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Care Following Successful Cardiopulmonary Cerebral Resuscitation

Following successful cardiopulmonary cerebral resuscitation, relation may be short-lived. Up to 68% of dogs and 38% of cats may experience a second arrest during the same hospitalization, often within hours of the initial one.

Numerous factors predispose to repeated arrests, including persistence of the underlying disease that precipitated the initial event, reperfusion or central nervous system injury, hypoventilation, diminished cardiac output, and cardiac arrhythmias. To assure successful hospital discharge, close attention must be given to the patient's dynamic status. Monitoring the animal in the postarrest period is just as important as CPR itself.

During cardiopulmonary arrest, tissue perfusion ceases and cell damage ensues. After CPR, restoration of spontaneous circulation returns oxygen to deprived tissues, setting off a cascade that leads to further cellular damage in every system of the body. Free radicals that are produced tear electrons off lipid molecules, DNA, and other intracellular molecules, causing extensive and sometimes irrevocable cell damage.

Reperfusion damage is accompanied by abnormalities that were present before arrest; therefore, inadequacies in vital organ function can be predicted. Most important is the effect on the brain and myocardium. In the brain, neuronal swelling can cause increased intracranial pressure, as well as the release of potentially harmful neurotransmitters (eg,

glutamate), which can trigger neuronal apoptosis. Many patients remain comatose or have brain stem dysfunction that predisposes to hypotension and hypoventilation. Cardiac arrhythmias and decreased myocardial contractility contribute to poor cardiac output.

Levels of Care Essential Care

Patients that experience cardiopulmonary arrest for a short period and for a readily reversible reason (eg, those with anesthetic-related or vagally mediated arrest) can sometimes be treated easily and discharged from the hospital after a monitoring period of at least 24 hours. Close observation should assure that normal mentation, oxygenation, and blood pressure are restored within a few minutes of return to spontaneous circulation. Continued monitoring should confirm that vital parameters remain within the normal range, and rapid attention to any abnormalities may be enough to ensure a successful outcome.

Advanced Care

Animals with more serious disease conditions, particularly when the cause of the cardiopulmonary arrest is not readily reversible, and those in which the arrest lasted longer than 1 to 2 minutes, require

more intense care. Monitoring should include repeated physical examinations and immediate blood testing, including hematocrit, total protein, plasma electrolytes, venous and arterial blood gases, and blood lactate. In addition, continuous electrocardiography, arterial and central venous blood pressure monitoring, pulse oximetry, end-tidal capnography, and urine output should be monitored as necessary so that the clinician can learn of subtle deteriorations before they become catastrophic.

Laboratory testing should include measurement of white blood cell and platelet counts, prothrombin and partial thromboplastin times, and markers of renal and hepatic function (eg, blood urea nitrogen, creatinine, and total bilirubin). Treatment may include administration of supplemental oxygen or positive-pressure ventilation, intravenous fluids, colloids or blood transfusions, intravenous vasopressor therapy, and management of elevated intracranial pressure or oliguria.

When to Consider Referral

Animals that experience cardiopulmonary arrest from any disease process that cannot be easily reversed should be referred to a 24-hour facility for continued monitoring and care. Patients whose mentation, oxygenation, ventilation, cardiac rhythm, blood pressure, coagulation, and urine output are not normal within 1 to 2 hours after arrest will probably require prolonged hospitalization and 24-hour care.

When Referral Is Not an Option

Successful resuscitation must be quickly followed by efforts to correct the underlying disease process, diagnosis of the extent of organ injury, and intensive monitoring. Reversible problems, such as hyperkalemia, hypovolemia, anemia, or upper airway obstruction, should be urgently treated. Anesthetic drugs should be reversed whenever possible.



Optimal neurologic outcome may be achieved through efforts to minimize intracranial pressure, including administration of mannitol, elevation of the head to 30°, and avoidance of jugular vein compression or coughing. When elevating the head, it is important to avoid bending the neck, which can compress the jugular vein and thereby increase intracranial pressure. Therefore, the whole body, neck, and head should be placed on a board elevated to a 30° angle.

Brain Function

Vital parameters must be monitored and optimized on an organ–system basis. Brain function is the first priority (Figure 1). Following resuscitation, mannitol (0.5–1 g/kg IV over 20 min) is usually administered. Mannitol is a scavenger of oxygen free radicals, and it removes intracellular water molecules from cerebral neurons with cytotoxic edema by virtue of its osmotic effects.

Respiratory Function

Respiratory function should be monitored by using arterial blood gases, pulse oximetry, and end-tidal capnography. Supplemental oxygen should be provided. If arterial partial pressures of oxygen are less than 60 mm Hg (or if oxygen saturation cannot be maintained above 92%) or the partial pressure of carbon dioxide exceeds 60 mm Hg, positive-pressure ventilation with bag-valve mask or ventilator may be needed (Figure 2). These values are guidelines only—when respiratory fatigue appears imminent, mechanical ventilation is warranted.



Extubation should be postponed until the patient can maintain a normal PaCO₂ (< 45 mm Hg) and oxygen saturation values above 92% without 100% oxygen to prevent any episodes of hypoxia or hypercarbia. Extubation may also be delayed in patients with severe neurologic or cardiovascular abnormalities. Some patients may require low doses of benzodiazepines or opioids to maintain intubation.

continues

CPCR = cardiopulmonary cerebral resuscitation; PaCO₂ = partial pressure of carbon dioxide

Cardiovascular Function

Continuous electrocardiography should be initiated, and any arrhythmias affecting perfusion should be treated. Animals with severe bradyarrhythmias, such as third-degree atrioventricular block or sinus arrest, may require placement of a temporary pacemaker. In dogs, the most common tachyarrhythmias are ventricular premature contractions and ventricular tachycardia. If the overall heart rate is not significantly elevated (160 beats/min), then the arrhythmia is unlikely to be directly contributing to decreased tissue perfusion and may not require treatment with an antiarrhythmic drug. Rather, the clinician should treat the underlying cause by normalizing myocardial oxygen delivery (intravascular volume, hematocrit, and oxygenation), electrolytes, and acid–base status.

Ventricular tachycardia and ventricular premature contractions at higher rates are likely to affect cardiac output and should be treated with intravenous lidocaine (2–4 mg/kg IV bolus; then 30–80 mcg/kg/min by continuous infusion) or procainamide (10–15 mg/kg IV bolus; then 25–50 mcg/kg/min by continuous infusion) if the arrhythmia does not respond to lidocaine. Supraventricular tachycardias are less common and do not usually require treatment, but if necessary can be addressed with diltiazem (0.125–0.35 mg/kg as a slow bolus over 2–3 min).

Arterial blood pressure should be monitored frequently, ideally by using an arterial catheter (**Figure 3**). Alternatively, Doppler or oscillometric blood pressure measurement can be used. Systolic arterial pressure should be maintained above 100 mm Hg, and mean arterial pressure should be above 70 mm Hg. In the absence of preexisting cardiac failure, hypotensive patients should receive intravenous boluses of crystalloid fluids, colloids, or blood products, as indicated



After an arrest, measurement of arterial pressure by arterial catheter is ideal because this method is accurate even at low blood pressures. Placement of the catheter also allows sample collection for arterial blood gas analysis.

by postarrest packed cell volume/total protein and electrolytes. A central venous (through the needle or over-the-wire) catheter can be placed in the jugular vein to measure central venous pressures, which should be maintained at 5 to 10 cm H₂O in dogs and 2 to 5 cm H₂O in cats.

If blood pressure is still inadequate after reexpansion of intravascular volume, positive inotropes or vasopressors may be considered. Dopamine is often chosen as a first-line vasopressor, usually starting as a continuous infusion at 5 to 8 mcg/kg per minute for its inotropic (β 1-receptor) effects, but it can be titrated to within the vasoconstrictive (α -receptor agonist) dose range of 10 to 15 mcg/kg/min if necessary to maintain target blood pressures. When target blood pressures are not achieved with dopamine alone, norepinephrine (0.01–0.4 mcg/kg/min) or dobutamine (5–15 mcg/kg/min) may be added, titrating from the low end of the dose range to effect. Measuring

serum lactate may be useful for evaluating tissue perfusion, with the goal of keeping the lactate level below 2 mmol/L.

Animals with coagulopathies, or those suspected of having disseminated intravascular coagulation, will probably require treatment with blood products, such as fresh frozen plasma.

Renal Function

Urine output monitoring is the best way to assess renal perfusion. Minimal urine output should be 0.5 to 1 mL/kg/hr. Urine of spontaneously voiding patients may be collected on diapers, which are weighed. If oliguria is a concern, a urinary catheter with a closed collection system may be needed for optimal monitoring. Oliguria (if the patient has adequate intravascular volume and blood pressure) may require treatment with diuretics, such as mannitol or furosemide.

Hypothermia

Patients that are comatose or stuporous may benefit from mild hypothermia. Because inadvertent severe hypothermia can occur easily, active cooling should not be attempted; however, patients that are spontaneously hypothermic after arrest should not be actively warmed unless their temperature falls below 93° F (33.8° C).

The Referral Process

The referring veterinarian should provide a complete medical record including a description of the arrest, the suspected inciting cause, all drugs administered with doses, and laboratory and imaging results. Ideally, a veterinarian should accompany intubated patients during transport, especially if repeated administration of sedative or anesthetic drugs might be required. Supplemental oxygen can be provided, and intravenous fluids can be set at a gravity drip rate for transport, or discontinued for short transport times. A cost estimate should be provided by the referral facility and discussed with the owner before transport. ■

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