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A Pharmacologic Review of Cardiac Arrest

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Cardiac arrest is manifested by arrhythmias (ventricular fibrillation or pulseless ventricular tachycardia, pulseless electrical activity, or asystole) resulting in minimal to no forward blood flow to the body's oxygen-dependent tissues. Defibrillation and cardiopulmonary resuscitation (CPR) should be initiated immediately as they have been shown to increase return of spontaneous circulation and survival to discharge rates. Cardiac arrest in the surgical patient population has devastating consequences. Data specific to the surgical patient found that 1 in 203 surgical patients experienced cardiac arrest requiring CPR within 30 days after surgery. A subgroup analysis found that 1 in 1,020 plastic surgery patients required CPR in this same time frame. Thirty-day mortality in the general surgery patient population was 72%. The American Heart Association updates the advanced cardiac life support (ACLS) guidelines every 5 years. Their latest publication in 2010 recommended that the resuscitative protocol be transitioned from its basic life support sequence of airway-breathing-chest compressions to chest compressions-airway-breathing. All health care professionals should have an understanding of the clinical presentation and medical management of cardiac arrest. Maintaining biannual basic life support and ACLS certification ensures that health care professionals remain current with American Heart Association guideline recommendations. Guideline-directed management of cardiac arrest should include timely implementation of the ACLS algorithm to maximize patient outcomes.

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Surgically related cardiac arrest is a major health concern with significant morbidity and mortality. Over the past decade, patients requiring in-hospital cardiopulmonary resuscitation (CPR) had a 22% survival rate to hospital discharge (Girotra et al., 2012). Preventing cardiac arrest in the surgical patient is not always possible; however, preparation to handle this situation is key to maximizing successful resuscitation in cardiac arrest. Knowing the appropriate measures proposed by treatment guidelines, employing good communication among health care providers, and timely administration of medical interventions are vitally important for patient outcomes. The purpose of this review article is to provide a nursing perspective on cardiac arrest and discuss its guideline-directed medication management.

ADVANCED CARDIOVASCULAR LIFE SUPPORT MANAGEMENT

Both intraoperative and postoperative cardiac arrests are major health concerns with significant morbidity and mortality rates. Retrospective data from 250 U.S. hospitals determined that at 30 days or less after surgery, 1 in 203 surgical patients experienced cardiac arrest requiring CPR. Limited data specific to the plastic surgery patient found the incidence of CPR at 30 days or less after a plastic surgery case is 1 in 1,020. More than 75% of the surgical patients who required resuscitation for a cardiac arrest had experienced a complication often occurring prearrest such as pneumonia, venous thromboembolism, preoperative sepsis, or acute renal failure/insufficiency. Consequently, 30-day mortality in these patients was 72%. The majority of these plastic surgery patients who received CPR died the day of attempted resuscitation (Kazaure, Roman, Rosenthal, & Sosa, 2013).

To provide the most effective, time-efficient care in medical emergencies, health care providers should be well versed in basic life support (BLS) and advanced cardiac life support (ACLS). A team-based approach with clear delineation of each team member's role, clear communication among team members, and familiarity with the ACLS algorithms (Figures 1 and 2), code cart, and medication administration will maximize resuscitative efforts (Field et al., 2010). Team members should stay current with the latest American Heart Association (AHA) guidelines, while recertifying in BLS and ACLS every

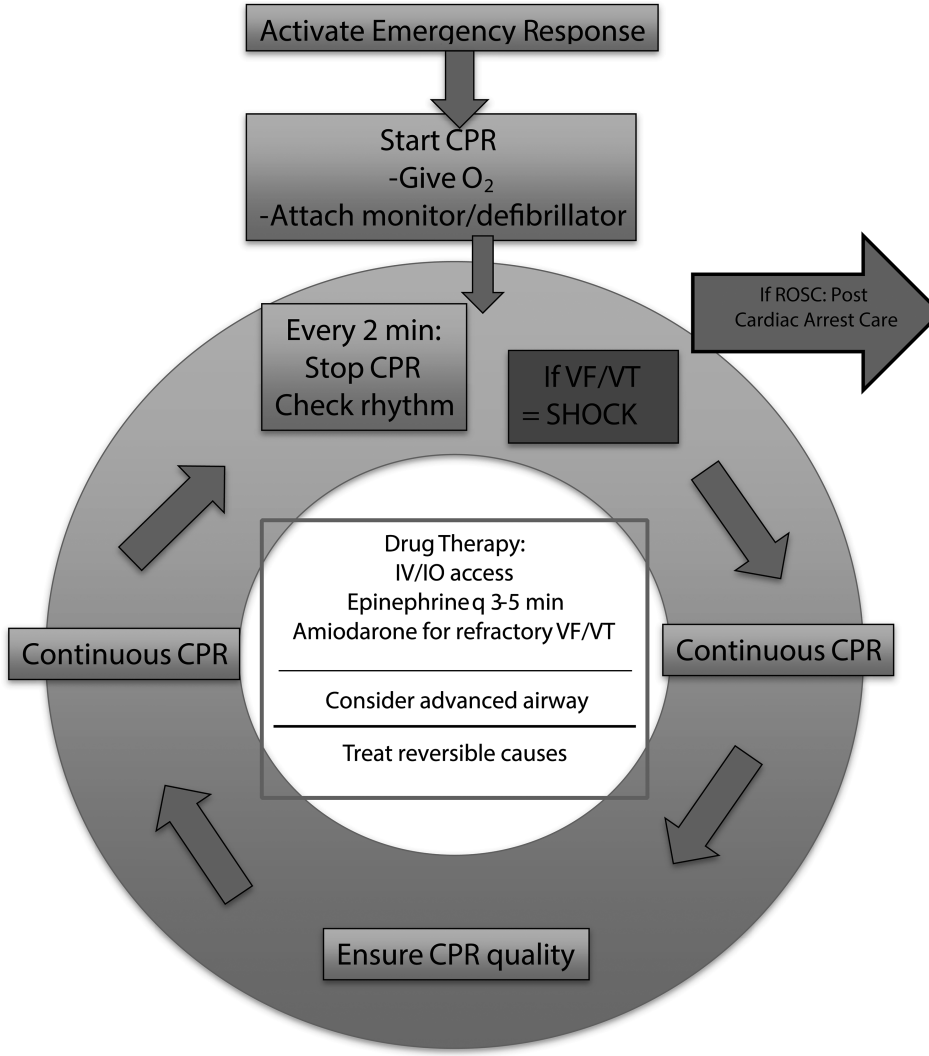

FIGURE 1. Cardiac arrest circular algorithm. CPR = cardiopulmonary resuscitation; IO = intraosseous; IV = intravenous. From *Advanced Cardiovascular Life Support Provider Manual* by E. Sinz, K. Navarro, E. Soderberg, 2011, Dallas, TX: First American Heart Association Printing.

2 years. Between certification courses, team members can participate in code simulation to improve adherence to AHA standards and increase confidence and comfort during a true code situation (Andreatta, Saxton, Thompson, & Annich, 2011; Wayne et al., 2008).

Every 5 years the AHA updates its ACLS guidelines. The last update published in 2010 recommended several changes. The resuscitative protocol has transitioned its BLS sequence from airway–breathing–chest compressions to chest compressions–airway–breathing. The emphasis of early chest compressions is based on out-of-hospital data that showed survival was greater when bystanders attempted CPR than when no attempt at CPR was made. Additional updates included that chest CPR should consist of at least 100 chest compressions per minute at a depth of at least 2 inches in adults (Hazinski et al., 2010).

Cardiac arrest will present as one of four possible rhythms: ventricular fibrillation (VF), pulseless ventricular tachycardia (VT), pulseless electrical activity (PEA), or asystole. These rhythms provide minimal to no forward flow of oxygenated blood to the body's tissues, necessitating outside measures of CPR, supplemental oxygen, and vasoactive medications in an effort to achieve return of spontaneous circulation (ROSC). Early initiation of CPR and appropriate defibrillation of VF/pulseless VT have been shown to increase patient survival rate (Abrams, McNally, Ong, Moyer, & Dyer, 2013; Agarwal, Hess, Atkinson, & White, 2009; Caffrey, Willoughby, Pepe, & Becker, 2002). Caffrey et al. evaluated random bystander usage of an automated external defibrillator at three Chicago airports from 1999 to 2001. Over these 2 years, 18 patients experienced VF. Fourteen of these patients received defibrillation within 5 min, 11 of whom were successfully resuscitated. At 1 year postarrest, 10 of 11 were still alive and neurologically intact. Of the four patients who did not receive bystander defibrillation within 5 min, there

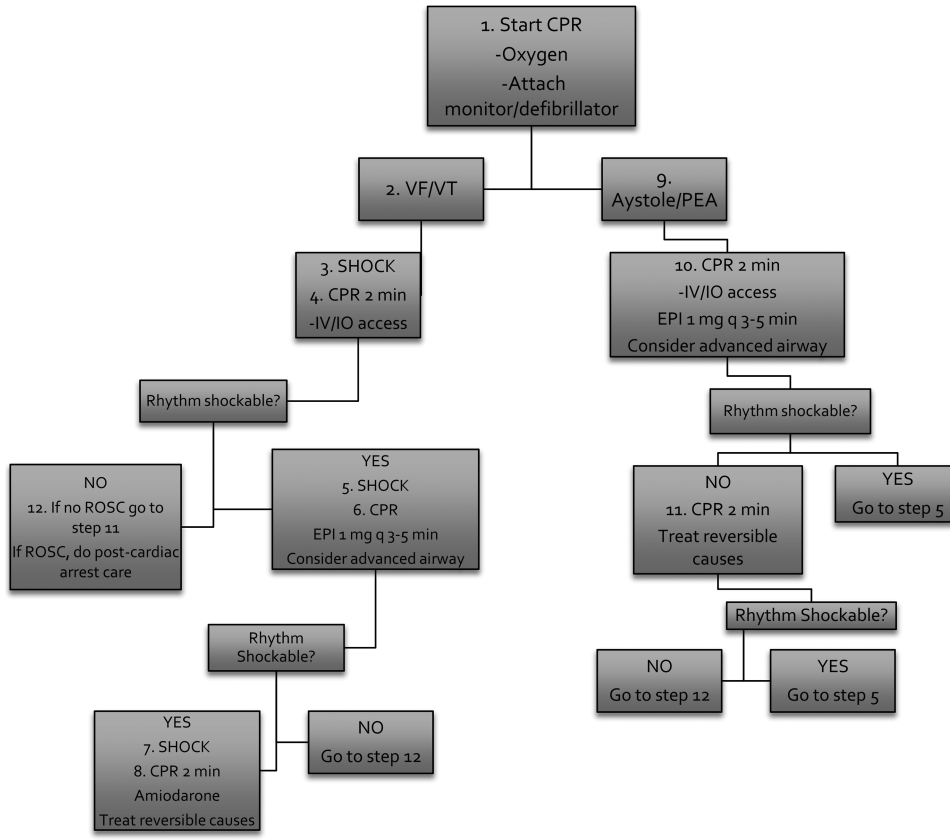

FIGURE 2. Cardiac arrest algorithm. CPR = cardiopulmonary resuscitation; IO = intraosseous; IV = intravenous; VF = ventricular fibrillation; VT = ventricular tachycardia. From *Advanced Cardiovascular Life Support Provider Manual* by E. Sinz, K. Navarro, E. Soderberg, et al., 2011, Dallas, TX: First American Heart Association Printing.

were no survivors (Caffrey et al., 2002). Conversely, vasoactive medications, such as epinephrine and vasopressin, have been shown to increase ROSC but have not been shown to increase rates of survival to discharge (Neumar et al., 2010). Many of the clinical trials evaluating these vasoactive medications preceded the current guideline recommendations of early CPR and the postcardiac arrest care algorithm. While vasoactive medications are recommended in the 2010 ACLS algorithm to increase ROSC, whether the medications in conjunction with CPR, defibrillation, and the other ACLS core measures will translate to increase rates of survival to discharge is yet unknown (Neumar et al., 2010).

VF/PULSELESS VT

Ventricular fibrillation is a disorganized, rapid, and erratic ventricular contraction, while pulseless VT is a more organized, rapid, and irregular myocardial contraction. Both result in minimal to no forward blood flow to the body's oxygen-dependent tissues. Defibrillation and CPR should be initiated immediately as they have been shown to increase survival to discharge rates (Abrams et al., 2013; Agarwal et al., 2009; Caffrey et al., 2002). If VF/pulseless VT persists, despite at least 1 defibrillation and 2 min of CPR, epinephrine may be given. Epinephrine acts as an agonist at α_1-, β_1-, and β_2-adrenergic receptors. Stimulation of the α_1 receptors results in vasoconstriction, whereas stimulation of the β_1 receptors results in increased heart rate and force of contractility. Effects on the β_2-adrenergic receptors result in dilation of the smooth muscle of the bronchi, and a decrease in hepatic venous resistance, which results in an increase in venous return (Clinical Pharmacology (Epinephrine), 2014). Epinephrine (1 mg) is administered as an IV push to potentially increase myocardial blood, prior to the next shock. Alternatively, in a patient without IV access, epinephrine may be given intraosseously (IO) through an IO device into the sternum, humerus, and tibia. Epinephrine is available in various product sizes and concentrations. Code situations require prompt medication administration, and, therefore, a prefilled syringe is frequently stocked in emergency code carts. It contains a 10-ml premixed 1:10,000 epinephrine concentration glass syringe that manually twists into its accompanying plastic syringe barrel and is quickly ready for IV administration to the patient. The entire syringe (1 mg = 10 ml) is administered. Code situations are stressful in nature and if epinephrine vials are the only option, an easy way to quickly

determine the amount of fluid to withdraw is essential to properly timed medication administration. There are two common vial concentrations, the 1:10,000 and the 1:1,000. An easy way to quickly withdraw the correct volume is to take the number preceding the comma and that amount of volume equals 1 mg of epinephrine (e.g., **10** mL of 1:**10**,000 = 1 mg; **1** mL of 1:**1**,000 = 1 mg).

Amiodarone is the first antiarrhythmic medication given during VF/pulseless VT cardiac arrest that is refractory to CPR, shock, and vasopressors. Amiodarone inhibits calcium, sodium, and potassium channels while blocking α- and β-adrenergic receptors resulting in a broad-spectrum antiarrhythmic effect. Amiodarone prolongs myocardial action potentials and delays cardiac repolarization causing its antifibrillatory effect. Amiodarone has been shown to increase ROSC in patients with refractory VF/pulseless VT and increase out-of-hospital survival to hospital admission when compared with placebo or lidocaine, another antiarrhythmic (Dorian et al., 2002). For patients with VF/pulseless VT, amiodarone is given as a 300 mg IV bolus as a first dose, 150 mg for the second dose. Amiodarone is available in a 150 mg/3ml vial. Of note, for noncardiac arrest arrhythmias such as atrial fibrillation or atrial tachycardia, amiodarone is not given as an IV bolus but initiated as an infusion to minimize the hypotensive side effects induced by its polysorbate 80 and benzyl alcohol drug solvents. If patients do have ROSC after amiodarone administration, blood pressure should be closely monitored and determination made if a vasopressor drip is required to maintain adequate blood pressure (Neumar et al., 2010).

If amiodarone is not available, lidocaine, although second line, may be used instead. Lidocaine is a sodium channel blocker that exerts it antiarrhythmic effect by increasing the electrical stimulation threshold of the ventricle and the His-Purkinje system as well as suppressing spontaneous depolarization in the ventricles during diastole (Clinical Pharmacology (Amiodarone), 2014; Lexi-Comp (Amiodarone), 2014). The initial dose during VF/pulseless VT arrest is 1–1.5 mg/kg IV/IO. Lidocaine is available in 100-mg prefilled syringes for rapid administration. Of note, lidocaine is less preferred than amiodarone, because lidocaine has not been shown to increase rates of ROSC or hospital admission after out-of-hospital arrests (Neumar et al., 2010). Should patients experience ROSC after lidocaine administration, patients should be monitored for bradycardia, hypotension, and additional arrhythmias as lidocaine can be proarrhthymic (Lexi-Comp (Lidocaine), 2014).

PEA/ASYSTOLE

Pulseless electrical activity and asystole are cardiac arrest rhythms with a very poor prognosis. Survival to hospital discharge is less likely with an initial rhythm of PEA (12%) or aystole (11%) than for first documented rhythms of VF (37%) or pulseless VT (37%) (Meaney et al., 2010). Pulseless electrical activity and asystole are managed utilizing the same ACLS treatment algorithm. Pulseless electrical activity is an organized rhythm without a pulse, whereas asystole has no discernible electrical activity, presenting as a "flat line" on the electrocardiogram monitor.

When treating PEA/asystole, code team members should consider potentially reversible causes of PEA/aystole, because correction of such cause will increase survival likelihood. The reversible causes can be remembered by the 5 H's and 5 T's in Table 1. Vasopressors should be initiated as early as possible following PEA/asystolic arrest and at 3- to 5-minute intervals until ROSC or a shockable rhythm develops. The purpose of epinephrine and vasopressin is to increase myocardial and cerebral blood flow during CPR and obtain ROSC. Epinephrine (1 mg) is administered IV/IO every 3–5 min during PEA/asystole followed by a 20-ml flush of 0.9% saline. Vasopressin, an alternative to epinephrine, works

TABLE 1 Potentially Reversible Causes of Pulseless Electrical Activity and Asystole

H's	Intervention	T's	Intervention
Hypothermia	Various	Tension pneumothorax	Needle decompression Tube thoracostomy
Hypoxia	Oxygenate, ventilate, advanced airway	Tamponade	Pericardiocentesis
Hypovolemia	Intravenous fluids	Toxins	Intubation, antidote if available
Hydrogen ion (acidosis)	Ventilate, sodium bicarbonate	Thrombosis (pulmonary)	Surgical embolectomy, fibrinolytic therapy
Hyperkalemia/ Hypokalemia	Calcium chloride, Sodium bicarbonate, glucose + insulin/Replete K^+, MgClinical Pharmacology (Vasopressin), 2014^+	Thrombosis (coronary)	Revascularize

Note. From Advanced Cardiovascular Life Support Provider Manual by E. Sinz, K. Navarro, E. Soderberg, et al., 2011, Dallas, TX: First American Heart Association Printing.

by causing peripheral vasoconstriction, and increasing coronary perfusion pressures by stimulating smooth muscle V_1 receptors in coronary vascular beds (Clinical Pharmacology (Vasopressin), 2014; Miano & Crouch, 2006). Theoretical advantages of vasopressin include its longer half-life compared with epinephrine (15 min vs. 3 min) and its potential to be more effective in patients with a metabolic acidosis that can occur during cardiac arrest (Hameln Pharmaceuticals Ltd., 2009). Animal data suggest that metabolic derangement of the α-adrenergic receptor occurs at low pH, resulting in diminished vasopressor effect of catecholamines like epinephrine and norepinephrine, whereas the pressor effect of vasopressin is unaffected by pH change (Fox, May, & Mitch, 1992; Wenzel et al., 1999). However, human clinical trials have demonstrated no difference in ROSC, survival to discharge, or neurologic outcomes when comparing epinephrine with the combination of epinephrine plus vasopressin (Callaway et al., 2006; Gueugniaud et al., 2008). Thus, one dose of vasopressin 40 units IV/IO may replace either the first or second epinephrine dose (Sinz et al., 2011). The sole dosage form of vasopressin is a 20 units/1 ml vial, thereby requiring 2 vials per dose (Neumar et al., 2010).

MEDICATION DELIVERY

Ideally, all patients undergoing CPR will have IV access for medication administration. If patients do not have IV access, alternative routes of administration include IO and the endotracheal (ET) route for patients who are intubated. Intraosseous access is preferred over the ET route. The IO insertion site depends on the particular IO device but includes the sternum, humerus, and tibia. Intraosseous insertion requires either manual pressure or a battery-powered drill (Day, 2011). Although little is known about drug bioavailability of code medications through an IO access, IO drug dosing is the same as the recommended IV dose (Neumar et al., 2010). If neither IV or IO access is available, but the patient has an ET tube, naloxone, atropine, vasopressin, epinephrine, and lidocaine, which can be remembered by the acronym NAVEL, are absorbed and can be given endotracheally. Endotracheal medication dosing typically requires 2–2.5 times greater than the recommended IV dose and the medication should be diluted with either sterile water or normal saline and inject directly into the ET tube (Neumar et al., 2010).

CONCLUSION

Cardiac arrest is a devastating public health problem with low survival rates, requiring prompt medical delivery in attempt to resuscitate the patient. The ACLS algorithm provides evidence-based recommendations for the treatment of cardiac arrest. Prompt delivery of CPR, oxygen, and vasopressors are the standard of care for all cases of cardiac arrest. Early defibrillation and antiarrhythmics are indicated in patients with VF/pulseless VT. Although preventing cardiac arrest in the surgical patient is not always possible, preparation to handle these situations is key in maximizing the patient's successful outcome.

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