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Airway Management During Cardiopulmonary Resuscitation

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Abstract

Purpose of the review This review summarizes the updated literature on airway management during cardiopulmonary resuscitation (CPR). It provides guidance for clinicians to carefully incorporate the most recent recommendations related to airway management, oxygenation, and ventilation both during CPR and after return of spontaneous circulation.

Recent Findings The American Heart Association and the International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care provide updated recommendations related to airway management during CPR, which focus on advanced airway strategies in out-of-the hospital cardiac arrest and in-hospital cardiac arrest. There is no evidence that any single advanced airway technique is superior to the other in terms of survival and neurological outcomes. There is controversy as to whether early advanced airway management could lead to favorable outcome.

Summary Advanced airway strategies and alternatives to airway management (including passive oxygenation) can be utilized in different settings while minimizing interruption in chest compressions.

Keywords Cardiopulmonary resuscitation · Airway management · Advanced airway · Oxygenation · Ventilation · Perioperative cardiac arrest · Supraglottic airway · Endotracheal intubation · Videolaryngoscopy · Out-of-the hospital cardiac arrest · In-hospital cardiac arrest · Cardiopulmonary resuscitation in prone position · Airway management during pregnancy

Introduction

In the United States, the incidence of out-of-the hospital cardiac arrest (OHCA) is 76.5 per 100,000 with 10.6% of patients surviving their initial hospitalization and 8.2% recovering with good functional status. 1.2% of adults admitted to US hospitals experience in-hospital cardiac arrest (IHCA). 25.8% of those patients are discharged from the hospital and 82% of those have good functional outcomes [1, 2]. Early cardiopulmonary resuscitation (CPR) and defibrillation are important treatment steps; however, adequate oxygenation and ventilation are also important in preventing organ damage from hypoxia. Recent trials have evaluated the impact of the choice of airway management and the timing of airway management strategies on the survival to hospital discharge and neurological outcomes. This review presents a summary of the recent literature and the most recent guidelines regarding the changes in airway management during cardiopulmonary resuscitation for adult cardiac arrest as well as for pediatric and neonatal resuscitation. Many of the studies were applied to OHCA setting, and the recommendations for IHCA are extrapolated from OHCA studies.

Perioperative cardiac arrest and cardiac arrest outside the operating room present challenges to anesthesiologists and other clinicians who provide airway management. There are few studies that emphasize the specifics of airway management during perioperative cardiac arrest and outside the operating room cardiac arrest. As a result, clinicians providing airway management should refer to the American Heart Association (AHA) guidelines when performing advanced airway management during CPR.

This article is part of the Topical Collection on *Airway Management*

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Search Strategy:

The literature search included the PubMed, EMBASE, and Cochrane database between 2016 and 2021. Included articles focused on airway management during cardiopulmonary resuscitation in the adult, pediatric, and neonatal population, and in the pregnant patient. Other keywords used included advanced airway, supraglottic airway and endotracheal intubation in OHCA and IHCA. Included articles were published guidelines, systematic reviews, randomized controlled trials, and observational trials. Case reports, conference proceedings, editorials, animal studies, manikin studies, and non-English articles were excluded. A total of 840 articles were found after removing duplicates. Screening resulted in the inclusion of 360 articles. Upon title and abstract review, 134 articles met inclusion criteria for full text review.

Airway management and the Cardiopulmonary Resuscitation Guidelines

Airway management and ventilation are crucial components of advanced cardiac life support (ACLS). Airway management during cardiopulmonary resuscitation (CPR) provides adequate oxygenation and ventilation, prevents hypoxic injury, and increases the chances of overall and neurological survival. In the 2019 updated guidelines, recommendations were updated related to the use of advanced airway devices, the need for training, and the need to master an advanced airway strategy in addition to a second (backup) strategy. The guidelines also emphasized the use of capnography [3•]. The 2019 and 2020 focused updates on ACLS guidelines emphasized that either bag-mask ventilation or an advanced airway strategy may be considered during CPR for adult cardiac arrest in any setting while minimizing interruptions in chest compression [4••]. Placement of an advanced airway device can be delayed until after 2 rounds of chest compressions are completed if bag mask ventilation is adequate. The 2020 BLS guidelines simplified rescue breathing to be 10 breaths per minutes or every 6 s while using either a supraglottic airway (SGA) or an endotracheal tube (ETT). The use of an SGA is prioritized in situations where clinicians have received minimal training in airway management or when the intubation success rate is low (Fig. 1) [4••]. In 2021, the international consensus on CPR and emergency cardiovascular care (ECC) released an updated summary on advanced life support, including special situations such as airway management in drowning, use of barrier devices, and the performance of CPR in the prone position [5••].

Airway Management for Perioperative Cardiac Arrest

The reported incidence of perioperative cardiac arrest is 4.3–19.7 per 10,000 anesthetics that involve cardiac and non-cardiac surgeries [6••]. In a report using the National Anesthesia Clinical Outcomes Registry (NACOR), the analysis of 1,691,472 anesthetics included procedures performed in the radiology and gastrointestinal suites, and reported the incidence to be 5.6 cardiac arrests per 10,000 anesthetics [7]. Many risk factors have contributed to the incidence of perioperative cardiac arrest, including anesthesia for emergency procedures, trauma patients, and hemodynamically unstable patients. Airway-related cardiac arrest can result from post-intubation hemodynamic instability, difficult airway and hypoxia, or during emergence and extubation [8]. Other airway-related causes of cardiac arrests include respiratory depression during Monitored Anesthesia Care (MAC) or conscious sedation. In all situations, perioperative cardiac arrest can contribute to the complexity and difficulty of airway management during CPR. During perioperative cardiac arrest related to airway management, if an advanced airway is not in place, the clinician managing the airway should revert back to the basics of ACLS and consider an advanced airway management strategy [4••]. The basics of advanced airway management during cardiac arrest include bag-mask ventilation or placement of an advanced airway management device (either an SGA or ETT) based on the skills of the airway manager.

Airway Techniques and Devices during Cardiopulmonary Resuscitation

Rescue Breathing

Rescue breathing provides oxygenation and ventilation to a patient who is unconscious and not spontaneously breathing. Rescue breathing can be performed via mouth-to-mouth, with or without a barrier, or via bag mask ventilation (BMV). Visible chest rise is required to confirm the appropriate technique while avoiding excessive ventilation. Rescue breathing should be delivered as one breath every 6 s (or 10 breaths per minute). Once CPR is started, two ventilations should be initiated after completing 30 compressions [9, 10]. Once return of spontaneous circulation (ROSC) is obtained, rescue breaths should continue at the same rate, if the patient is not spontaneously breathing, while performing pulse checks every 2 min. Per the 2020 updated AHA guidelines, either BMV or an advanced airway strategy may be considered during CPR to provide rescue breathing for

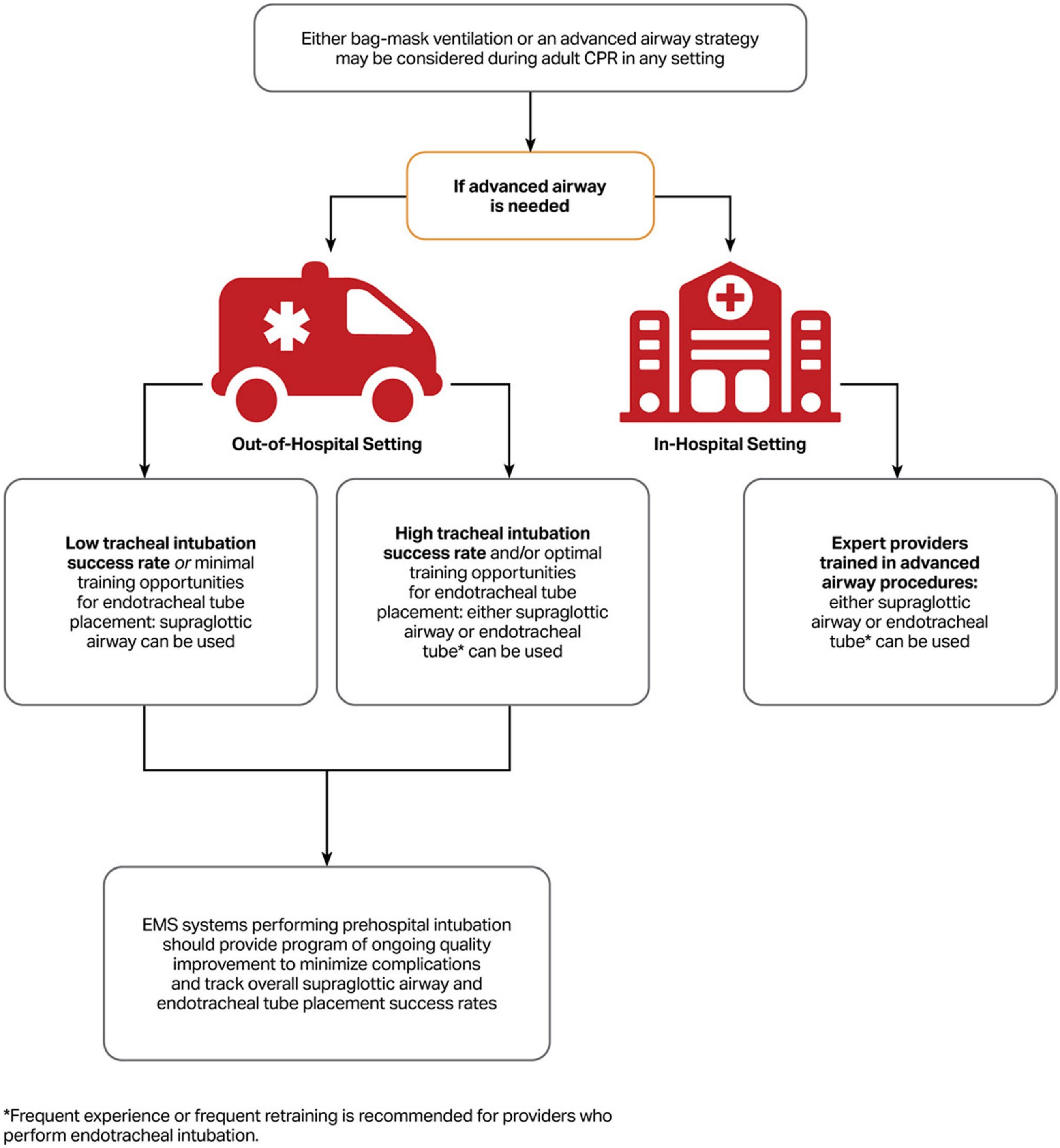

Fig. 1 Representation of Advanced Life Support recommendations for the use of advanced airways during cardiopulmonary resuscitation. EMS, emergency medical services. Reprinted with Permission from Panchal et al. 2020

adult cardiac arrest in any setting, based on the provider's skills and the situation [4••].

Advanced Airway Management

The choice of whether to place an endotracheal tube or a supraglottic airway for oxygenation and ventilation should depend on the level of training of the provider as well the success rate of endotracheal intubation (if known). (Fig. 1). In settings where providers receive minimal training for endotracheal tube placement or the tracheal intubation success rate is low, then SGA placement would be preferred. In an in-hospital setting, an advanced airway should be used by expert providers trained in airway management. Many of the airway recommendations for airway management in IHCA are extrapolated from the OHCA studies.

The updated ACLS guidelines released in 2020 emphasized that clinicians should master one advanced airway technique as well as a second technique as a backup strategy. Multiple recent studies have compared the use of an SGA versus an ETT and found no difference in survival or neurological outcomes between the two devices [11, 12]. As a result, the 2020 updated guidelines provided recommendations to use either technique during CPR in any setting (OHCA or IHCA). In a recent observational study including 14,969 patients, use of an early advanced airway strategy in the form of endotracheal intubation (ETI) was correlated with favorable neurological outcomes [13]. Timing of advanced airway placement has been evaluated in 2 recent studies. Okubo et al. performed a secondary analysis of the Pragmatic Airway Resuscitation Trial (PART) to evaluate the impact of timing of advanced airway placement on patient outcome. In this analysis, the authors evaluated different cohorts based on timing of advanced airway placement and divided them into 4 cohorts (0-< 5 min, 5-< 10 min, 10-< 15 min, and 15–20 min). The results showed no association with the timing of advanced airway placement and survival to hospital discharge. Delay in advanced airway placement was associated with poor one month neurological outcomes among patients with OHCA [14, 15••]. However, in an observational study of a nationwide cohort in Japan, early endotracheal intubation was associated with improved survival for a non-shockable rhythm (but not for a shockable rhythm) when compared to delayed endotracheal intubation [16••]. In a recent RCT comparing i-gel SGA placement versus ETI (AIRWAYS-2 trial) in an OHCA setting, there were no statistically significant differences between both interventions in terms of patient outcomes at 3 and 6 months [17•]. When comparing SGA and ETI in cost-effectiveness and quality of life, the results showed no statistically significant difference between groups in terms of cost or quality of life [18••]. However in an earlier study evaluating the impact of early ETI on survival in IHCA, the results showed that early intubation was associated with decreased survival to discharge [19]. Since the data is conflicting related to the ideal timing for advanced airway placement, it is recommended to follow the ACLS recommendations to use an advanced airway strategy when feasible and based on the clinical situation.

Supraglottic Airway Devices

Per the most recent guidelines, use of a SGA device is recommended as an alternative to an endotracheal tube. Either option could be chosen based on the skills of the provider and the success rate of endotracheal intubation (ETI). The use of an SGA allows effective ventilation that results in a waveform capnography pattern similar to that obtained with an ETT in place. There is no evidence that an ETT is superior to a SGA in terms of survival and neurological outcomes. In the initial analysis of the Pragmatic Airway Resuscitation Trial (PART) comparing the outcomes of a laryngeal tube (LT) versus ETI in OHCA, the investigators found that the initial insertion of an LT was associated with significantly greater 72-h survival compared to initial ETI [12]. In a secondary analysis of the PART trial comparing the outcomes of BMV versus advanced airway placement, authors found that BMV was associated with improved OHCA outcomes, improved survival to discharge, and neurologically intact survival compared to an advanced airway strategy [20]. Advanced airway insertion first pass success was associated with increased ROSC but no other outcomes [21•]. In another secondary analysis of PART trial comparing the time of interruption of chest compressions, the investigators found that LT placement was associated with a shorter duration of interruption of chest compressions [22].

Endotracheal Intubation Techniques

Several studies have evaluated the success rate of ETI when using different intubation techniques during CPR. In 2 recent studies comparing the success rate of intubation using videolaryngoscopy (VL) versus direct laryngoscopy during CPR, the studies showed that the use of VL was associated with a higher first attempt success rate compared to direct laryngoscopy [23, 24]. VL was also associated with better glottic visualization and lower esophageal intubation rate. In another prospective study, the use of VL in an anesthesiologist-staffed helicopter emergency medical service was associated with high first pass success rates [25]. There is also preliminary evidence that the use of VL may achieve intubation with minimal interruption of chest compressions [23, 26, 27]. However, there may be limitations to the use of VL in OHCA settings, such as the presence of blood, vomit, or secretions, or bright light, which can obscure visualization of the glottis on the video screen and may decrease intubation success rates.

Confirmation of Endotracheal Tube Placement During Cardiopulmonary Resuscitation

Continuous waveform capnography is recommended to confirm the correct placement of an endotracheal tube (ETT) or an SGA. Waveform capnography was 100% specific for confirming ETT position during cardiac arrest in multiple studies [28, 29]. Continuous waveform capnography is recommended to decrease the risk of unrecognized ETT misplacement or dislodgment. In addition, capnography is used to evaluate the effectiveness of CPR as well as to prognosticate and predict return of spontaneous circulation (ROSC) [29, 30•, 31]. A sustained increase in the $ETCO_2$ (more than 40 mmHg) has been shown to be an indication for ROSC. The 2021 international consensus on CPR and emergency cardiovascular care (ECC) science continues to endorse the use of capnography to confirm adequate ventilation and as an indicator for ROSC [5••].

Cricoid Pressure During Airway Management in Cardiopulmonary Resuscitation

Currently, there is no evidence that cricoid pressure facilitates ventilation or decreases the risk of aspiration during cardiac arrest. Cricoid pressure may prevent adequate ventilation and the appropriate placement of an SGA or ETT. There might be an increased risk of airway trauma during intubation while performing cricoid pressure [32, 33]. Current guidelines recommend against the routine use of cricoid pressure as part of the airway management during CPR.

Alternative Methods for Oxygen delivery During Cardiopulmonary Resuscitation

Oxylator

The Oxylator (CPR Medical Devices Inc., Ontario, Canada) is a patient-responsive emergency ventilation device that can be used in the automatic or manual mode [34]. In the automatic mode, it delivers oxygen or air to the patient at a constant flow rate of 30 L per minute during inspiration, until a set airway pressure is achieved (maximum 45 cm H_2O). Then it switches to the passive exhalation phase at an airway pressure of 2–4 cm H_2O. It operates as a closed loop system, and it will trigger inspiration with every decompression phase. The advantages of the Oxylator are the consistency in ventilation and oxygenation at a pre-set pressure, avoidance of hyperventilation or gastric insufflation, and allowing a CPR provider to focus on other resuscitation measures since this device is hands free [34].

ResQPOD

ResQPOD is an impedance threshold device that increases circulation during CPR by creating a negative thoracic pressure during ventilation that allows chest recoil and improves blood flow to the major organs. It is recommended by the AHA as a class 2 recommendation during CPR as a method to enhance venous return during chest compression. In the ResQTrial, the addition of the impendence threshold device to standard CPR showed improved survival to hospital discharge [4••, 35, 36]. In an analysis of the Pragmatic Airway Resuscitation Trial (PART), thoracic impedance oscillations were utilized to characterize ventilation waveform patterns during ventilation with both a laryngeal tube and an ETT [37•].

Passive Oxygen Insufflation

Continuous oxygen delivery during apnea via passive oxygen insufflation may allow oxygenation without the need for active ventilation. Passive oxygenation can be performed through an oropharyngeal airway and an oxygen mask, which will minimally interrupt chest compressions. Also, it reduces the risk of hyperventilation, increased gastric insufflation and the compromise of circulation as a result of hyperventilation. Passive oxygen insufflation has been described in the 2010 AHA guidelines; however, in the updated 2015–2020 guidelines, passive ventilation techniques are not recommended for routine use during CPR [4••, 38, 39].

Airway Management after Return of Spontaneous Circulation (ROSC)

The AHA guidelines emphasized care after ROSC to include identification of the cause of cardiac arrest, management of multisystem organ failure, Targeted Temperature Management (TTM) and neurological prognostication. In addition, the guidelines addressed different goals for airway management, oxygenation, and ventilation after ROSC. Per the 2020 guidelines, it is reasonable to use the highest available oxygen concentration during resuscitation and after ROSC until arterial oxyhemoglobin saturation or the partial pressure of arterial oxygen can be obtained. This is based on the expert opinion and is endorsed in the 2021 international consensus on CPR and ECC recommendations [5••]. Hypoxia should be avoided in patients who remain comatose after ROSC, and once a reliable measurement is available, oxygen should be titrated to an oxygen saturation of 92–98%. Maintaining a $PaCO_2$ in the normal range (35–45 mmHg) may be reasonable in comatose patients [40].

Airway Management Outside the Operating Room

Clinicians who perform airway management may be called to assist with emergency airway management outside the operating room. This can be in the emergency department (ED), the intensive care unit (ICU), the cardiac care unit, or other locations in the hospital. This patient population is critically ill and at increased risk of complications, such as peri-intubation collapse leading to cardiac arrest, when compared to patients undergoing elective surgery [41•, 42••]. This poses an additional challenge for the clinician managing the airway while caring for patients with low physiological reserve [41•, 42••, 43••]. During cardiac arrest, there may not be adequate time to obtain more information on the patient regarding previous airway difficulty. Availability of appropriate equipment and supportive personnel will contribute to the success of airway management. Although videolaryngoscopy (VL) is a preferred method in these circumstances by many providers, the availability of VL or the contamination of the airway with vomiting or blood may reduce the success rate of VL. In the ICU setting, the use of high flow nasal cannula for pre-oxygenation was proven to be effective in reducing the severity of desaturation [44].

Challenges in Airway Management During Cardiopulmonary Resuscitation

Infection Risk

The recent Coronavirus (COVID-19) pandemic raised concerns related to the aerosolization of infectious viral particles during CPR and airway management in COVID-19 patients who are in cardiac arrest. The AHA published updated guidelines related to BLS and ACLS in adults, pediatric, and neonatal patients with suspected or confirmed COVID-19 infection [45••]. The goal was to provide guidance for healthcare providers who care for patients in cardiac arrest while maintaining their safety [45••, 46••]. Recommendations related to oxygenation, ventilation, and airway management focused on the use of strategies to minimize the aerosolization risk. Attaching a High-Efficiency Particulate Air (HEPA) filter is recommended. Patients in cardiac arrest should be intubated with a cuffed tube at the earliest possible opportunity, and when intubating patients, it is better to minimize attempts by allowing the most experienced provider to intubate and to pause chest compressions during intubation. Other recommendations related to airway management focused on the use of VL to reduce the exposure to aerosolized particles. If intubation is delayed, an SGA with a HEPA filter could be an alternative.

With increased knowledge about the virus, a more stable personal protective equipment (PPE) supply, and vaccination of frontline healthcare providers and the public, the AHA released updated guidance in 2021 and 2022 for healthcare providers aimed to reduce the provider risk to infection, reduce the provider's exposure, and provide timely care [46••] The 2022 recommendations emphasize the use of PPE before performing CPR, defibrillation and airway management [47].

Cardiopulmonary Resuscitation in the Prone Position

The increased practice of pronation of COVID-19 patients resulted in updated 2021 recommendations by the International Consensus on CPR and ECC related to special situations in CPR, including CPR in the prone position [5••]. When patients with cardiac arrest are in the prone position with an advanced airway already in place, if immediate supination is not feasible, then CPR should be initiated while the patient is prone. If the patient is in the prone position without an advanced airway in place, it is recommended to turn the patient supine as quickly as possible to begin CPR and provide adequate airway management [48••]. However, more studies are needed to reflect the impact of CPR for surgical patients undergoing spine or brain surgery while in the prone position.

Airway Management in Patients with Possible Cervical Spine Injury

The current 2020 AHA guidelines recommend manual in-line stabilization during airway management in patients with suspected cervical spine injury. Spinal immobilization devices may pose challenges for airway management during CPR. Currently, no specific method of intubation has been proven to be the safest for this population. There is some degree of cervical motion with all methods of intubation, and the data is lacking regarding the impact of this movement on clinical outcome [49–51].

Airway Management in Pediatric Advanced Life Support

Most pediatric cardiac arrests are triggered by respiratory compromise. Airway management and adequate ventilation are the main fundamentals of pediatric resuscitation. Assisted ventilation using BMV is well accepted, however, it may result in interruptions of chest compressions and increased risk of aspiration and barotrauma. The use of an advanced airway technique may result in improved ventilation, reduce the risk of aspiration, and minimize interruptions in chest compressions. The 2019–2020 updated pediatric basic and advanced life support guidelines focused on recommendations for advanced airway management. Recent trials showed that ETI and BMV achieve similar rates of survival and neurological outcomes in pediatric OHCA [52, 53]. Similarly, there were no differences in the outcomes between SGA and ETI. However, the data is lacking in regards to recommendations for the use of an advanced airway in IHCA. In a recent large cohort study using ETI in pediatric OHCA, results showed that it was associated with worse outcomes regardless of the etiology of the cardiac arrest [54•]. In a recent systematic review and meta-analysis, ETI or SGA were not superior to BMV in the resuscitation of children in cardiac arrest [55]. Regardless of the airway strategy chosen, the ventilation rate in children should be 20–30 breaths per minute, or 1 breath every 2–3 s while performing CPR [56•]. Excessive ventilation should be avoided and the use of supplemental oxygen should be titrated to target an oxygen saturation of 94–99% [56•, 57]. In an updated international consensus on CPR and ECC science for pediatric life support, most recommendations from the 2019 and 2020 guidelines are similar regarding choice of airway device, oxygenation, and ventilation during cardiac arrest, with the only change being a focus on the preferred use of BMV for ventilation in the pediatric OHCA [58].

Airway Management in Neonatal Advanced Life Support

Most newborns (85%) born at term will initiate breathing within 10–30 s, and an additional 10% will do that in response to stimulation. 5% of term infants, however, require positive pressure ventilation, 2% require intubation, and around 0.1% require chest compressions [59••, 60]. For newborns who do not initiate adequate breathing efforts after stimulation, clinicians should deliver effective ventilation using a facemask. If not effective, providers should check for airway patency and apply positive pressure ventilation pressure. If this strategy continues to be ineffective, then an advanced airway should be utilized, either an SGA or an ETT. While supporting oxygenation and ventilation, heart rate (HR) is monitored and chest compressions should be initiated if the HR is below 60 beats/minute. Per the 2015–2020 AHA guidelines for neonatal resuscitation, suctioning the airway is reserved only if the airway appears obstructed or if positive pressure ventilation (PPV) is required [61]. Routine suctioning is not recommended as suctioning may lead to bradycardia, apnea, or risk of iatrogenic infection.

For preterm newborn infants who are receiving PPV for bradycardia or inadequate respiratory efforts, the current guidelines recommend against the routine use of sustained inflation for more than 5 s. Data is lacking for full term and late preterm infants as to the duration of insufflation needed for ventilation. In addition, the 2020 guidelines endorse prior recommendations regarding the use of positive end expiratory pressure (PEEP) during initial ventilation of premature newborn infants. The recent guidelines also endorse prior recommendations regarding the use of continuous positive airway pressure over intubation or intermittent PPV. For preterm newborns who require respiratory support, it is recommended to start with lower oxygen concentrations (21–30%) rather than higher concentrations (60–100%), then titrate oxygen concentration using pulse oximetry [59••, 60, 62]. Goal pulse oximetry values are 85–95% at 10 min after birth [62].

Airway Management for Cardiopulmonary Resuscitation During Pregnancy

The incidence of maternal cardiac arrest is approximately 1 in 12,000 admissions for labor and delivery in the United States [4••]. Common causes of maternal cardiac arrest include hemorrhage, heart failure, amniotic fluid embolism, sepsis, venous thromboembolism, and complications of anesthesia. Ventilation and oxygenation are important components of management in the setting of pregnancy due to increased maternal metabolism, increased oxygen consumption, and decreased functional reserve capacity caused by the gravid uterus. This makes pregnant women more prone to hypoxia, which might result in fetal hypoxia that can have detrimental effects. As a result, an advanced airway strategy should be performed early during maternal cardiac arrest. The airway of a pregnant patient is anticipated to be difficult, due to distorted landmarks caused by edema and increased risk of bleeding due to vascularity. Hence, it is recommended that the most experienced healthcare provider performs the intubation. To maintain ventilation in the unstable pregnant patient, providers should maintain a higher PEEP and a plateau pressure less than 30. Oxygenation goals should be higher when compared to the non-pregnant population, in order to avoid fetal hypoxemia. The goals of ventilation should aim at lower $PaCO_2$ values of 30 which maintain the maternal–fetal CO2 gradient and an appropriate hemoglobin-oxygen affinity [63].

Conclusion

Recommendations for airway management during cardiopulmonary resuscitation have been updated in the recent guidelines and studies on OHCA. BMV versus an advanced airway strategy should depend on the skills of the provider as well as their tracheal intubation success rate. There is no evidence that one advanced airway technique is better than the other in terms of the outcome. Clinicians should utilize the available resources when feasible to ensure the best favorable outcome for the patient.

Declarations

Conflict of Interest The authors have no conflicts of interest to declare.

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• Of importance
•• Of major importance

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