Prognostic value of three veterinary illness scores in three dogs post cardiac arrest

Prognostische waarde van drie veterinaire ziektescores bij drie honden na hartstilstand

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ABSTRACT

The post-cardiac arrest (PCA) phase is a critical period that requires intensive care and monitoring. Cardiac arrest and the precipitating disease that led to cardiac arrest have important pathophysiologic effects on the animal. In this study, the applicability of veterinary illness scores is explored on post-cardiac arrest cases to identify their potential prognostic values in the post-cardiac arrest phase. Three cases with different pre-existing diseases are described and the PCA phase is evaluated using the modified Glasgow Coma Scale (mGCS), the Animal Medical Center (AMC) Performance Scale and the Acute Patient Physiologic and Laboratory Evaluation (APPLE) score. Each score assesses a different aspect of a dog's physiology and comes with advantages and disadvantages. A new illness score based on these three scores could provide more appropriate monitoring and prognostic value.

SAMENVATTING

De fase na reanimatie is een kritieke periode die intensieve zorg en monitoring vereist. Hartstilstand en de ziekte die tot hartstilstand heeft geleid, hebben belangrijke pathofysiologische effecten op het dier. In deze studie wordt de toepasbaarheid van veterinaire ziektescores bij honden na hartstilstand onderzocht. Er worden drie gevallen beschreven met verschillende, reeds bestaande aandoeningen en de PCA-fase wordt geëvalueerd met behulp van de modified Glasgow Coma Scale (mGCS), de Animal Medical Center (AMC) Performance Scale en de Acute Patient Physiologic and Laboratory Evaluation (APPLE) score. Elk scoresysteem beoordeelt een verschillend aspect van de fysiologie van een hond en heeft voor- en nadelen. Een nieuwe ziektescore gebaseerd op deze drie scoresystemen zou een geschiktere monitoring en prognostische waarde kunnen bieden.

INTRODUCTION

Cardiopulmonary arrest (CPA) is a stressful event with an often disappointing outcome. Cardiopulmonary resuscitation (CPR) in dogs and cats results in return of spontaneous circulation (ROSC) in only 35% of cases (Hofmeister et al., 2009). Nowadays, only 2-34% of post-cardiac arrest (PCA) dogs and cats survive to hospital discharge, depending on the study. The survival rate is higher in cats than in dogs (Kass and Haskins, 1992; Hofmeister et al., 2009; Smarick et al., 2012; Hoehne et al., 2019). Only seventy cases of PCA dogs and cats surviving to hospital discharge have been described in the veterinary literature (Hoehne et al., 2019). A small cross-sectional study was conducted at the Department of Small Animals, Faculty of Veterinary Medicine, Ghent University. The percentage of dogs and cats achieving ROSC was 34.3%. However, the percentage of cases surviving to hospital discharge was only 3% (Verdoodt, 2021). These data suggest that there is a clear discrepancy between the number of animals achieving ROSC and those surviving to discharge. The post-cardiac arrest (PCA) period is critical for animal survival. Reassessing and optimizing treatment options during this phase could result in a higher percentage of survivors (Boller et al., 2012; Boller and Fletcher, 2015; Boller and Fletcher, 2020).

Survival is determined by several factors: the cause of the arrest, the general condition of the animal, and the pathophysiological changes caused by the arrest itself. These pathophysiological changes consist of the effects of ischemia during arrest and reperfusion after arrest (Neumar et al., 2008; Fletcher and Boller, 2013). Ischemia and reperfusion can cause multi-organ failure, anoxic brain injury and myocardial dysfunction, which can lead to cardiogenic shock. These symptoms, together with those due to the underlying cause of the arrest, are part of a syndrome called post-cardiac arrest syndrome. As mentioned above, this syndrome is fatal in the majority of cases (Neumar et al., 2008; Smarick et al., 2012; Boller and Fletcher, 2015; Boller and Fletcher, 2020).

In human medicine, several scoring systems and algorithms exist to assess the prognosis of PCA patients. Examples include the Cardiac Arrest Survival Post-Resuscitation In-hospital (CASPRI) score (Chan et al., 2012), the Pittsburgh Cardiac Arrest Category (PCAC) score (Nassal et al., 2022) and an algorithm developed by the European Resuscitation Council (Sandroni et al., 2014; Boller and Fletcher, 2020). A veterinary equivalent of a prognostic algorithm or scoring system for PCA dogs and cats is not yet available.

Modified Glasgow Coma Scale

A potentially applicable assessment system for the neurological status of PCA cases is the modified Glasgow Coma Scale (MGCS) (Platt et al., 2001; Platt, 2015). Cardiac arrest can cause important neurological problems due to anoxia (Boller et al., 2012; Boller and Fletcher, 2015; Boller and Fletcher, 2020). Therefore, evaluating the neurological state of the animal after cardiac arrest could be a useful tool to assess the prognosis of the animal. The MGCS is most commonly used to determine the prognosis in animals with head trauma. The MGCS is calculated by assessing the consciousness, the motor activity and the brainstem reflexes to determine neurological function. A score of 15-18 out of 18 is associated with a good prognosis. A score between 9 and 14 indicates a guarded prognosis and a score below 8 is associated with a grave prognosis (Platt et al., 2001; Waldrop et al., 2004; Boller and Fletcher, 2015; Platt, 2015; Ash et al., 2018).

Animal Medical Center Performance Scale

The Animal Medical Center (AMC) Performance Scale assesses the general functional performance of the animal. This scoring system was used in a study by Burk and Mauldin in 1992 to determine the prognosis for animals receiving radiotherapy. It assesses the animal's ability to function normally. The functional performance of a dog or cat can be severely compromised by a cardiac arrest event. Therefore, a score that assesses this aspect of an animal's health could potentially provide information about their chances of survival. The AMC Performance Scale assesses the weight, the appetite, the elimination, the alertness and the tolerance to exercise. The score ranges from 0 to 100. A low score is associated with a negative prognosis and a high score is associated with a good prognosis (Burk and Mauldin, 1992).

Acute Patient Physiologic and Laboratory Evaluation score

The Acute Patient Physiologic and Laboratory Evaluation (APPLE) score assesses the severity of illness in dogs in the ICU. The APPLE score is calculated using blood parameters (creatinine, white blood cell count, albumin, bilirubin and lactate), oxygen saturation, mental status, respiratory rate, age and the presence of free fluid in any body cavity. This score can be used to estimate the survival chances of intensive care cases (Hayes et al., 2010). This scoring system also exists for cats, the feline APPLE score. This score is calculated using a different set of parameters compared to the canine score (Hayes et al., 2011). There are two different scores for both the canine and feline models: a 10-variant score and a 5-variant score. The use of the 5-variant score implies a loss of discrimination as it is based on fewer parameters. However, it is useful when less data is available or when time is limited (Hayes et al., 2010; 2011). These two APPLE scores reflect the severity of the physiological abnormalities in ill dogs and cats. A higher score is associated with a worse prognosis and the score is distributed from 0 to 80. Cardiac arrest can cause significant changes in an animal's normal physiology, which implies that these scores could be affected in these cases. In addition, these two models are independent of the primary diagnosis, which means that they could also be used to assess the prognosis of post-cardiac arrest cases (Hayes et al., 2010; 2011).

Providing prognostic advice to owners is difficult due to the diversity and the low prevalence of PCA cases. The aim of this study was to determine whether one of these scoring systems can be used as a prognostic tool and as an aid in therapeutic decision making for PCA cases.

MATERIAL AND METHODS

A quantitative study was carried out to record all cardiopulmonary resuscitations at the Small Animal Clinic of Ghent University between October 1st 2022 and May 31st 2023. This information was collected with the help of the staff of the hospitalization and anesthesia departments, as well as the students who rotate in these two departments. Several posters were displayed in both departments to inform staff and stu-

Table 1. The Modified Glasgow Coma Scale (Adapted from: Ash, et al. 2018).

Modified Glasgow Coma Scale			
			Score
Motor activity	Normal gait, normal spinal reflexes		6
	Hemiparesis, tetraparesis or decerebrate rigidity		5
	Recumbent, intermittent extensor rigidity		4
	Recumbent, constant extensor rigidity		3
	Recumbent, constant extensor rigidity with opisthotonos		2
	Recumbent, hypotonia of muscles, depressed or absent spinal reflexes		1
Brainstem reflexes	Normal pupil reflexes and oculocephalic reflexes		6
	Slow pupil reflexes and normal to reduced oculocephalic reflexes		5
	Bilateral unresponsive myosis with normal to reduced oculocephalic reflexes		4
	Pinpoint pupils with reduced to absent oculocephalic reflexes		3
	Unilateral, unresponsive mydriasis with reduced to absent oculocephalic reflexes		2
	Bilateral, unresponsive mydriasis with reduced to absent oculocephalic reflexes		1
Level of consciousness	Occasional periods of alertness and responsive to environment		6
	Depression or delirium, capable of responding but response may be inappropriate		5
	Semicomatose, responsive to visual stimuli		4
	Semicomatose, responsive to auditory stimuli		3
	Semicomatose, responsive only to repeated noxious stimuli		2
	Comatose, unresponsive to repeated noxious stimuli		1
MGCS score	3-8	Grave	
	9-14	Guarded	
	15-18	Good	

dents how to report cases of CPR. Of the dogs and cats who underwent CPR, only those who survived more than two hours after CPR were included in the study.

The three scores were adapted into a format that is easy to use in practice and specifically modified to fit with the data routinely collected at the Faculty Clinic (Tables 1, 2, 3). These scores were calculated for each case at different (non-standardized) timepoints after arrest. Specifically for the APPLE score, the score was adjusted to fit with the parameters available at the time of measurement. No additional blood tests were performed to supplement to the measurement of the score.

RESULTS

A total of 75 cardiopulmonary resuscitations took place at the Small Animal Veterinary Clinic of the Ghent University during the study period. Seven cases (9%) achieved ROSC and three cases (4%) survived until discharge. The four cases (5%) that achieved ROSC and died before discharge could not be included in the study due to their short survival time. One cat achieved ROSC but failed to breathe independently after the cardiac event and was therefore euthanized thirty minutes after ROSC. Two dogs developed rearrests at 5 minutes and 17 minutes after ROSC, respectively. Finally, one dog was euthanized two hours after the cardiac event due to the poor prognosis of the initial disease. No assessment was made by the evaluator during these two hours. The three cases that survived to discharge were included in the study. All three were dogs.

Case 1

A male castrated American Staffordshire terrier dog of nine years old was presented with chronic bleeding from a castration incision. The castration had been performed by the owner's veterinarian three weeks prior to presentation. Wound healing was delayed, and a scrotal hematoma developed due to self-trauma. On the morning of presentation, the dog was found by the owners in a pool of blood with pale mucous membranes.

On clinical evaluation, an anemic shock was diagnosed. Clinical examination findings were a systolic heart murmur of 1-2/6 on the left side, strong pulses, tachycardia and pale mucous membranes. There was mild blood loss through the castration incision. Hematology showed regenerative anemia of 13.8%, lymphocytosis, neutrophilia and monocytosis. The biochemistry profile showed hyperglycemia, mild hypoproteinemia and hypochloremia and mildly elevated alkaline phosphatase were present. The coagulation profile was normal. The blood group was DEA 1.1-.

The dog's cardiovascular status was stabilized with a bolus of Ringer lactate of 20 ml kg^{-1}, after which a blood transfusion of DEA 1.1- whole blood was administered at a rate of 15 ml kg^{-1} over four hours. The hemorrhage was stable until the morning after presentation, when a large amount of blood loss was noted through the castration incision. The dog was taken to the anesthesia department for an emergency exploratory surgery. During induction of anesthesia, the dog developed pulseless electrical activity and CPR was initiated. Resuscitation was successful after chest compressions, administration of atropine (0.04 mg kg^{-1} IV; Atropine Sulfate Sterop, Laboratoria STEROP, Belgium), a second whole blood transfusion (DEA1.1-) of 20 ml kg^{-1} and one bolus of 10 ml kg^{-1} of hypertonic saline (7.5% NaCl). Surgery consisted of hemorrhage control by means of ligation of the testicular blood vessels followed by scrotal ablation. Over the next few days, the dog received supportive care including infusion therapy, maropitant (1 mg kg^{-1} IV SID; Cerenia, Zoetis, Belgium), methadone (0.2 mg kg^{-1} IV q4 hours; Insistor, Richter Pharma, Belgium) and pantoprazole (1 mg kg^{-1} IV BID; Pantomed, Takeda Belgium). The dog improved and was discharged after three days.

The veterinary illness scores were measured 24, 31, 34 and 49 hours after resuscitation. The MGCS was 18/18 during all measurements. The AMC Performance Scale gradually improved as follows: 30, 40, 80 and 80 out of 100. Lastly, the APPLE score was relatively stable at 16, 16, 16 and 15 out of 56.

Case 2

A twelve-year-old male castrated mixed breed dog was presented with multiple trauma from a bite incident and a car accident. The dog was bitten by another dog, ran away and was hit by a car. The dog developed respiratory distress and was taken to a local veterinarian. The dog was treated with an unknown dose of glucocorticoids, and chest radiographs were taken. A diaphragmatic hernia was diagnosed, and the dog was transferred to the Small Animal Hospital of Ghent University.

Table 2. The Animal Medical Center Performance Scale (Adapted from: Burk et al., 1992).

AMC Performance Scale (modified Karnofsky score)		
	Score	
1. Normal	100	- Alert - Normal appetite - Ideal or overweight, no change in body condition
	90	- Normal activity and exercise tolerance - Normal elimination behaviour
2. Good	80	- Mild depression or dull, slow to respond to surroundings but normal response to physical stimuli, responds to name - Mild anorexia – decreased consumption of normal diet
	70	- Mild weight loss; adequate condition - Mild decrease in activity/exercise tolerance – wants to exercise, tires more easily - Occasional inappropriate elimination with apparent awareness
3. Fair	60	- Moderate depression – dull, poor response to surroundings, fair response to physical stimuli, doesn't respond to name - Moderate anorexia – eats only special "favored" foods
	50	- Moderate weight loss/physical condition – mild loss, inadequate condition - Moderate decrease in activity/exercise tolerance – willing to exercise, tires readily - Has some inappropriate eliminations with no awareness
4. Poor	40	- Severe depression – stuporous, slow and poor response to surroundings and physical stimuli - Severe anorexia – eats special food only when coaxed/handfed
	30	- Severe weight loss/physical condition – marked weight loss, inadequate physical condition - Severe decrease in activity/exercise tolerance – doesn't want to exercise - Unaware or frequent inappropriate eliminations
5. Moribund	20	- Semicomatose or comatose - Complete anorexia – skin and bones
	10	- Cachexia, "Skin and Bones" - Keeping with above pattern - No voluntary or involuntary exercise - Total fecal and/or urinary incontinence
	0	- Dead

Table 3. The Acute Patient Physiologic and Laboratory Evaluation score (Adapted from: Hayes et al., 2010).

Canine APPLE score			
Age (years)		**Oxygen saturation -** SpO_2 (%)	
	Score		Score
0-2	0	98-100	0
3-5	6	95-97	1
6-8	8	90-94	4
> 8	7	< 90	10
Respiratory rate (bpm)		**Lactate** (mmol/l)	
	Score		Score
< 25	0	< 1	0
25-36	3	1-3,95	2
37-48	5	3,96-5,01	3
49-60	6	> 5,01	6
> 60	5		
Creatinine (µmol/l)		**WBC** (x 10^9/l)	
	Score		Scor
0-55	0	< 5,1	9
56-119	1	5,1-8,5	0
120-199	8	8,6-18	2
> 200	9	> 18	3
Albumine (g/l)		**Fluid score**	
	Score		Score
< 26	6	No abdominal, thoracic or pericardial free fluid identified	0
26-30	7	Abdominal OR thoracic OR pericardial free fluid identified	4
31-32	9	Two or more of abdominal, thoracic and pericardial free fluid identified	3
33-35	0		
> 35	2		
Mentation score			
			Score
Normal			0
Able to stand unassisted, responsive but dull			5
Can stand only when assisted, responsive but dull			7
Unable to stand, responsive			8
Unable to stand, unresponsive			13
C-APPLE SCORE (TOTAL) = …….. (Max. 74)			

Clinical examination revealed dyspnea, paradoxical breathing, pale mucous membranes, tachycardia, weak pulses and severe hypothermia. There was also a superficial laceration on the left hip and several ecchymoses in the groin area. Blood tests showed elevated alkaline phosphatase, urea and lactate. Point-of-care ultrasound revealed a small amount of free fluid in the abdomen. The dog was stabilized with three boluses of Ringer lactate of 20 ml kg^{-1}. The effect of fluid administration on lactate levels was not monitored. The clinical condition deteriorated over time and emergency surgical repair of the hernia was required. Cardiopulmonary arrest occurred during anesthesia and resuscitation was successful after thirty seconds with chest compressions, atropine (0.04 mg kg^{-1} IV; Atropine Sulfate Sterop, Laboratoria STEROP, Belgium) and adrenaline (0.01 mg kg^{-1} IV; Adrenaline Sterop, Laboratoria STEROP, Belgium). An estimated 40 ml kg^{-1} intraoperative blood loss occurred due to splenic rupture and was managed with a bolus of Ringer lactate of 20 ml kg^{-1}, a hypertonic crystalloid bolus of 4 ml kg^{-1} and a whole blood transfusion of 20 ml kg^{-1} over four hours.

Follow-up treatment consisted of supportive care with maropitant (1 mg kg^{-1} IV SID; Cerenia, Zoetis, Belgium), methadone (0.2 mg kg^{-1} IV q4 hours; Insistor, Richter Pharma, Belgium) and amoxicillin/clavulanic acid (20 mg kg^{-1} IV TID; Amoxiclav Sandoz, Sandoz GmbH, Austria). A thoracocenthesis was performed on the first and the second day of hospitalization due to postoperative filling of the thoracic cavity with serohemorrhagic pleural effusion. Thereafter, the amount of pleural effusion progressively decreased. The patient improved and was discharged three days after surgery.

The veterinary illness scores were measured at 5, 8 and 18 hours post cardiac arrest. The MGCS was 18/18 at all the time measurements. The AMC Performance Scale ranged from 75 to 80 out of 100 at the last measurement. Finally, the APPLE score was 37, 32 and 24 out of 56.

Case 3

A one-year-old male castrated Pomeranian dog was presented with a foreign body in the esophagus. The dog had ingested a chicken bone approximately one hour prior to presentation and rapidly developed respiratory distress and cyanosis. After stabilization with oxygen at a local veterinarian, chest radiographs were obtained. A radiopaque foreign body was identified in the esophagus at the base of the heart.

Clinical examination revealed dyspnea and nonproductive coughing. Tracheal reflex was positive. The patient was stabilized in an oxygen cage at 50% oxygen before being transferred to the anesthesia department for endoscopic removal of the foreign body. During transfer, the dog became cyanotic. After endotracheal intubation, a large amount of sputum came out of the endotracheal tube. The dog was stable under anesthesia until the saturation dropped acutely during manipulation of the foreign body. A pneumothorax was suspected but thoracocenthesis was inconclusive. The dog went into cardiopulmonary arrest soon after. Resuscitation efforts were successful with chest compressions and adrenaline (0.01 mg kg^{-1} IV; Adrenaline Sterop, Laboratoria STEROP, Belgium). After resuscitation, the foreign body was pushed into the stomach by endoscopy. Based on the abdominal radiographs, it was expected that the bone would be digested and not cause obstruction.

During hospitalization, 50-60% oxygen was required to keep the dog stable in terms of arterial oxygen saturation levels. A rapid improvement of the clinical condition was observed afterwards, resulting in discharge from the hospital two days after the procedure. One week later, the foreign body was no longer visible in the abdomen on radiographs.

Measurement of the veterinary illness scores was performed at 10 and 14 hours post cardiac arrest. The MGCS was 18/18 at both times. The AMC Performance Scale was 40 and 60 out of 100. The APPLE score was 5/65 at both measurements.

DISCUSSION

The percentage of dogs and cats achieving ROSC varies between studies ranging from 34% to 60%, although the results in the current study were lower (Hofmeister et al., 2009; Buckley et al. 2011; Hogen et al., 2022). However, the percentage of dogs or cats surviving until discharge was similar to the numbers found in the literature (Kass and Haskins, 1992; Hofmeister et al., 2009; Smarick et al., 2012; Hoehne et al., 2019).

Different veterinary illness scores exist for different purposes and cases. The MGCS, the APPLE score and the AMC Performance Scale were specifically selected for this study because they are used to assess different aspects of an animal's health. None of these have been studied for the use in PCA cases, although the MGCS is recommended for neurological follow-up of PCA cases (Boller and Fletcher, 2015).

The MGCS provided positive results across the different assessments of each case. Several reasons may explain these findings. First, the cause of the cardiac arrest was non-neurological and there were no neurological symptoms prior to arrest. Second, not all PCA cases develop neurological symptoms due to PCA syndrome (Cerchiari et al., 1993; Neumar et al., 2008; Binks and Nolan, 2010; Boller et al., 2012; Smarick et al., 2012; Mongardon et al., 2013; Boller and Fletcher, 2015). The MGCS can be used for follow-up in the first 24 hours. Neuroprognostication can be performed afterwards, as it is reliable from 24 hours after arrest (Morrison et al., 2010; Sandroni et al., 2018).

The AMC Performance Scale scores gradually improved over the different measurements and a higher score indicates a better prognosis. The scores appeared to be evolving similarly compared to the general health and well-being of the dogs. Based on these findings, it appears to be important to interpret multiple measurement results, instead of one single measurement. The scoring was based on the worst parameter. For example, if severe anorexia was found in a dog with a good mental status, it would still receive a score of 40. When interpreting this score, it may be difficult to distinguish a stressed dog from a sick one, as parameters such as activity and appetite can be influenced by the hospital context.

For the APPLE score, the 10-variant score was chosen because of its wider range of assessment parameters and higher prognostic value. Due to the unavailability of some blood parameters, the total score was recalculated without these parameters. The effect of converting the total score cannot be determined without further research. The APPLE score is related to the prognosis because it reflects the severity of pathological abnormalities in the animal's normal physiology (Hayes et al., 2010; Hayes et al., 2011). In two of the dogs, the APPLE score was stable and indicated a rather positive prognosis. For case 2, the APPLE score was initially moderately high, indicating a guarded prognosis. Over time, the score gradually improved.

Each score assesses a different aspect of the patient's health, and the combination of the three scores provides a comprehensive picture of the animal. Depending on the case, some scores may be more useful than others. For example, an animal with neurological symptoms will be more accurately monitored by MGCS (Platt et al., 2001; Platt, 2015), even though both the AMC Performance Scale and the APPLE score include an assessment of mentation (Burk and Mauldin, 1992; Hayes et al., 2010). The AMC Performance Scale is useful for the clinical evolution of the patient and can be used for any type of case. PCA dogs and cats are critical patients, so a more intensive follow-up with the APPLE score may prove useful. As treatment needs to be adapted to the presentation of the PCA dog or cat, this could be true for the scoring system as well. For example, if an animal is suspected of having an abdominal, pleural or pericardial effusion, follow-up with the APPLE score would be interesting. However, each score has its advantages and disadvantages in the monitoring of PCA cases. Potentially, creating a new scoring system based on these three scores could provide a more appropriate follow-up of the cases.

Illness scoring systems can be useful for individual trends and prognosis. These scores and their prognosis can provide the clinician with supportive information to make therapeutic decisions, such as switching treatment to different drugs, deciding on euthanasia, etc. However, it is important to consider the animal as a whole and not to make decisions based on the scores alone. Negative or positive prognostic results could also assist the clinician in explaining the animal's condition to the owner (Hayes, 2010; Hayes and Mathews, 2023). The prognostic value of these three scores in PCA cases cannot be defined, as the study population is limited and does not include non-survivors. However, a few studies have been performed on prognostication with the MGCs (Platt et al., 2001; Sharma and Holowaychuk, 2015) and the APPLE score (Hayes et al., 2010), where a prognostic value was identified in head trauma patients and intensive care patients, respectively.

The study design has several limitations. First, the authors relied on information provided by veterinarians and students to identify and signal cases for the study. Some of these cases were not scored as early as desired due to late detection. This contributed to the limited number of scoring data available for each patient and loss of information on one patient that achieved ROSC and was euthanized two hours later. It also resulted in data being collected at irregular times rather than a more systematic approach with fixed measurement times. In addition, the scores were not measured at standardized time points after the first measurement. However, from a clinical point of view, this relates to a realistic situation, in which high levels of stress for the staff involved in a CPR situation, may well lead to deviation from standard operating procedures.

Second, no additional laboratory tests were done specifically for the study. For this reason, the APPLE score could never be fully completed for each case, as no additional blood tests were performed in the three cases. This may be a limitation in terms of the clinical usefulness of the APPLE score system.

Third, the study size only consisted of three patients, all of whom survived to discharge. This can be explained by several reasons. CPR is often a procedure with a low success rate. The population of PCA animals is small (Kass and Haskins, 1992; Hofmeister et al., 2009; Smarick et al., 2012; Hoehne et al., 2019). In addition, as mentioned above, the information was dependent on the contribution of staff and students. This resulted in the loss of data about one patient who survived more than one hour after CPR due to late detection, and animals who did not survive the PCA phase could not be included. Dogs or cats who died in the post-cardiac arrest phase due to rearrest or euthanasia were not included because of their short survival time. However, evaluation of the scores in cases who do not survive the PCA phase is necessary to provide information on the prognostic value of these scores. This illustrates the difficulty in recruiting cases for the PCA phase. Therefore, no objective and quantified conclusions could be drawn due to the limited patient population.

Finally, one of the original aims of measuring interpersonal variation in scoring was not achieved due to the constant change of staff during the week. For this reason, the enrolled cases could not be followed up by the same group of scorers during their hospitalization, with the exception of the first author.

CONCLUSION

Further research is warranted on the use of veterinary illness scores in the PCA setting for prognosis and follow-up. A new veterinary illness score should be created or one of the existing scores could be adapted for more appropriate hands-on patient monitoring in terms of clinical applicability.

REFERENCES

Ash K., Hayes G.M., Goggs R., Sumner J.P. (2018). Performance evaluation and validation of the animal trauma triage score and modified Glasgow Coma Scale with suggested category adjustment in dogs: A VetCOT registry study. *Journal of Veterinary Emergency and Critical Care 28(3*), 192-200.

Binks, A., Nolan, J.P. (2010). Post-cardiac arrest syndrome. *Minerva Anestesiologica 76*, 362-368.
Boller, E.M., Fletcher, D.J. (2015). Post-cardiac arrest care. In: Silverstein D.C. and Hopper K. (editors). *Small Animal Critical Care Medicine*. Second edition, Saunders Elsevier, USA, p. 17-25.
Boller, M., Boller, E.M., Oodegard, S., Otto, C.M. (2012). Small animal cardiopulmonary resuscitation requires a continuum of care: proposal for a chain of survival for veterinary patients. *Journal of the American Veterinary Medical Association 240*, 540-554.
Boller, M., Fletcher, D.J. (2020). Update on cardiopulmonary resuscitation in small animals. *The Veterinary Clinics of North America. Small Animal Practice 50*, 1183-1202.
Buckley G.J., Rozanski E.A., Rush J.E. (2011). Randomized, blinded comparison of epinephrine and vasopressin for treatment of naturally occurring cardiopulmonary arrest in dogs. *Journal of Veterinary Internal Medicine 25(6)*, 1334-1340.
Burk, R.L., Mauldin, G.N. (1992). Use of a performance scale in small animal radiation-therapy. *Veterinary Radiology and Ultrasound 33*, 388-391.
Cerchiari, E.L., Safar, P., Klein, E., Cantadore, R., Pinsky, M. (1993). Cardiovascular function and neurologic outcome after cardiac-arrest in dogs. the cardiovascular postresuscitation syndrome. *Resuscitation 25*, 9-33.
Chan P.S., Spertus J.A., Krumholz H.M., Berg R.A., Li Y., Sasson C., Nallamothu B.K. (2012). A validated prediction tool for initial survivors of in-hospital cardiac arrest. *The Archives of Internal Medicine 172(12)*, 947-953.
Fletcher, D.J., Boller, M. (2013). Updates in Small Animal Cardiopulmonary Resuscitation. *Veterinary Clinics of North America. Small Animal Practice 43*, 971-987.
Hayes, G., Mathews, K. (2015). In: Silverstein D.C., Hopper K. (editors). *Small Animal Critical Care Medicine*. Second edition, Saunders Elsevier, USA, p. 67-75.
Hayes, G., Mathews, K., Doig, G., Kruth, S., Boston, S., Nykamp, S., Poljak, Z., Dewey, C. (2010). The acute patient physiologic and laboratory evaluation (apple) score: a severity of illness stratification system for hospitalized dogs. *Journal of Veterinary Internal Medicine 24*, 1034-1047.
Hayes, G., Mathews, K., Doig, G., Kruth, S., Boston, S., Nykamp, S., Poljak, Z., Dewey, C., (2011). The feline acute patient physiologic and laboratory evaluation (feline apple) score: a severity of illness stratification system for hospitalized cats. *Journal of Veterinary Internal Medicine 25*, 26-38.
Hoehne, S.N., Hopper, K., Epstein, S.E. (2019). Prospective evaluation of cardiopulmonary resuscitation performed in dogs and cats according to the RECOVER guidelines. *Frontiers in Veterinary Science 6*, 439.
Hofmeister, E.H., Brainard, B.M., Egger, C.M., Kang, S. (2009). Prognostic indicators for dogs and cats with cardiopulmonary arrest treated by cardiopulmonary cerebral resuscitation at a university teaching hospital. *Journal of the American Veterinary Medical Association 235*, 50-57.
Hogen T., Cole S.G., Drobatz K.J. (2018). Evaluation of end-tidal carbon dioxide as a predictor of return of spontaneous circulation in dogs and cats undergoing cardiopulmonary resuscitation. *Journal of Veterinary Emergency and Critical Care 28(5)*, 398-407.
Kass, P.H., Haskins, S.C. (1992). Survival following cardiopulmonary resuscitation in dogs and cats. *Journal of Veterinary Emergency and Critical Care 2*, 57-65.
Mongardon, N., Bougle, A., Geri, G., Daviaud, F., Morichau-Beauchant, T., Tissier, R., Dumas, F., Cariou, A. (2013). Pathophysiology and management of post-cardiac arrest syndrome. *Annales Françaises d'Anesthésie et de Réanimation 32*, 779-786.
Deakin C.D., Morrison L.J., Morley P.T., Callaway C.W., Kerber R.E., Kronick S.L., Lavonas E.J., Link M.S., Neumar R.W., Otto C.W., Parr M., Shuster M., Sunde K., Peberdy M.A., Tang W., Hoek T.L., Böttiger B.W., Drajer S., Lim S.H., Nolan J.P. (2010). Advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. *Resuscitation 81 Suppl 1*, e93-e174.
Nassal, M.M.J., Nichols, D., Demasi, S., Rittenberger, J.C., Panchal, A.R., Kurz, M.C., Service, U.P.-C.A. (2022). External validation of Pittsburgh Cardiac Arrest Category illness severity score. *Resuscitation 172*, 32-37.
Neumar, R.W., Nolan, J.P., Adrie, C., Aibiki, M., Berg, R.A., Bottiger, B.W., Callaway, C., Clark, R.S.B., Geocadin, R.G., Jauch, E.C., et al. (2008). Post-Cardiac Arrest Syndrome Epidemiology, Pathophysiology, Treatment, and Prognostication A Consensus Statement From the International Liaison Committee on Resuscitation (American Heart Association, Australian and New Zealand Council on Resuscitation, European Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Asia, and the Resuscitation Council of Southern Africa); the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; and the Stroke Council. *Circulation 79*, 350-379.
Platt, S. R. (2015). Coma scales. In: Silverstein D,C., Hopper K. (editors). *Small Animal Critical Care Medicine*. Second edition, Saunders Elsevier, USA, p. 422-425.
Platt, S.R., Radaelli, S.T., McDonnell, J.J. (2001). The prognostic value of the modified Glasgow Coma Scale in head trauma in dogs. *Journal of Veterinary Internal Medicine 15*, 581-584.
Sandroni C., Cariou A., Cavallaro F., Cronberg T., Friberg H., Hoedemaekers C., Horn J., Nolan J.P., Rossetti A.O., Soar J. (2014). Prognostication in comatose survivors of cardiac arrest: an advisory statement from the European Resuscitation Council and the European Society of Intensive Care Medicine. *Resuscitation 85(12)*, 1779-1789.
Smarick S.D., Haskins S.C., Boller M., Fletcher D.J. (2012). Recover evidence and knowledge gap analysis on veterinary CPR. *Journal of Veterinary Emergency and Critical Care 22 Suppl 1*, 85-101.
Verdoodt, F., (2021). Cardiopulmonary resuscitation and the RECOVER guidelines at the Faculty of Veterinary Medicine, Ghent University. *Vlaams Diergeneeskundig Tijdschrift 90*, 125-132.
Waldrop, J.E., Rozanski, E.A., Swanke, E.D., O'Toole, T.E., Rush, J.E. (2004). Causes of cardiopulmonary arrest, resuscitation management, and functional outcome in dogs and cats surviving cardiopulmonary arrest. *Journal of Veterinary Emergency and Critical Care 14*, 22-29.