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EQUIPMENT AND TECHNIQUES

AUSTRALIAN RESUSCITATION COUNCIL

NEW ZEALAND Resuscitation Council Whakahauora, Aotearoa

EMA

Equipment and Techniques in Adult Advanced Life Support. ARC and NZRC Guideline 2010

Australian Resuscitation Council, New Zealand Resuscitation Council

A wide range of equipment is available for use in ALS. The role of such equipment should be subject to constant evaluation. The use of any item of equipment requires that the operator is appropriately trained and maintains competency in its use. Frequent retraining (theory and practice) is required to maintain both BLS and ALS skills. The optimal interval for retraining has not been established.[1]

Airway adjuncts can be used to facilitate ventilation, to better maintain the airway, or to provide access to the airway (e.g. for suctioning). [Class B; Expert consensus opinion]

Oxygen

There is insufficient evidence to support or refute the use of a titrated oxygen concentration or constant 21% oxygen (room air) when compared with 100% oxygen during adult cardiac arrest. In the absence of any other data there is no reason to change the current treatment algorithm, which includes use of 100% oxygen during adult cardiac arrest.[2] [Class A; Expert consensus opinion]

High concentration (100%) oxygen should be used on all patients as soon as it becomes available, provided that adequate ventilation is maintained. Oxygen should never be withheld because of the fear of adverse effects.[2] [Class A; Expert consensus opinion]

There is insufficient evidence to support or refute the use of passive oxygen delivery during compression only CPR to improve outcomes (ROSC, hospital discharge rate and improve neurological survival) when compared with oxygen delivery by positive pressure ventilation.[2]

Airway

Airway manoeuvres

The basic life support techniques of chin lift and head tilt are covered in Guideline 4.

Jaw thrust

In this technique, the rescuer is commonly positioned at the top of the victim's head, although a jaw thrust may be applied from the side or in front. The jaw is clasped with both hands and the mouth is held open by the thumbs.

Pressure is applied with the index (or middle) fingers behind the angles of the jaw. The jaw is gently thrust upwards and away from the chest, moving the tongue away from the back of the throat. Gentle head tilt may also be necessary to maintain airway patency with this technique.

A jaw thrust may be required in the recovery position if the victim's airway is not patent.

[Class A; Expert consensus opinion]

Basic airway adjuncts

Artificial airways

The endotracheal tube has generally been considered the optimal method of managing the airway during cardiac arrest. There is evidence that without adequate training and experience, the incidence of complications, such as unrecognized oesophageal intubation, is unacceptably high. Alternatives to the tracheal tube that have been studied during CPR include the bag-valve mask and advanced airway devices such as the laryngeal mask airway (LMA) and oesophageal-tracheal combitube (Combitube). There is still no data to support the routine use of any specific approach to airway management during cardiac arrest.

The choice of airway adjunct will be determined by availability of such devices, and the training and experience of the resuscitation team members.[2] [Class A; Expert consensus opinion]

Oro- and nasopharyngeal airways have long been used in cardiac arrest, despite never being studied in this clinical context. It is reasonable to continue to use oral and naso-pharyngeal airways when performing bag-mask ventilation in cardiac arrest, but in the presence of a known or suspected basal skull fracture an oral airway is preferred. It is still necessary to use head tilt and jaw support, or jaw thrust. [Class B; Expert consensus opinion]

Oropharyngeal airway

Oral airways should be appropriately sized and not be forcibly inserted. They should be reserved for unconscious, obtunded victims. Laryngospasm or vomiting with aspiration may result in those patients who still have a gag reflex. [Class B; Expert consensus opinion]

Nasopharyngeal airway

Despite frequent successful use of nasopharyngeal airways by anaesthetists, there are no published data on the use of these airway adjuncts during CPR. One study in anesthetised patients showed that nurses inserting nasopharyngeal airways were no more likely than anaesthetists to cause nasopharyngeal trauma. One study showed that the traditional methods of sizing a nasopharyngeal airway (measurement against the patient's little finger or anterior nares) do not correlate with the airway anatomy and are unreliable. In one report insertion of a nasopharyngeal airway caused some airway bleeding in 30% of cases. Two case reports involve inadvertent intracranial placement of a nasopharyngeal airway in patients with basal skull fractures. In the presence of a known or suspected basal skull fracture an oral airway is preferred but if this is not possible and the airway is obstructed, gentle insertion of a nasopharyngeal airway may be life-saving (ie, the benefits may far outweigh the risks).[3]
[Class B; LOE Expert consensus opinion]

Advanced airway adjuncts

There is inadequate evidence to define the optimal timing of advanced airway placement during cardiac arrest.[2]
The airway devices/adjuncts used during a cardiac arrest must be chosen according to local training and availability. [Class A; LOE Expert consensus opinion] To avoid substantial interruptions in chest compressions providers may defer attempts to insert devices/adjuncts until return of spontaneous circulation (ROSC). [Class B; LOE Expert consensus opinion]

Endotracheal intubation

There were no randomised trials that assessed the effect of airway and ventilation management with bag-valve mask (BVM) alone versus airway management that includes tracheal intubation in adult victims of cardiac arrest. The only published randomised controlled trial that compared tracheal intubation with BVM ventilation was performed in children who required airway management out-of-hospital. In this study there was no difference in survival-to-discharge rates but it is unclear how applicable this paediatric study is to adult resuscitation. The study had some important limitations, including the provision of only 6 hours of additional training for intubation, limited opportunity to perform intubations, and short transport times. Two studies compared outcomes from out-of-hospital cardiac arrest in adults treated by either emergency medical technicians or paramedics. The skills provided by the paramedics, including intubation and intravenous (IV) cannulation and drug administration, made no difference in survival to hospital discharge.
The reported incidence of unrecognised misplaced tracheal tube is 6% to 14%. An additional problem common to any advanced airway is that intubation attempts generally require interruptions in chest compressions. There is insufficient evidence to support or refute the use of any specific technique to maintain an airway and provide ventilation in adults with cardiopulmonary arrest. Either bag-valve mask alone or in combination with tracheal intubation is acceptable for ventilation during CPR. Rescuers must weigh the risks and benefits of intubation versus the need to provide effective chest compressions. The intubation attempt will require interruption of chest compressions, but once an advanced airway is in place ventilation will not require interruption or even pausing of chest compressions.
To avoid substantial interruptions in chest compressions providers may defer an intubation attempt until return of spontaneous circulation (ROSC). [Class B; Expert consensus opinion] To ensure competence healthcare systems that utilize advanced airways should address factors such as adequacy of training and experience and quality assurance. Providers must confirm tube placement and ensure that the tube is adequately secured. [Class A; LOE Expert consensus opinion]
Endotracheal intubation remains the gold standard for airway maintenance and airway protection in CPR. In addition to providing optimal isolation and patency of the airway intubation allows ventilation with 100% oxygen and suctioning of the airway and also provides possible access for the delivery of some drugs. However if endotracheal intubation is attempted ongoing CPR must be maintained and attempts at intubation should not interrupt cardiac compressions for more than 20 seconds. [Class A; Expert consensus opinion]
Once an endotracheal tube has been passed:

- Inflate cuff with enough air to prevent a leak
- Confirm placement by assessing chest inflation, auscultation and direct observation.
- To protect against unrecognised oesophageal intubation, secondary confirmation with waveform capnography is recommended.
- Firmly secure tube

[Class A; LOE Expert consensus opinion]

Confirmation of placement of endotracheal tube

Unrecognized oesophageal intubation is the most serious complication of attempted tracheal intubation. Routine confirmation of correct placement of the tracheal tube should reduce this risk.
Two studies of waveform capnography to verify tracheal tube position in victims of cardiac arrest after intubation demonstrated 100% sensitivity and 100% specificity in identifying correct tracheal tube placement. One of these studies included 246 intubations in cardiac arrest with 9 oesophageal intubations and the other included 51 cardiac arrests with an overall oesophageal intubation rate of 23% but it is not specified how many of these occurred in the cardiac arrest group.
Three studies with a cumulative total of 194 tracheal and 22 oesophageal tube placements demonstrated an overall 64% sensitivity and 100% specificity in identifying correct tracheal tube placement when using the same model capnometer (no waveform capnography) on prehospital cardiac arrest victims. The sensitivity may have been adversely affected by the prolonged resuscitation times and very prolonged transport times of many of the cardiac arrest victims studied. Intubation was performed after arrival at hospital and time to intubation averaged more than 30 minutes.
Studies of colorimetric $ETCO_2$ detectors, the syringe aspiration oesophageal detector device the self-inflating bulb oesophageal detector device and non-waveform End Tidal CO_2 capnometers show that the accuracy of these devices is similar to the accuracy of clinical assessment for confirming the tracheal position of a tracheal tube in victims of cardiac arrest.[2]
Waveform capnography is recommended to confirm and continuously monitor the position of a tracheal tube in victims of cardiac arrest and it should be used in addition to clinical assessment (auscultation and direct visualization is suggested). [Class A; Expert consensus opinion]
See also Guideline 11.1.1

Alternatives to endotracheal intubation

In some communities tracheal intubation is not permitted or practitioners have inadequate opportunity to maintain their intubation skills. Under these circumstances several studies indicate a high incidence of unrecognized oesophageal intubation misplacement and unrecognized dislodgment. Prolonged attempts at tracheal intubation are harmful: the cessation of chest compressions during this time will compromise coronary and cerebral perfusion. Several alternative airway devices have been considered or studied for airway management during CPR. The Combitube and the LMA are the only alternative devices to be studied specifically during CPR and none of the studies have been adequately powered to study survival as a primary end point. Instead most researchers have studied insertion and ventilation success rates.

Summary of science

Studies comparing supraglottic airway to tracheal intubation have generally compared insertion time and ventilation success rates. No study has shown an effect of the method of ventilation on survival. There are no data to support the routine use of any specific approach to airway management during cardiac arrest.[2]

Nine studies compared a variety of supraglottic airway devices with the tracheal tube during cardiac arrest and a further six studies compared a variety of supraglottic airway devices with the tracheal tube in patients undergoing anaesthesia.

Overall in these studies the supraglottic airway device performed as well as, or better than, the tracheal tube with respect to successful insertion and/or time to tube insertion or to ventilation. One study retrospectively compared outcomes in cardiac arrest patients treated with esophageal-tracheal combitube or tracheal tube and found no difference in ROSC, survival to admission or survival to discharge. One study compared survival in cardiac arrests managed with laryngeal mask airway with an historical control group of cardiac arrests managed with tracheal tube and found that ROSC was significantly higher in the study period (61% vs 36%).

Eight manikin studies with simulated cardiac arrest and nine manikin studies without simulated cardiac arrest showed that successful insertion rates and/or time to insertion or to ventilation for a variety of supraglottic airway devices were as good, or better than, for the tracheal tube.

Nine studies documented that when a supraglottic airway device is used as a rescue airway after failed tracheal intubation, most patients can be ventilated successfully with the supraglottic airway device.

Two studies performed while wearing anti-chemical protective clothing, one randomized crossover trial on anaesthetized patients and a second pseudorandomized study on manikins, found increased time to tracheal tube insertion but not to laryngeal mask airway insertion.

Three manikin studies comparing a supraglottic airway device with the tracheal tube during ongoing chest compressions demonstrated decreased time to intubation with the supraglottic airway device as well as reduced no flow time. One non-randomized manikin study found that chest compressions caused only a minor increase in time to tracheal intubation but not to supraglottic airway device insertion.

Further data are needed on the adequacy of ventilation with the various supraglottic airway devices if chest compressions are not interrupted and comparison of the various supraglottic airway devices with bag-mask ventilation and with each other when used clinically by inexperienced and by experienced providers.[2]

A supraglottic airway device may be considered by healthcare professionals trained in its use as an alternative to bag-mask ventilation during cardiopulmonary resuscitation. [Class B; Expert consensus opinion] Healthcare professionals trained to use supraglottic airway devices (eg. LMA) may consider their use for airway management during cardiac arrest and as a backup or rescue airway in a difficult or failed tracheal intubation. [Class B; Expert consensus opinion]

Ventilation

Bag-Valve-Mask

Where difficulty with bag-mask-valve resuscitation is experienced, two trained operators may be required i.e. the first to manage the airway and the second to operate the bag. [Class B; Expert consensus opinion]

Oxygen-Powered Resuscitators

These devices have a limited place but can provide high oxygen concentrations in experienced hands. [Class B; Expert consensus opinion] Devices that do not comply with current Australian Standards should not be used.

Mechanical Ventilators

One pseudo-randomized study suggests that use of an automatic transport ventilator with intubated patients may enable the EMS team to perform more tasks while subjectively providing similar ventilation to that of a bag-valve device.

One study suggests that use of an automatic transport ventilator with intubated patients provides similar oxygenation and ventilation as use of a bag-valve device with no difference in survival.

Recommendations

There is insufficient evidence to support or refute the use of an automatic transport ventilator over manual ventilation during resuscitation of the cardiac arrest victim with an advanced airway.

Both manual ventilation and mechanical ventilation have advantages and disadvantages in the initial management of cardiac arrests. These relate largely to the risks of hyperventilation (with manual ventilation), and hypoventilation (with mechanical breaths not being delivered). Irrespective of the mode of delivery of breaths, the adequacy of delivery of those delivered breaths should be regularly assessed. [Class B; Expert consensus opinion]

Hyperventilation may be harmful

Reports containing both a small case series and an animal study showed that hyperventilation is associated with increased intrathoracic pressure, decreased coronary and cerebral perfusion, and, in animals, decreased return of spontaneous circulation (ROSC). In a secondary analysis of the case series that included patients with advanced airways in place after out-of-hospital cardiac arrest, ventilation rates of >10 per minute and inspiration times >1 second were associated with no survival. Extrapolation from an animal model of severe shock suggests that a ventilation rate of 6 ventilations per minute is associated with adequate oxygenation and better hemodynamics than ≥12 ventilations per minute.[4]

[Class B; LOE IV]

Inadvertent gas trapping

Eighteen articles involving 31 cases reported unexpected return of circulation (and in some cases prolonged neurologically intact survival) after cessation of resuscitation attempts. One case series suggested that this occurred in patients with obstructive airway disease. Four studies reported unexpected return of circulation in 6 cases in which resuscitation had ceased and ventilation was shown on repeated occasions (or was highly likely) to result in gas trapping and consequent hemodynamic compromise. The authors of all these studies suggested that a period of disconnection from ventilation during resuscitation from PEA may be useful to exclude gas trapping.[3] [Class B; LOE IV]

Recommendation for Frequency of ventilation

When ventilating a victim without an advanced airway, ventilation should be continued at a ratio of 30 compressions to 2 ventilations, irrespective of the number of rescuers, until an advanced airway is in place.

After an advanced airway (e.g. tracheal tube, Combitube, LMA) is placed, ventilate the patient's lungs with supplementary oxygen to make the chest rise. During CPR for a patient with an advanced airway in place it is reasonable to ventilate the lungs at a rate of 6 to 10 ventilations per minute without pausing during chest compressions to deliver ventilations. [Class B; Expert consensus opinion]

Simultaneous ventilation and compression may adversely effect coronary perfusion[8] and has been associated with decreased survival.[9] As previously recommended, one starting point to provide consistent ventilation and an adequate minute volume while minimising interruptions to CPR, and minimising the likelihood of excessive ventilation, is to provide one breath after each 15 compressions (delivering the breath during the relaxation phase of compression, without a significant pause).[10] [Class B; Expert Consensus Opinion] See also Guideline 11.1.1

The adequacy of ventilation with supraglottic airway devices during uninterrupted chest compressions is however unknown. Theoretically a compression to ventilation ratio of 30:2 may be continued in patients with an advanced airway (ETTs LMAs and other supraglottic arways). This has advantages for simplicity of teaching, allows intermittent assessment of adequacy of ventilation, and also overcomes the problems associated with inefficient ventilation if breaths are delivered at the same time as the peak of the compressions. [Class B; Expert consensus opinion]

Use the same initial tidal volume and rate in patients regardless of the cause of the cardiac arrest. Carbon dioxide estimation via arterial blood gas analysis (but not End-Tidal Carbon Dioxide) may allow individual titration of ventilation.

[Class B; Expert consensus opinion]

Monitoring of ventilation

There is insufficient evidence to support or refute the use of peak pressure and minute ventilation monitoring to improve outcome from cardiac arrest. There is indirect evidence that monitoring the respiratory rate with real time feedback is effective in avoiding hyperventilation and achieving ventilation rates closer to recommended values, but there is no evidence that ROSC or survival is improved.[2]

Circulation

Healthcare providers should perform chest compressions for adults at a rate of approximately 100 compressions per minute and to compress the lower half of the sternum by at least 5 cm (approximately 1/3 of the antero-posterior diameter of the chest). Rescuers should allow complete recoil of the chest after each compression. [Class A; LOE IV]

When feasible, rescuers should frequently alternate "compressor" duties (i.e. every 2 minutes), regardless of whether they feel fatigued, to ensure that fatigue does not interfere with delivery of adequate chest compressions. It is reasonable to use a duty cycle (ie, ratio between compression and release) of 50%. [Class A; Expert consensus opinion] CPR with the patient in a prone position is a reasonable alternative for intubated hospitalized patients who cannot be placed in the supine position. [Class B; LOE Expert consensus opinion]

Rescuers should minimize interruptions of chest compressions. It is reasonable for instructors, trainees, and providers to monitor and improve the process of CPR to ensure adherence to recommended compression and ventilation rates and depths. [Class B; LOE III-2] See also Guideline 11.1.1.

Techniques to assist circulation during CPR

CPR prompt or feedback devices[1,5]

Evidence from 22 manikin studies consistently demonstrated that CPR prompt/feedback devices used during CPR improved the quality of CPR performance on manikins. Three additional manikin studies examined the utility of video/animations on mobile phone devices: two studies showed improved checklist scores and quality of CPR and faster initiation of CPR while the third study showed that participants using multi-media phone CPR instruction took longer to complete tasks than dispatcher-assisted CPR. Two manikin studies that used two-way video communication to enable the dispatcher to review and comment on CPR in real time produced equivocal findings.

There are no studies demonstrating improved patient outcomes with CPR prompt/feedback devices. One study each in children and adults showed that metronomes improved chest compression rate and increased end-tidal carbon dioxide. Five studies evaluating the introduction of CPR prompt/feedback devices in clinical practice (pre/post comparisons) found improved CPR performance.

There may be some limitations to the use of CPR prompt/feedback devices. Two manikin studies report that chest compression devices may overestimate compression depth if CPR is being performed on a compressible surface such as a mattress on a bed.[6] One study reported harm to a single participant when a hand got stuck in moving parts of the CPR feedback device. A further manikin study demonstrated that additional mechanical work is required from the CPR provider to compress the spring in one of the pressure sensing feedback devices. One case report documented soft tissue injury to a patient's chest when an accelerometer device was used for prolonged CPR.

Recommendations

CPR prompt /feedback devices may be considered for clinical use as part of an overall strategy to improve the quality of CPR. [Class B; LOE III-2]

Instructors and rescuers should be made aware that a compressible support surface (e.g. mattress) may cause a feedback device to overestimate depth of compression.[6]

See also Guideline Cardiopulmonary Resuscitation for Advanced Life Support Providers.

Pacing

Four studies addressed the efficacy of pacing in cardiac arrest. These studies found no benefit from routine pacing in cardiac arrest patients. Use of pacing (transcutaneous, transvenous, needle) in cardiac arrest (in-hospital or out-of-hospital) did not improve ROSC or survival. There was no apparent benefit related to the time at which pacing was initiated (early or delayed in established asystole), location of arrest (in-hospital or out-of-hospital), or primary cardiac rhythm (asystole, PEA). Five case series a review with two additional case reports, and a moderate sized case series, support percussion pacing in p-wave asystolic cardiac arrest/complete heart block or hemodynamically unstable patients with bradycardia. In these reports, sinus rhythm with a pulse was restored using different pacing techniques.

Electrical pacing is not effective as routine treatment in patients with asystolic cardiac arrest.[2]

The routine use of pacing (electrical or fist) is not recommended.

The use of pacing after cardiac surgery is considered in the "Resuscitation in Special Circumstances Guideline".

Monitoring during CPR

End-tidal carbon dioxide

The studies published over the past 5 years were consistent with the older literature, which showed that higher end-tidal CO_2 values during CPR correlate with ROSC. In experimental models end-tidal CO_2 concentration during ongoing CPR correlated with cardiac output, coronary perfusion pressure and successful resuscitation from cardiac arrest.

Five of the studies found that $ETCO_2$ was accurate for predicting patients who could not be resuscitated; some giving a time frame for that prediction of 20 minutes. However, two studies documented patients who did not meet the $ETCO_2$ range but who survived. Multiple studies by one group showed that when $ETCO_2$ exceeded 10 mm Hg, all patients achieved ROSC.

In one of these studies all the survivors had an initial $ETCO_2$ higher than 10 mmHg. Similarly, two studies showed that if the $ETCO_2$ did not exceed 10 mmHg, survival was zero.[2]

Recommendations

Quantitative measurement of end tidal CO_2 may be a safe and effective non-invasive indicator of cardiac output during CPR and may be an early indicator of return of spontaneous circulation in intubated patients. [Class B; Expert consensus opinion]

Although low values of end tidal CO_2 are associated with a low probability of survival, there are insufficient data to support or refute a specific cut off of end tidal CO2 at different time intervals as a prognostic indicator of outcome during adult cardiac arrest. [Class B; Expert consensus opinion]

Continuous capnography or capnometry monitoring, if available, may be beneficial by providing feedback on the effectiveness of chest compressions. [Class B; Expert consensus opinion] No studies have addressed this topic directly.

Arterial Blood Gas

There was evidence from 11 studies that arterial blood gas values are an inaccurate indicator of the magnitude of tissue acidosis during cardiac arrest and CPR in both the in-hospital and out-of-hospital settings. The same studies indicate that both arterial and mixed venous blood gases are required to establish the degree of acidosis.[3]

Arterial blood gas analysis alone can disclose the degree of hypoxemia and highlight the extent of metabolic acidosis. Arterial CO_2 is an indicator of adequacy of ventilation during CPR. If ventilation is constant an increase in $PaCO_2$ is a potential marker of improved perfusion during CPR. Arterial blood gas monitoring during cardiac arrest enables estimation of the degree of hypoxemia and the adequacy of ventilation during CPR, but should not interfere with overall performance of good CPR.[3] [Class B; LOE II and IV]

Ultrasound during cardiac arrest

The use of cardiac ultrasound during cardiac arrest may allow identification of many cardiac and non-cardiac causes of cardiac arrest. Three studies examined the prognostic value of the presence or absence of sonographic cardiac motion in cardiac arrest. One retrospective chart review and one prospective comparison documented the diagnostic accuracy of trans-esophageal ultrasound in detecting the cause of circulatory collapse.

One study documented the frequency of pulmonary embolism in pulseless electrical activity arrest as detected with trans-eosphageal ultrasound. An additional two prospective observational studies examined the use of trans-thoracic ultrasound by 'non-expert' sonographers to detect pericardial effusion and other causes of pulseless electrical arrest.

Three prospective studies examined ultrasound determination of cardiac standstill as a predictor of clinical outcomes and return of spontaneous circulation in patients in cardiac arrest. Absence of cardiac motion on sonography during resuscitation of patients in cardiac arrest was highly predictive of death: of the 341 patients from the three studies, 218 had no detectable cardiac activity and only 2 of these had return of spontaneous circulation (no data on survival to hospital discharge).[2]

Recommendation

The use of ultrasound or echocardiography, when available, to guide cardiac arrest management should be considered. [Class B; LOE IV]

Other techniques and devices to perform CPR

Several techniques or adjuncts to standard CPR have been investigated and the relevant data was reviewed extensively as part of the Consensus on Science process.[7] The success of any technique depends on the education and training of the rescuers or the resources available (including personnel). Techniques reviewed include: Open-chest CPR, Interposed Abdominal Compression CPR, Active Compression-Decompression CPR, Open Chest CPR, Load Distributing Band CPR, Mechanical (Piston) CPR, Lund University Cardiac Arrest System CPR, Impedance Threshold Device, and Extracorporeal Techniques.[7]

Because information about these techniques and devices is often limited, conflicting, or supportive only for short-term outcomes, no recommendations can be made to support or refute their routine use.

While no circulatory adjunct is currently recommended instead of manual CPR for routine use, some circulatory adjuncts are being routinely used in both out-of-hospital and in-hospital resuscitation. If a circulatory adjunct is used, rescuers should be well-trained and a program of continuous surveillance should be in place to ensure that use of the adjunct does not adversely affect survival. [Class B; LOE IV]

Open Chest CPR

There are no published randomized controlled trials and very limited data in humans comparing open-chest CPR to standard CPR in cardiac arrest. Four relevant human studies, 2 after cardiac surgery and 2 after out-of-hospital cardiac arrest showed that open-chest cardiac massage improved coronary perfusion pressure and increased ROSC. Evidence from animal studies indicates that open-chest CPR produces greater survival rates, perfusion pressures, and organ blood flow than closed-chest CPR. Open-chest CPR should be considered for patients with cardiac arrest in the early postoperative phase after cardiothoracic surgery or when the chest or abdomen is already open. Open chest CPR should also be considered after penetrating chest injures.[7] [Class B; LOE III-2]

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