in CPP, ROSC, 24-hour survival, or neurological recovery.[85] An experimental study in pigs (LOE 6) compared cerebral and myocardial blood flow achieved with vest CPR inflated to 150 mm Hg, to previously published studies of conventional CPR in the same model from the same laboratory and found no difference in efficacy.[86] One adult human clinical study (LOE 6) comparing vest CPR (pressures of 180–250 mm Hg), in a small number of patients (n = 15) that had suffered prolonged (42 ± 16 minutes) unsuccessful conventional CPR with sternal compressions at a force of 400 N, found vest CPR generated greater CPP but there was no significant improvement in occurrence of ROSC.[87] In this study, early vest CPR was also performed in 17 patients after 13 ± 4 minutes of unsuccessful conventional CPR. There was a trend toward increased ROSC in this group, but it was not statistically significant. A second adult human clinical study (LOE 6) evaluated vest CPR in 9 patients at pressures of 200 – 300 mm Hg and found it generated similar CPP to conventional CPR.[88] Only 1 study of vest CPR in cats (LOE 3) could be identified. This study demonstrated vest CPR could successfully resuscitate cats with VF in an experimental setting, but no control group was included so the relative efficacy of this approach compared to conventional CPR could not be determined.[89]

One experimental dog study (LOE 3) compared vest CPR with both manual and mechanical sternal compression techniques and found that vest CPR generated the lowest CPP of all methods evaluated.[90] It is important to note that in this study, the inflation pressure of the vest

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was only 100 mm Hg, which could explain the deviation from the findings in other vest CPR studies.

Knowledge gaps

There are no clinical veterinary studies comparing lateral chest compressions versus circumferential chest compressions, although 2 human infant studies raise the possibility that circumferential compressions may be superior.

Lateral chest compressions (BLS05B)

PICO Question

In medium and large-sized dogs with cardiac arrest (P), does placing hands over the highest point of the chest for chest compressions (I), compared to placing hands over the heart for chest compressions (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

One experimental dog study evaluated mitral valve motion with differing hand placement during lateral chest compression but no studies were found that compared any outcome measures of CPR with different hand positions in lateral chest compressions. No evidence-based recommendations on hand placement for chest compressions can be made at this time.

Summary of the evidence

In clinical veterinary medicine, chest compressions in dogs and cats are most commonly performed with the animal in lateral recumbency. Compressions are performed directly over the heart in an attempt to generate blood flow via the cardiac pump mechanism or over the highest point of the chest in an effort to utilize the thoracic pump mechanism. There were no studies identified that directly compared performance of lateral chest compressions by placing hands over the highest point of the chest with placing hands directly over the heart. One experimental dog study (LOE 3) was identified that used transthoracic and transesophageal echocardiography to evaluate how external chest compressions impacted mitral valve motion in dogs of 18–26 kg.[91] This study reported that when lateral chest compressions were performed directly over the heart, the mitral valve closed and the left ventricle was deformed supporting the cardiac pump theory for the mechanism of blood flow for this type of compressions. When lateral chest compressions were performed on regions of the chest wall not directly over the heart, the mitral valve leaflets did not appose, suggesting that the effects of external compressions vary with compression technique, with the cardiac pump theory predominating when compressions are done directly over the heart while the thoracic pump theory predominates when compressions are done over other portions of the chest wall. Therefore, it is possible that one technique has superiority over the other, but no data currently are available to answer this question.

Knowledge gaps

There are no studies evaluating hemodynamics, or ROSC rates with differing hand placement for lateral chest compressions in dogs and cats.

Patient position for chest compressions (BLS06)

PICO Question

In dogs and cats with cardiac arrest (P), does performing chest compressions with the animal in dorsal recumbency (I), compared to lateral recumbency (C), improve outcome (O) (eg, ROSC, survival)?

Conclusion

Given the lack of high-quality evidence, no evidence-based recommendation regarding the best body position for chest compressions in dogs and cats can be made at this time.

Summary of the evidence

In clinical veterinary medicine, chest compressions are most commonly performed with the animal in lateral recumbency, although the majority of experimental animal studies on CPR are performed with the animals in dorsal recumbency. Unfortunately, very little research has compared the relative efficacy of chest compressions in these 2 body positions.

The 1 experimental dog study (LOE 3), identified reported higher left ventricular pressures and aortic flow when manual compressions were delivered with the dogs in lateral recumbency rather than dorsal recumbency.[92] Unfortunately no statistical analysis was provided. The investigators also reported that cardiac chamber dimensions appeared to change more dramatically when compressions were performed in lateral recumbency. A prospective observational study of cardiopulmonary resuscitation in clinical veterinary patients (LOE 2) found that lateral chest compressions were associated with a higher likelihood of ROSC in dogs and cats.[3] As this was an observational study and lateral chest compressions were performed in a far greater number of animals (88%) than sternal compressions (12%), a cause and effect relationship cannot be determined from these data.

An experimental pig study (LOE 6) evaluated mechanical chest compressions done in lateral versus dorsal recumbency (compressions delivered over the sternum) in 3 animals and found no difference in cardiac output or coronary blood flow.[57] All 3 animals received 2 cycles of both lateral and sternal chest compressions in a nonrandomized order (lateral-sternal-lateral-sternal). The authors reported greater thoracic trauma in this group of animals compared to those that just received lateral chest compressions. Given the small number of animals in this experiment, the nonrandomized order of chest compressions, and the use of a mechanical chest compression device, these results have limited value.

Knowledge gaps

There are no studies evaluating the hemodynamic and outcome benefits of chest compressions in lateral versus dorsal recumbency in dogs and cats.

Chest compression rate (BLS07)

PICO Question

In dogs and cats with cardiac arrest (P), does the use of any specific rate for external chest compressions (I), compared with standard care (approximately 100/min) (C), improve outcome (ROSC, survival) (O)?

Conclusion

One high-quality experimental canine study and multiple human clinical trials show that higher compression rates (100–120/min versus 60/min) were associated with superior survival rates. Chest compression rates as high as 120–150/min were associated with good cardiac output and stable CPP, but have not been directly compared to rates of 100/min.

Summary of the evidence

Only 1 experimental dog study (LOE 3) was identified that specifically assessed the effect of compression rate on ROSC and 24-hour survival.[93] In this study, 26 dogs with induced VF were resuscitated using either a compression rate of 60/min or 120/min. The 120/min group were more likely to attain ROSC (12/13) compared to the 60/min group (2/13). The 120/min group also had better 24-hour survival (8/13) compared to the 60/min group (2/13). This study most closely answered the clinical question posed.

There are a number of variables related to chest compression rate that render interpreting the effect of this single element on ROSC difficult. For instance, cardiac output and perfusion are often used as endpoints in resuscitation studies. Since stroke volume is inversely related to heart rate, those factors that affect stroke volume such as force of compression, compression/decompression time, and mechanisms of compression (thoracic pump versus cardiac pump), must be standardized to evaluate only the effect of rate.[94,95]

Three LOE 3 studies were found that showed indirect supporting evidence for survival through improved cardiac output and stable coronary perfusion and cerebral flow with compression rates as high as 150/min in dogs.[90,92,96] In contrast, 2 other LOE 3 studies found no improvement in cerebral blood flow or survival when the compression rate of 60/min was compared to higher compression rates.[97,98] Halperin et al demonstrated that compression rate had no effect on vital organ perfusion in dogs weighing 12–32kg receiving external chest compressions (LOE 3).[95]

Knowledge gaps

The optimal rate of chest compressions in human and veterinary CPR is undetermined. Prospective, randomized, controlled studies evaluating outcome in patients receiving chest compressions at higher rates are warranted.

Chest wall recoil (BLS08)

PICO Question

In dogs and cats with cardiac arrest (P), does optimizing chest wall recoil (I), compared with standard care (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

Three experimental pig studies showed that leaning, (ie, not allowing full chest wall recoil between individual chest compressions) decreased hemodynamic performance as opposed to allowing full chest wall recoil. Several human clinical studies demonstrated that leaning occurs commonly during CPR. It is reasonable to recommend that "leaning" on the chest should be avoided and complete chest wall recoil should be allowed during CPR in dogs and cats.

Summary of the evidence

Allowing complete chest wall recoil (ie, avoiding leaning) between chest compressions during CPR is recommended in the current American Heart Association Guidelines for Emergency Cardiovascular Care and Cardiopulmonary Resuscitation.[56] Although leaning has

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been reported to occur commonly during human clinical CPR (LOE 6), no studies have evaluated the occurrence of leaning during CPR in veterinary clinical patients.[99,102] Evidence in support of this recommendation is derived from 3 LOE 6 studies using VF pig models that demonstrate improved coronary and cerebral perfusion pressures with complete chest recoil during the decompression phase of CPR, when compared to leaning.[100,103,104]

Knowledge gaps

Although experimental evidence shows better hemodynamic performance when complete chest wall recoil is allowed to occur during CPR, no evidence exists as to whether the likelihood of ROSC or survival to discharge is improved in human or veterinary patients.

Interposed abdominal compression CPR (BLS09)

PICO Question

In dogs and cats with cardiac arrest (P), does the use of interposed abdominal compressions-CPR (I), compared with standard CPR (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

Multiple high-quality canine and porcine experimental studies report improved hemodynamic performance using intraabdominal compressions (IAC) compared to standard CPR. In human clinical trials, increased survival to discharge has been documented in 2 studies, and no benefit in 1 study. No increased harm has been documented in any study. It is reasonable to consider IAC-CPR in dogs and cats at this time.

Summary of the evidence

IAC-CPR has been trialed in 8 experimental studies in dogs and 2 in pigs. Six of the dog experimental studies (LOE 3) show a benefit to IAC-CPR over standard CPR with respect to increasing blood flow, blood pressures, venous return, cerebral blood flow, and cardiac output.[105,110] Two studies in dogs (LOE 3) by the same authors concluded no benefit for 24-hour survival and also no additional harm to using IAC-CPR.[98,111] No studies show a benefit of standard CPR over IAC-CPR for any of the parameters described. The canine experimental studies suggest a possible beneficial effect of IAC in regards to generating an increase in blood flow with the risk of patient injury not different from that of standard CPR.

Two pig experimental models (LOE 6) show a benefit of IAC-CPR over standard CPR with respect to better hemodynamic performance during CPR and more subjects surviving the induced arrest and a *trend* toward better 24-hour survival.[111] Two good-quality human studies (LOE 6) show an increased survival to hospital discharge with IAC-CPR compared to standard CPR including 2 meta-analyses.[1,112] One lower quality human study (LOE 6) showed improved $ETCO_2$ values with IAC-CPR compared to standard CPR.[113] However, 1 high-quality controlled study in humans (LOE 6) suggests no advantage.[114] These human studies are of spontaneous in- and out-of-hospital cardiac arrest. There is no evidence of increased trauma with IAC-CPR in dogs (LOE 3).[111] There is no evidence opposing the clinical question, and there are no articles describing experimental or clinical use of IAC-CPR in cats.

Overall there is evidence to support that IAC-CPR maybe superior to standard CPR and is unlikely to cause harm. It is important to note that many studies used automated devices to perform IAC-CPR, so the ability to generate similar results in clinical veterinary patients using manual techniques is unknown.

Knowledge gaps

Although there is experimental evidence of improved hemodynamics in dogs and pig with IAC-CPR, evidence for improved survival in veterinary medicine is lacking at this time. The increased survival to discharge rates seen in some human studies will need to be repeated in dogs and cats with a manual technique in order for this to be relevant to veterinary clinical patients.

Timing of CPR cycles (BLS12)

PICO Question

In dogs and cats with cardiac arrest (P), does the use of any other specific timing for interruptions to chest compressions to diagnose the rhythm (I), as opposed to the recommended technique of every 2 minutes (C), improve outcome (eg, ROSC, survival) (O)?

Conclusion

There are no animal or human studies directly addressing this issue. Two human clinical trials of fair quality suggest that 2 minutes of uninterrupted chest compressions before checking the rhythm is associated with increased survival compared to more frequent pauses in CPR. There is insufficient information to determine the optimal timing for interrupting CPR to diagnose the rhythm, and as such it is reasonable to maintain the current recommendation of continuous chest compressions for 2 minutes before a rhythm check.

Summary of the evidence

There are no animal or human studies that specifically address the optimal duration of CPR before pausing to assess the rhythm. There is evidence that the frequency and duration of interruptions to chest compressions can impact the outcome from CPR. In experimental pig studies (LOE 6), it has been shown that it takes approximately 60 seconds of continuous chest compressions to build up maximal CPP and pauses in chest compressions are associated with immediate decreases in CPP.[35,115]

There is some evidence from human clinical trials that a period of BLS CPR is beneficial prior to performing a rhythm check. In a prospective, observational analysis of witnessed human arrests (LOE 6), providing 2-minute (200 chest compressions at 100 compressions/min) blocks of uninterrupted chest compressions, only pausing to perform a rhythm check ± defibrillation, was associated with significant improvement in survival and neurological state when compared to a cohort of patients treated using the 2000 American Heart Association guidelines where chest compressions were frequently interrupted.[116] Mosier et al reported similar results in a retrospective analysis (LOE 6) of the use of the same protocol.[117] Unfortunately, no randomized controlled trials have been performed to address this issue.

Knowledge gaps

The optimal timing of interrupting chest compressions to diagnose the rhythm is unknown in both human and veterinary medicine. As VF and optimal timing of defibrillation is a major focus of the human studies on this issue, canine- and feline-specific research would be important to validate these findings for veterinary patients.

Rescuer fatigue during CPR (BLS18)

PICO Question

In veterinary CPR providers (P), does performing CPR for an extended period of time (eg, 5 minutes) (I), compared to a short time (eg, 1 minute) (C), impair quality of CPR (eg, chest compression depth, leaning, compression rate) (O)?

Conclusion

One human clinical study and 5 experimental manikin studies demonstrate a loss in quality of chest compressions within the first 1 to 3 minutes. One further manikin study showed chest compressions were well sustained for 2 minutes while another found that they could be maintained for 10 minutes. Although the ideal time to alternate rescuers performing chest compressions is unknown, alternating rescuers every 2 minutes is supported by the evidence available.

Summary of the evidence

Effective chest compressions must be performed at an adequate rate, and appropriate chest wall compression and decompression must be maintained. Performing chest compressions is strenuous exercise and leads to rescuer fatigue; this suggests that the rescuer doing chest compressions should be alternated on a regular basis, if possible. There are several studies in the literature, primarily manikin-based studies, demonstrating that degradation in chest compression quality occurs within the first 1 to 2 minutes of chest compressions and that 5 minutes of chest compressions by a single rescuer is too long. No animal studies addressing this issue were found.

One human clinical study and 6 manikin studies (LOE 6) reported a decline in the quality of chest compressions over time. The clinical study found that the depth of chest compressions declined after 90 seconds of CPR despite provision of automated audiovisual CPR feedback.[118] There is evidence that fatigue and loss of chest compression quality can occur as early as 1 minute after starting chest compressions. A manikin study (LOE 6) showed that the number of correct chest compressions (defined by hand position and compression depth) performed declined every minute for the 5-minute study period from 93% in the first minute to 67%, 39%, 31%, and 18% for each following minute, respectively. Further, the rescuers in this study failed to identify when they were fatigued.[119] In another manikin study (LOE 6), the quality of chest compressions significantly declined after the first minute of CPR, although rescuers on average did not identify fatigue until they had performed 2 minutes of CPR.[120] Three additional manikin studies (LOE 6) suggested chest compressions for 3 minutes or longer was associated with loss of compression quality.[121–123]

Adequate chest wall decompression is also essential for effective CPR, and rescuer fatigue may contribute to incomplete chest wall decompression. One manikin study (LOE 6) demonstrated that incomplete chest wall decompression is a common problem in CPR and noted that rescuer fatigue contributed to the occurrence of inadequate decompression.[99]

In contrast to all the other studies identified, Bjorshol et al (LOE 6) found that the quality of chest compressions could be maintained for a 10-minute period of single-rescuer CPR on manikins at varying C:V ratios.[124] Although chest compression depth declined after the first

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2 minutes, it remained above an acceptable level for the entire study.

Knowledge gaps

Although there are no animal studies evaluating this issue, it is likely that the research findings described above are applicable to veterinary patients as well. Prospective studies evaluating the occurrence of fatigue in rescuers performing CPR in veterinary patients, particularly in cats using a one-hand technique, are warranted. It is also not known how the size and chest conformation of dogs will impact rescuer fatigue.

Discussion

There is no strict definition of BLS as it pertains to CPR. In this consensus statement, BLS includes recognition of CPA, airway management, ventilation, and chest compressions in a manner similar to the current human CPR guidelines. Although rapid defibrillation is also considered part of BLS in human CPR guidelines due to automatic external defibrillator access in the pre-hospital setting, the low incidence of VF as a presenting arrest rhythm in veterinary patients and limited availability of electrical defibrillation resulted in incorporation of electrical defibrillation into the ALS domain. This definition of BLS was selected for consistency, and it provides a suitable framework on which training programs for both lay rescuers and veterinary medical personnel can be developed in the future.

Clinical studies in people have shown that early recognition of CPA and rapid initiation of BLS can improve outcome.[125,126] It is likely to be similar in veterinary medicine with shorter initiation of CPR times potentially improving the chance of ROSC. Proper training of veterinary personnel in recognition of CPA, including identification of agonal breathing and accurate pulse assessment is important. With the current evidence from human medicine indicating minimal harm to patients receiving CPR while not in arrest, BLS should be initiated if there is any doubt a patient has arrested.

Because of the higher incidence of asphyxial cardiac arrest in dogs and cats compared to humans, early institution of ventilation is considered essential in canine and feline CPA victims, although it should not delay or interrupt initiation of chest compressions. The role of mouth-to-snout ventilation or bag-mask ventilation is not well defined for veterinary medicine, but fortunately orotracheal intubation is relatively simple in most dogs and cats. Use of a laryngoscope is important when performing intubation in the CPR setting, the endotracheal tube cuff must be inflated, and the tube secured effectively to prevent dislodgement. As there is an emphasis on early chest compressions, intubation of animals in lateral recumbency is ideal to avoid interruption of chest compressions. This may require specific training to ensure all members of the CPR team are comfortable with this procedure.

Human CPR guidelines have recently changed to recommend initiation of chest compressions before ventilation, suggesting CAB rather than the traditional ABC approach for lone-rescuer CPR. The evidence presented in this summary suggests this approach (ie, start CPR with 30 chest compressions before providing 2 breaths in a lone rescuer scenario) is a reasonable recommendation for lay-rescuer CPR in veterinary medicine. However, the majority of veterinary CPR is performed in-hospital with multiple rescuers present, and in this setting, chest compressions, intubation, and ventilation should be initiated simultaneously. Evidence from the current human literature emphasizes the importance of the rapid initiation of uninterrupted chest compressions during CPR in order to improve chances of ROSC.[77,78] This is also of paramount importance in veterinary medicine and every attempt to minimize interruptions in chest compressions should be made.

Evaluation of the evidence related to chest compression technique (BLS02, BLS07) suggests that the chest should be compressed one-third to half of its width in lateral recumbency at a rate of 100 compressions/min. There is some evidence to suggest faster compression rates could be of benefit, an area that requires further study. These recommendations are in keeping with the current human guidelines of "push hard and push fast" and a similar approach should be introduced to veterinary CPR training, although caution should be used in small dogs and cats. Performing chest compressions is strenuous and rotating compressors between 2-minute cycles of continuous chest compressions is recommended to prevent rescuer fatigue. Chest compressions should not be interrupted within the 2-minute cycle in order to generate maximal CPP and the number and duration of interruptions to chest compressions should be minimized.

In veterinary medical facilities with trained CPR teams, BLS should be integrated with ALS procedures and monitoring so that as many tasks as possible are accomplished in parallel. If personnel are limited, it is important to initiate BLS procedures immediately prior to ALS or monitoring. Although proper ALS and monitoring are key to optimizing the outcome for CPA, good-quality BLS is the essential first step.

Given the paucity of research on veterinary CPR, an extensive list of knowledge gaps emerged from this analysis. In the area of BLS, the most pressing area for future investigation is the ideal body position for chest compressions and the relative efficacy of different hand positions and techniques during chest compressions. Given the variety in size and conformation of canine and feline patients, it is unlikely that there will be 1 optimal CPR technique for all. Future veterinary CPR research should be focused on comparisons between cats, small, medium, and large breed dogs as well as variable canine chest conformations as important aspects of study design. These areas of inquiry are unique to veterinary medicine, and it is vital that we focus our efforts on answering these fundamental BLS questions.

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Appendix

RECOVER Basic Life Support Domain Worksheet Authors

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