Guideline 11.6 – Equipment and Techniques in Adult Advanced Life Support

Summary

This guideline applies to adults who require advanced life support (ALS).

Who is the audience for this guideline?

This guideline is for health professionals and those who provide healthcare in environments where equipment and drugs are available.

Summary of Recommendations

This guideline has been updated based on evidence reviews including the 2019 to 2023 International Liaison Committee on Resuscitation (ILCOR) ALS Taskforce evidence reviews.[1-5] The Australian and New Zealand Committee on Resuscitation (ANZCOR) makes the following recommendations:

1. The highest possible inspired oxygen concentration is used on all patients during cardiopulmonary resuscitation (CPR). Oxygen should never be withheld because of the fear of adverse effects.
2. ANZCOR suggests using bag-mask ventilation (BMV) or an advanced airway strategy during CPR for adult cardiac arrest in any setting.
3. If an advanced airway is used, ANZCOR suggests a supraglottic airway (SGA) for adults with OHCA in settings with a low tracheal intubation (TI) success rate.
4. If an advanced airway is used, ANZCOR suggests a SGA or TI for adults with out–of-hospital cardiac arrest (OHCA) in settings with a high TI success rate. If an advanced airway is used, we suggest a SGA or TI for adults with in-hospital cardiac arrest (IHCA).
5. In adults in cardiac arrest, when standard airway management strategies (e.g. oropharyngeal airway and bag-mask, supraglottic airway, or tracheal tube) have failed, it is reasonable for appropriately trained rescuers to attempt front-of-neck surgical airway access using a cricothyroidotomy technique.
6. Waveform capnography should be used to confirm and continuously monitor the position of a tracheal tube during CPR in addition to clinical assessment.
7. When ventilating a person without an advanced airway, ventilation should be continued at a ratio of 30 compressions to 2 ventilations.

8. CPR prompt / feedback devices may be considered for clinical use to provide data as part of an overall strategy to improve quality of CPR at a systems level.
9. End-tidal carbon dioxide ($ETCO_2$) cut-off values alone should not be used as a mortality predictor or for the decision to stop a resuscitation attempt.
10. If cardiac ultrasound is available and can be performed without interfering with standard ALS, it may be considered to try and identify potentially reversible causes of cardiac arrest.
11. An impedance threshold device (ITD) should not be routinely used in addition to standard CPR.
12. Automated mechanical chest compression devices should not be routinely used to replace manual chest compressions.
    However, they may be a reasonable alternative to high-quality manual chest compressions in situations where sustained high-quality manual chest compressions are impractical or compromise provider safety.
13. ANZCOR suggests that extracorporeal cardiopulmonary resuscitation (ECPR) may be considered as a rescue therapy for selected patients with cardiac arrest when conventional CPR is failing in settings in which it can be implemented.

Guideline

A wide range of equipment is available for use in ALS. The role of 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 Basic Life Support (BLS) and ALS skills.

Airway adjuncts can be used to facilitate ventilation, to better maintain the airway, or to provide access to the airway (e.g. for suctioning) [Good Practice Statement].

1.0 | Oxygen during CPR

This topic was last reviewed in 2015. An Evidence Update was performed as part of the ILCOR 2020 review process, which identified 2 observational studies published since 2015.[2] The recommendation is unchanged from 2015.

There are no adult human studies that directly compare maximal inspired oxygen with any other inspired oxygen concentration. In one observational study of patients receiving 100% oxygen and tracheal intubation during CPR, a higher measured PaO_2 during CPR was associated with improved return of spontaneous circulation (ROSC) and hospital admission.[6]

Recommendations

ANZCOR suggests that the highest possible inspired oxygen concentration is used on all patients during CPR [CoSTR 2015 weak recommendation, very low certainty evidence].[7] Oxygen should never be withheld because of the fear of adverse effects.

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.

2.0 | Airway

2.1 | Airway manoeuvres

The BLS techniques of chin lift and head tilt are covered in ANZCOR Guideline 4.

Jaw thrust

In this technique, the rescuer is commonly positioned at the top of the person'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 off the posterior pharynx. 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 person's airway is not patent [Good Practice Statement].

2.2 | Basic airway adjuncts

Oropharyngeal 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 (BMV) in cardiac arrest, but in the presence of a known or suspected basal skull fracture an oropharyngeal airway is preferred. It is still necessary to use head tilt and jaw support, or jaw thrust [Good Practice Statement].

Oropharyngeal airway

Oral airways should be appropriately sized and not be forcibly inserted. They should be reserved for unconscious, obtunded persons. Laryngospasm or vomiting with aspiration may result in those patients who still have a gag reflex [Good Practice Statement].

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 lifesaving (i.e. the benefits may far outweigh the risks)[8] [Good Practice Statement].

2.3 | Advanced airway devices

The tracheal 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 BVM device and advanced airway devices, such as the supraglottic airways (SGA) e.g. Laryngeal Mask Airway (LMA) and i-gel), laryngeal tube, and oesophageal-tracheal tube (Combitube).

Chest compressions alone do not provide adequate ventilation during prolonged cardiac arrest. Airway management is therefore required to facilitate ventilation, improve oxygenation and reduce the risk of gastric regurgitation and aspiration. ILCOR and ANZCOR have regularly reviewed the use of advanced airway devices during cardiac arrest. Following the publication, in 2018, of 3 randomised control trials (RCTs) investigating airway management during cardiac arrest,[9-11] ILCOR commissioned a systematic review.[12] The ALS Task Force analyzed this to produce the ILCOR CoSTR on advanced airway management recommendations that were published in the 2019 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations.[1]

Consensus on science

Seventy-one observational studies and 11 controlled trials of airway management in patients with OHCA were identified with a high risk of bias and heterogeneity. Because of these risks and the availability of RCTs, no meta-analyses were performed for these studies. The systematic review (SR) focused on the 3 RCTs published in 2018, which were larger and powered for more relevant outcomes. Different comparisons and heterogeneity prevented meta-analyses of these RCTs. The Jabre study compared BMV with tracheal intubation (TI) in a physician-based system, while the Benger and Wang studies compared SGA devices with TI in non-physician-based systems. The TI success rate was 98% in the Jabre study, 70% in the Benger study, and 52% in the Wang study. Success rates were not defined identically in the 3 studies; which led to concerns about generalizability of the findings. As a result, the task force considered two different settings when evaluating the overall certainty of evidence: a setting with a low TI success rate (similar to the systems in the Benger and Wang studies) and a setting with a high TI success rate (similar to the Jabre study). Overall, there is no high-certainty evidence to recommend an advanced airway strategy over BMV and no high-certainty evidence to recommend a specific advanced airway device over another.

Recommendations

ANZCOR suggests using BMV or an advanced airway strategy during CPR for adult cardiac arrest in any setting [CoSTR 2019, weak recommendation, low to moderate certainty of evidence].

If an advanced airway is used, ANZCOR suggests an SGA for adults with OHCA in settings with a low TI success rate [CoSTR 2019, weak recommendation, low certainty of evidence].

If an advanced airway is used, ANZCOR suggests an SGA or TI for adults with out-of-hospital cardiac arrest (OHCA) in settings with a high TI success rate (weak recommendation, very low certainty of evidence). If an advanced airway is used, ANZCOR suggests an SGA or TI for adults with in-hospital cardiac arrest (IHCA) [CoSTR 2019, weak recommendation, very low certainty of evidence].

Justification

There is currently no supporting evidence that an advanced airway (i.e., SGA or TI) during CPR improves survival or survival with a favorable neurological/functional outcome after adult cardiac arrest in any setting compared with BMV. This ILCOR 2019 CoSTR addresses airway management during CPR in adults; it does not address airway management after ROSC. After ROSC, survivors requiring mechanical ventilation and post-resuscitation care will require TI.

Advanced airway strategies usually start with a variable period of BMV and the timing and reasons for transitioning to an advanced airway device will vary, depending on the clinical scenario. In the 3 new RCTs patients treated with advanced airways had a period of BMV while providers prepared for device insertion; in some patients, an SGA was inserted as the first airway intervention without BMV. The term advanced airway strategy includes all of these options. We have not provided a precise value or range of values for low and high intubation success rate or an agreed-on definition. Studies have used different definitions of TI success. We considered the Wang and Benger RCTs as having a low TI success rate (51.6% and 69.8%, respectively) and the Jabre RCT as having a high success rate (97.9%).

We assume that TI success rates are high in the in-hospital setting, but there is limited evidence to support this, and success is likely to be site dependent. The recommendations for IHCA are based primarily on indirect evidence from the OHCA studies. There are no airway RCTs for IHCA.

We have not expressed a preference for a particular SGA device of those currently available (i-gel was used in the Benger RCT, and the Laryngeal Tube was used in the Wang RCT). The i-gel and LMA devices is widely available in Australia and New Zealand.

The performance of individual SGA devices varies and BMV can be difficult to perform, and effectiveness varies according to provider skills. The optimal bag-mask technique is unknown (e.g., 1-person or 2-person methods) including when used with adjuncts such as oropharyngeal or nasopharyngeal airways.

The ALS task force considered that the preferred airway option is likely to depend on the skills of the provider and the specific patient circumstances. In addition, patients may require different airway interventions at different stages of resuscitation.

Knowledge Gaps

The ILCOR ALS Task Force identified knowledge gaps related to:

- Prospective comparison of BMV with SGA use.
- Optimal airway management strategy for IHCA.
- Impact on outcome of using an advanced airway (SGA or TI) without prior BMV.
- Optimal SGA for use during cardiac arrest.
- Optimal time point during CPR to change to different airway techniques.

- Impact of different airway strategies on CPR quality (no-flow time), as well as oxygenation and ventilation during CPR.
- Training and clinical experience required to maintain proficiency in an airway technique.

The airway devices/adjuncts used during a cardiac arrest must be chosen according to local training and availability [Good Practice Statement]. To avoid substantial interruptions in chest compressions providers may defer attempts to insert devices/adjuncts until ROSC [Good Practice Statement].

To avoid substantial interruptions in chest compressions, providers may defer an intubation attempt until after ROSC [Good Practice Statement]. To ensure competence, healthcare systems that utilise 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 [Good Practice Statement].

In addition to providing optimal isolation and patency of the airway, tracheal intubation allows ventilation with 100% oxygen and suctioning of the airway and also provides possible access for the delivery of some drugs. However, if tracheal intubation is attempted, ongoing CPR must be maintained, laryngoscopy should be performed during chest compressions and attempts at intubation should not interrupt cardiac compressions for more than 5 seconds [Good Practice Statement].

Once tracheal intubation has been achieved:

- Inflate cuff with enough air to prevent a leak
- Confirm placement by assessing chest inflation, auscultation, by direct observation, and waveform capnography. Then, firmly secure the tube.

Emergency Front of Neck Airway Access During Cardiac Arrest

There is uncertainty regarding optimal strategies for emergency airway management in cardiac arrest when standard approaches to airway management fail. ILCOR commenced a review in 2023 to assess current evidence.

Recommendation

In adults in cardiac arrest, when standard airway management strategies (e.g, oropharyngeal airway and bag-mask, supraglottic airway, or tracheal tube) have failed, it is reasonable for appropriately trained rescuers to attempt front-of-neck airway access using a cricothyroidotomy technique [Good Practice Statement].

Confirmation of placement of endotracheal tube

This topic was last reviewed in 2015. An Evidence Update was performed as part of the ILCOR 2020 review process, and the recommendation is unchanged from 2015.

Unrecognised oesophageal intubation is the most serious complication of attempted TI. Routine confirmation of correct placement of the tracheal tube should reduce this risk.

Two studies of waveform capnography to verify tracheal tube position in persons in 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) in prehospital cardiac arrest. The sensitivity may have been adversely affected by the prolonged resuscitation times and very prolonged transport times of many of the cardiac arrest persons studied. Intubation was performed after arrival at hospital and time to intubation averaged more than 30 minutes.

Studies of colorimetric $ETCO_2$ detectors, syringe aspiration oesophageal detector device, self-inflating bulb oesophageal detector device and non-waveform $ETCO_2$ 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 people in cardiac arrest.

Recommendations

ANZCOR recommends using waveform capnography to confirm and continuously monitor the position of a tracheal tube during CPR in addition to clinical assessment [CoSTR 2015, strong recommendation, low certainty evidence].

ANCOR recommends that if waveform capnography is not available, a non-waveform carbon dioxide detector, oesophageal detector device or ultrasound, in addition to clinical assessment are alternatives [CoSTR 2015, strong recommendation, low certainty evidence].

Justification

These are strong recommendations despite the low certainty evidence, as a high value is placed on avoiding unrecognised oesophageal intubation. In 11 studies assessed, the mean incidence of unrecognised oesophageal intubation in cardiac arrest was 4.3% (range 0 to 14%).[7]

Additionally, waveform capnography is recommended as it may have other potential uses during CPR (e.g. monitoring ventilation rate, assessing quality of CPR, and alerting the presence of ROSC).

3.0 | Ventilation

3.1 | Bag-Valve-Mask Device

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].

3.2 | Oxygen-Powered Resuscitators

These devices have a limited place but can provide high oxygen concentrations in experienced hands [Good Practice Statement]. Devices that do not comply with current Australian/New Zealand Standards should not be used.

3.3 | Mechanical Ventilators

This topic was last reviewed in 2010.[6] An evidence update was included in the ILCOR 2020 review process and identified 1 small RCT and 3 observational studies. The recommendation is unchanged from 2010.

One pseudo-randomised study suggests that use of an automatic transport ventilator with intubated patients may enable the emergency medical services (EMS) team to perform more tasks while subjectively providing similar ventilation to that of a bag-valve device.[13]

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.[14]

Recommendations

ANZCOR suggests that there is insufficient evidence to support or refute the use of an automatic transport ventilator over manual ventilation during resuscitation of the cardiac arrest person 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 [Good Practice Statement].

3.4 | 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 ROSC. In a secondary analysis of the case series that included patients with advanced airways in place after OHCA, 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 haemodynamics than ≥12 ventilations per minute[15] [Good Practice Statement].

3.5 | 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 pulseless electrical activity (PEA) may be useful to exclude gas trapping[16] [Good Practice Statement].

Recommendations

When ventilating a person 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, SGA) 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 [CoSTR 2015, weak recommendation, very low certainty evidence].[7]

Simultaneous ventilation and compression may adversely affect coronary perfusion[17] and has been associated with decreased survival.[18] 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)[19] [Good Practice Statement].

The adequacy of ventilation with SGA 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 (ETT, LMA and other SGAs).

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 [Good Practice Statement].

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 and capnography may assist with monitoring ventilation and assessing quality of CPR, though these are more reliable once ROSC has been achieved [Good Practice Statement].

3.6 | 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.[8]

4.0 | Circulation

ANZCOR recommends that healthcare providers perform chest compressions for adults at a rate of approximately 100 to 120 compressions per minute **[**CoSTR 2015, strong recommendation, very low-quality evidence] and to compress the lower half of the sternum by approximately 5 cm (approximately 1/3 of the antero-posterior diameter of the chest) [CoSTR 2015, strong recommendation, low certainty evidence].[7] Rescuers should allow complete recoil of the chest after each compression.

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 (i.e. ratio between compression and release) of 50% [Good Practice Statement].

Rescuers should minimise 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 [Good Practice Statement].

CPR in the prone position

ILCOR commissioned a SR of the efficacy of CPR on the patient in a prone position for the 2021 CoSTR, partly in response to the practice of managing critically unwell COVID-19 patients in the prone position. Almost no evidence beyond case reports was found on this topic and therefore the treatment recommendations developed were primarily Good Practice Statements.[3]

Recommendations

ANZCOR suggests that for patients with cardiac arrest occurring while in the prone position with an advanced airway already in place and for whom immediate supination is not feasible or poses significant risk to the patient, initiating CPR while the patient is still prone is a reasonable approach [Good Practice Statement].

For patients with cardiac arrest occurring while in the prone position without an advanced airway already in place, ANZCOR recommends turning the patient supine as quickly as possible and beginning CPR [CoSTR 2021, strong recommendation, very low certainty evidence].

For patients with cardiac arrest with a shockable rhythm who are in the prone position and cannot be supinated immediately, attempting defibrillation in the prone position is a reasonable approach [Good Practice Statement].

Defibrillator pads can be applied either posterolateral (one in the left mid-axillary line, the other over the right scapula) or bi-axillary positions [Good Practice Statement].

Invasive blood pressure monitoring and continuous $ETCO_2$ monitoring may be useful to ascertain whether prone compressions are generating adequate perfusion, and this information could inform the optimal time to turn the patient supine [Good Practice Statement].

4.1 | CPR prompt or feedback devices

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 is no high level evidence that the use of CPR feedback devices during real time CPR improves survival or return of spontaneous circulation.[7,20,21] One study in children and another in adults showed that metronomes improved chest compression rate and increased $ETCO_2$. 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. 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. 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.[22]

Recommendations

ANZCOR suggests CPR prompt / feedback devices may be considered for clinical use to provide data as part of an overall strategy to improve quality of CPR at a systems level [CoSTR 2015, weak recommendation, very low certainty evidence].[7]

Justification

ANZCOR places a high value on resource allocation and cost effectiveness than widespread implementation of a technology with uncertain effectiveness during real time CPR. We acknowledge that data provided by CPR feedback devices may benefit other persons as part of a broader quality improvement system.

4.2 | 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.

Recommendations

Electrical pacing is not effective as routine treatment in patients with asystolic cardiac arrest.[8] ANZCOR recommends against the routine use of pacing (electrical or fist).

The use of pacing after cardiac surgery is considered in ANZCOR Guideline 11.10, 'Resuscitation in Special Circumstances'.

5.0 | Monitoring during CPR

5.1 | Monitoring to guide resuscitation

The ability to monitor physiological variables during CPR and tailor ALS interventions is appealing. Physiologic monitoring during CPR, including measurement of $ETCO_2$, arterial blood pressure and infrared spectroscopy are feasible. This topic was last updated in 2015, and a Scoping Review of paediatric and adult physiological monitoring during CPR was included in the 2020 review process.[2] The 2015 treatment recommendations are unchanged.[7]

$ETCO_2$ or Arterial Blood Pressure Monitoring

The review identified 1 observational propensity-matched cohort study of adult IHCA patients who were physiologically monitored (either by $ETCO_2$ or arterial line) and compared with 6064 patients without monitoring. Those monitored showed a higher rate of ROSC but not survival to discharge nor survival with favorable neurological outcome. The study did not specifically look at diastolic blood pressure. Even when an arterial line was in place, only about 1/3 reported using the diastolic blood pressure to guide their CPR efforts.[2]

Near-Infrared Spectroscopy (NIRS)

The review identified 2 systematic reviews that concluded that a higher cerebral oxygen saturation measured with NIRS was associated with a higher chance of ROSC and survival and a lower NIRS is associated with an increased mortality. However, there is no consensus on specific thresholds of cerebral oxygen saturation, and there was wide overlap of cerebral oxygen saturation values between patients with and without ROSC, which was also reflected in the cohort studies. Only 1 observational study compared rates of ROSC with and without NIRS monitoring and found no difference between groups. Many different NIRS devices with noninterchangeable saturation indices were used across the studies, complicating comparisons.[2]

Physiological monitoring during CPR is increasingly popular and potentially useful for both outcome prediction and real-time improvement in CPR quality. The heterogeneity and observational nature of available studies precludes specific recommendations.

5.2 | Waveform capnography (End-tidal carbon dioxide (ETCO2)) to predict outcome

This topic was last updated in a published 2015 CoSTR, and the systematic review that informed the CoSTR was published in 2018.[23] Evidence updates were included in the ILCOR 2020 review process and identified new observational studies. The task force decided not to update the systematic review because of the low likelihood of it leading to a change in treatment recommendations. The 2015 treatment recommendations remain unchanged.

Waveform capnography during CPR has potential roles in:

- Confirming tracheal tube placement.
- Monitoring the ventilation rate to assist in avoiding hyperventilation.
- Assessing the quality of chest compressions during CPR ($ETCO_2$ values are associated with compression depth and ventilation rate).
- Identifying ROSC during CPR (by an increased $ETCO_2$ value).
- Assessing prognosis during CPR (low $ETCO_2$ values may indicate a poor prognosis and less chance of ROSC). Failure to achieve a $ETCO_2$ value >10 mmHg after 20 min of CPR is associated with a poor outcome in observational studies.

Recommendations

ANZCOR recommends against using $ETCO_2$ cut-off values *alone* as a mortality predictor, or for the decision to stop a resuscitation attempt [CoSTR 2015, strong recommendation, low certainty evidence].

ANZCOR suggests that an $ETCO_2$ 10mmHg or greater measured after tracheal intubation or after 20 min of resuscitation, may be a predictor of ROSC [CoSTR 2015, weak recommendation, low certainty evidence].

ANZCOR suggests that an $ETCO_2$ of 10mmHg or greater measured after tracheal intubation, or an $ETCO_2$ 20mmHg or greater measured after 20 min of resuscitation may be a predictor of survival to discharge [CoSTR 2015, weak recommendation, moderate certainty evidence].

Justification

ANZCOR has put a higher value on not relying on a single variable ($ETCO_2$) and cut-off value when their usefulness in actual clinical practice, and variability according to the underlying cause of cardiac arrest, has not been established. The aetiology (e.g. asphyxia, pulmonary embolism (PE) of cardiac arrest could affect $ETCO_2$ values, and there is concern about the accuracy of $ETCO_2$ values during CPR.[7]

5.3 | Arterial Blood Gas

There is 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.[16]

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[16] [Good Practice Statement].

5.4 | Ultrasound during cardiac arrest

Does cardiac ultrasound during CPR change outcomes

In 2015, the question of whether the use of cardiac ultrasound during CPR changed outcomes was reviewed.[7] The use of cardiac ultrasound during cardiac arrest may allow identification of many cardiac and non-cardiac causes of cardiac arrest, and three studies have examined the prognostic value of the presence or absence of sonographic cardiac motion in cardiac arrest. Absence of cardiac motion on sonography during resuscitation of patients in cardiac arrest was highly predictive of death. One RCT compared the use of cardiac ultrasound during ALS to no use of cardiac ultrasound in adult patients with pulseless electrical activity (PEA) arrest. This study enrolled 100 patients in a convenience sample and reported ROSC for at least 10 seconds in 34% of patients in the ultrasound group versus 28% in the group with no ultrasound ($p=0.52$).

In addition, a systematic review addressing the utility of ultrasound studies (USS) as a diagnostic tool was carried out to inform the 2022 CoSTR.[24] Only a single observational study provided sufficient information to calculate the sensitivity and specificity of Point of Care ultrasound (POCUS) for specific pathophysiological states.

For the target conditions of cardiac tamponade, pericardial effusion, pulmonary embolism, myocardial infarction, aortic dissection, and hypovolemia, 11 observational studies with a high risk of bias provided sufficient data, to estimate individual positive predictive values only, among small subsets of between 1 and 10 patients with OHCA, IHCA, or intraoperative cardiac arrest. Individual estimates of positive predictive value have very wide confidence intervals and are difficult to interpret in the context of the very small subsets of subjects.

Recommendations

ANZCOR suggests against routine use of POCUS during CPR to diagnose reversible causes of cardiac arrest [CoSTR 2022, weak recommendation, very low certainty evidence].

ANZCOR suggests that if cardiac ultrasound can be performed without interfering with standard advanced cardiovascular life support protocols, it may be considered as an additional diagnostic tool to identify potentially reversible causes when clinical suspicion for specific reversible cause is present [CoSTR 2015, weak recommendation, very low certainty evidence].

Point-of-Care Echocardiography for Prognostication during CPR

This question was prioritized by the 2020 ALS Task Force due to the increasing popularity of the use of point-of-care echocardiography as a prognostic tool, as well as concern about potential pitfalls in interpretation. A systematic review of the intra-arrest prognostic capabilities of point-of-care echocardiography[25] was performed to inform the 2020 CoSTR.[2]

Consensus on Science

The systematic review identified no RCTs and 15 observational studies. The overall certainty of evidence was rated as very low for all outcomes primarily due to risk of bias, inconsistency, and/or imprecision. There was a substantial risk of bias due to prognostic factor measurement, outcome measurement, adjustment for prognostic factors, or confounding. Because of this and a high degree of clinical heterogeneity, no meta-analyses could be performed.

Recommendations

ANZCOR suggests against the use of point-of-care echocardiography for prognostication during CPR [CoSTR 2020, weak recommendation, very low-certainty evidence].

Justification

In making this recommendation the inconsistent definitions and terminology about the sonographic evidence of cardiac motion were considered. This included wide variation in the classification of anatomy, type of motion, and timing of point-of-care echocardiogram. Most studies suffer from high risk of bias related to prognostic factor measurement, outcome measurement, lack of adjustment for other prognostic factors, and confounding from self-fulfilling prophecy and unspecified timing of point-of-care echocardiography.

Knowledge Gaps

- There is no standardized or uniform definition of cardiac motion visualized on point-of care echocardiography during cardiac arrest.
- There are very few prognostic factor studies of point-of-care echocardiography during cardiac arrest performed with methodology that minimizes risk of bias.
- The inter-rater reliability of point-of-care echocardiography during cardiac arrest is uncertain.
- The relative roles and feasibility of transesophageal versus transthoracic echocardiography during CPR.

5.5 | Other techniques and devices for circulatory support during CPR

Several techniques or adjuncts to standard CPR have been investigated and the relevant data was reviewed extensively as part of the 2010 ILCOR Consensus on Science process.[25] The success of any technique depends on the education and training of the rescuers and/or the resources available (including personnel). Techniques reviewed include: Open-chest CPR, Interposed Abdominal Compression CPR, Active Compression-Decompression (ACD) CPR, Open Chest CPR, Load Distributing Band CPR, Mechanical (Piston) CPR, Lund University Cardiac Arrest System CPR, Impedance Threshold Device, and Extracorporeal Techniques.

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 [Good Practice Statement].

Evidence for specific techniques to assist circulation during CPR were initially reviewed in the 2015 ILCOR Consensus on Science process.[7]

Three technologies for which there have been significant developments since 2010 were considered:

- The impedance threshold device (ITD)
- Automated mechanical chest compression devices
- Extracorporeal CPR (ECPR).

5.5.1 The impedance threshold device (ITD)

For standard CPR, 1 RCT showed no clinically significant benefit in survival from the addition of the ITD.

Recommendations

ANZCOR recommends against the routine use of the ITD in addition to standard CPR [CoSTR 2015, strong recommendation, high certainty of evidence].[7]

For Active Compression CPR, 2 RCTs showed no clinically significant benefit in survival from the addition of the ITD to ACD CPR in a total of 421 out-of-hospital cardiac arrests.

Additionally, 2 RCTs did not demonstrate a clinically significant benefit in survival or neurological status from the addition of the ITD to ACD CPR compared with standard CPR.

5.5.2 Automated mechanical chest compression devices

Two RCTs demonstrated no improvement in survival or neurological outcome at 30, 180 days or 1 year compared with manual CPR. Three RCTs showed variable survival with good neurology at hospital discharge. Of two studies using the load-distributing band, one study showed harm, while the other showed no effect, and one study using the Lund University Cardiac Arrest System (LUCAS) device showed no effect. Five RCTs showed variable results for survival to hospital discharge. One RCT of IHCA showed benefit with use of a piston device compared with manual chest compressions. Two other RCTs of the LUCAS and 1 using a load-distributing band device showed neither benefit nor harm. Seven RCTs looked at the effect of ACDs on establishing ROSC: 2 showed a benefit, 1 showed harm and four showed no effect.

Recommendations

ANZCOR suggests against the routine use of automated mechanical chest compression devices to replace manual chest compressions [CoSTR 2015 weak recommendation, moderate certainty of evidence].

ANZCOR suggests that automated mechanical chest compression devices are a reasonable alternative to high-quality manual chest compressions in situations where sustained high-quality manual chest compressions are impractical or compromise provider safety [CoSTR 2015, weak recommendation, low quality evidence].

Justification

ANZCOR believes the emphasis in resuscitation should be on providing high-quality chest compressions with adequate depth, rate and minimal interruptions, regardless of whether they are delivered by machine or human. We acknowledge that application of a mechanical chest compression device without a focus on minimising interruptions in compressions and delay to defibrillation could cause harm.

However, we also acknowledge that 1 large RCT showed equivalence between very high-quality manual chest compressions and mechanical chest compressions delivered with a load-distributing band in a setting with rigorous training and CPR quality monitoring, and we recognise that there are situations where sustained high-quality manual chest compressions may not be practical. Examples include CPR in a moving ambulance, the need for prolonged CPR (e.g. hypothermic arrest), and CPR during certain procedures (e.g. coronary angiography or preparation for ECPR).

5.5.3 Extracorporeal CPR (ECPR)

ECPR can maintain vital organ perfusion while potential reversible causes of cardiac arrest are identified and treated, and has been used to support circulation in cardiac arrest refractory to conventional CPR. ECPR requires rapid skilled interventions and the optimal patient selection and timing of the therapy are not well defined.

This subject was fully reviewed in 2015, and ILCOR commissioned a new systematic review in 2018[27] which the ALS Task Force used to produce the ECPR recommendations in the 2019 CoSTR.[1] An evidence update review on ECPR was done for the 2021 CoSTR[3], and following additional recent publications an updated systematic review[28] was completed to inform the 2023 CoSTR.[5]

Consensus on science

For all OHCA and IHCA studies, the overall certainty of evidence was rated as very low for all outcomes. All individual studies were at a very serious risk of bias, mainly because of confounding. As a result of this confounding and a high degree of heterogeneity, no meta-analyses could be performed, and individual studies are difficult to interpret.

Recommendations

ANZCOR suggests that ECPR may be considered as a rescue therapy for selected patients with OHCA when conventional CPR is failing to achieve ROSC, in settings where it can be implemented [CoSTR 2023, weak recommendation, low-certainty of evidence].

ANZCOR suggests that ECPR may be considered as a rescue therapy for selected patients with IHCA when conventional CPR is failing to achieve ROSC, in settings where this can be implemented [CoSTR 2023, weak recommendation, very low-certainty evidence].

Justification

In making this weak recommendation, ANZCOR considered the extremely high mortality rate of patients in cardiac arrest refractory to conventional CPR. The published studies used selected patients for ECPR, not the general population of all cardiac arrest patients, and RCTs have not been performed to define the optimal population. ECPR is a complex intervention that requires considerable resources and training that are not universally available. We also acknowledge the value of an intervention that may be successful in individuals in whom usual CPR techniques have failed. ECPR can sustain perfusion while another intervention such as coronary angiography and percutaneous coronary intervention can be performed.

Knowledge Gaps

- The optimal post-cardiac arrest care strategy for patients resuscitated with ECPR.
- The patient groups most likely to benefit from ECPR.
- The optimal ECPR techniques.
- The optimal timing to initiate ECPR during resuscitation (i.e. early, late, when in the sequence).
- The potential role of ECPR during the peri-arrest period.
- The population-specific differences in indications for ECPR for IHCA and OHCA.
- The differences in quality of life (QOL) between survivors of ECPR and survivors of conventional CPR.
- The cost-effectiveness of ECPR.

5.6 | Open Chest CPR

There are no published randomised 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 (Refer to ANZCOR Guideline 11.10 Special Circumstances). Open chest CPR should also be considered after penetrating chest injures[24] [Good Practice Statement].

Abbreviations

Abbreviation	Meaning/Phrase
ACD	automated mechanical chest compression device

ALS	advanced life support
ANZCOR	Australian and New Zealand Committee on Resuscitation
BLS	basic life support
BMV	bag mask ventilation
CoSTR	Consensus on Science with Treatment Recommendations
CPR	cardiopulmonary resuscitation
ECPR	extracorporeal cardiopulmonary resuscitation
EMS	emergency medical services
$ETCO_2$	end-tidal carbon dioxide
IHCA	intra-hospital cardiac arrest
ILCOR	International Liaison Committee on Resuscitation
ITD	impedance threshold device
LUCAS	Lund university cardiac arrest system
NIRS	near-infrared spectroscopy
OHCA	out of hospital cardiac arrest
PaO_2	partial pressure of arterial oxygen
PEA	pulseless electrical activity
PE	pulmonary embolus
POCUS	point-of care ultrasound
QOL	quality of life
RCT	randomised control trial
ROSC	return of spontaneous circulation
SGA	supraglottic airway
SR	systematic review
TI	tracheal intubation

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About this Guideline

Search date/s	ILCOR literature search details and dates are available on the CoSTR page of the ILCOR website (https://costr.ilcor.org) and the relevant CoSTR documents e.g: https://costr.ilcor.org/document/advanced-airway-management-during-adult-cardiac-arrest https://costr.ilcor.org/document/diagnostic-test-accuracy-of-point-of-care-ultrasound-during-cardiopulmonary-resuscitation-to-indicate-the-etiology-of-cardiac-arrest https://costr.ilcor.org/document/extracorporeal-cardiopulmonary-resuscitation-ecpr-for-cardiac-arrest-als-sr https://costr.ilcor.org/document/prone-cpr-als-systematic-review
Question/PICO:	Are described in the CoSTR documents (https://costr.ilcor.org)
Method:	Mixed methods including ARC NHMRC methodology before 2017 and ILCOR GRADE methodology described in ILCOR publications since 2017.
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