Introduction: Cardiac arrest is a common emergency in acute hospitals. The Resuscitation Council (UK) Advanced Life Support Guidelines provide a systematic approach to cardiac arrest recognition, treatment and aftercare. This review provides an update on the current treatment guidelines and identifies areas where these may be strengthened.

Methods: The evidence informing the 2005 Resuscitation Guidelines is reviewed. New evidence since the publication of the guidelines was identified by searching Medline (December 2005–December 2008) with the term heart arrest or advanced life support.

Results: Opportunities for strengthening the chain of survival exist for each link. These include better recognition of critically ill patients at risk of cardiac arrest, improved quality of cardiopulmonary resuscitation, defibrillation strategies, which minimize pre- and post-shock pauses and development of post-resuscitation care bundles.

Conclusion: Emerging evidence suggests opportunities where Resuscitation Guidelines could be strengthened by focusing on specific aspects of the chain of survival.

Keywords: advanced life support/defibrillation/resuscitation

Introduction

Each year about 30 000 people sustain a cardiac arrest in hospitals throughout the UK, and 25 000 people per year have resuscitation attempted after an out-of-hospital cardiac arrest. Despite significant advances in our understanding of the pathophysiology of cardiac arrest and advances in treatment options, the overall outcome (survival to hospital discharge) remains poor at around 20% for in-hospital cardiac arrests and up to 5–10% for out-of-hospital arrests.

In 2000 the first International Resuscitation Guidelines were published with the aim of improving the practice and teaching of resuscitation following global collaboration led by The International Liaison Committee on Resuscitation (ILCOR). Guidelines for cardiopulmonary...
resuscitation (CPR) are continually modified and updated as resuscitation science advances in order to promote changes and developments. This is fundamental to both practice innovation and improvement in quality of patient outcomes. The last update took place in 2005 following the International Consensus Conference on CPR and Emergency Cardiac Care Science.\(^4\) The recommendations from this conference formed the basis for the European Resuscitation Council Guidelines, which were subsequently adopted by the Resuscitation Council (UK) and represent the widely accepted view of how resuscitation can be undertaken safely and effectively.

This article will review the evidence informing the 2005 Resuscitation Council (UK) Guidelines. New evidence since the publication of the guidelines was identified by searching Medline (December 2005–December 2008) with the term heart arrest or advanced life support. The article focuses on the literature that is particularly relevant to healthcare providers working in a hospital as opposed to pre-hospital setting.

**Chain of survival**

The chain of survival (Fig. 1) comprises of four links: early recognition of critical illness and call for help, early CPR, early defibrillation and post-resuscitation care.\(^5,6\) The chain identifies the critical links in a succession of events that are required to improve the outcomes from cardiac arrest. Recent revisions to the chain of survival saw the inclusion of cardiac arrest prevention and post-resuscitation care. This reflects the importance of the care that a patient receives both before an arrest occurs and following the return of spontaneous circulation in contributing to the patients’ eventual outcome.

![Chain of survival](image)

*Fig. 1* Chain of survival. Reproduced with permission from Jonathan Smart, Laerdal Medical, UK.
Early recognition and call for help

Cardiac arrest in hospital is rarely sudden and unexpected. In up to 85% of patients, signs of physiological deterioration are present in the hours leading up to a cardiac arrest. Systematic approaches for detecting and intervening early in the development of critical illness are increasing.\(^7\)

One of the most important developments has been the introduction of physiological track and trigger systems that were developed to aid the early recognition of the acutely ill patient.\(^8\) These systems track routinely measured physiological variables (such as respiratory rate, heart rate, blood pressure, urine output, etc.) to identify early signs of critical illness. Based on pre-determined abnormalities in single or combinations of physiological signs, a response from the critical care team is triggered.

A large number of different scoring systems have been developed, which include the medical emergency team (MET) calling criteria, modified early-warning system (MEWS), the patient at risk team (PART) criteria. The performance characteristics and ‘cut-point’ for triggering a response are critical to the success of these models, yet on the whole have been poorly defined and evaluated.\(^9\)–\(^11\) Reducing a trigger cut-point would improve the sensitivity, thus increasing the probability that the score would identify a sick patient. However, this would be at the cost of decreased specificity, and consequently increased workload. The MET scoring system had both sensitivity and specificity of <50% in the large Australian MERIT study.\(^9\),\(^12\) Smith et al.\(^11\) evaluated the performance of 33 aggregated, weighted early-warning scores and found area under the receiver operator curve values ranging from 0.657 (95% CI 0.636–0.678) to 0.782 (95% CI 0.767–0.797). Only 12 of these scoring systems could discriminate reasonably well between survivors and non-survivors. The use of age within the scoring system was associated with better performance.\(^13\) Further refinement in determining the optimal ‘cut-points’ and integration of physiological with demographic, co-morbidities and laboratory variables may help further improve the performance of these models.\(^7\)

Early CPR

*Initial assessment*

The adult advanced life support treatment algorithm summarizes the approach to the initial management of a patient in cardiac arrest (Fig. 2). After confirming that a patient is un-responsive, the airway should be opened and the patient checked for signs of life. The 2005
Fig. 2 Advanced life support treatment algorithm. Reproduced with permission from the Resuscitation Council (UK).
guidelines emphasize the need to minimize the time taken to confirm the cardiorespiratory arrest. Evidence from studies shows that prolonged periods of time are taken to perform separate breathing and pulse checks and that the diagnostic accuracy of these checks in isolation are limited. Experienced healthcare practitioners are encouraged to simultaneously check for breathing and a carotid pulse. In an un-responsive patient, the absence of normal breathing and a carotid pulse confirms the diagnosis of cardiac arrest. Attention is drawn to the fact that agonal breathing (slow, irregular, deep or sighing respirations) is common in the early stages after cardiac arrest and should not be mistaken as a sign of life. If cardiac arrest is confirmed, the resuscitation team should be called. In the UK, the National Patient Safety Agency (NPSA) recommends a single standardized telephone number in hospitals for alerting the resuscitation team (2222).

**Cardiopulmonary resuscitation**

Chest compressions at a ratio of 30 compressions to 2 ventilations should be commenced pending the arrival of a defibrillator. The importance of the quality of CPR has been reinforced in a series of observational studies in humans. Chest compression depth, rate, ventilation rate and duration of pre-shock pauses have all been shown to influence the likelihood of a successful resuscitation attempt. Despite these compelling data, observational studies during real life resuscitation attempts consistently demonstrate sub-optimal implementation of resuscitation guidelines in practice.

Interruptions in chest compression are common during resuscitation and have an adverse impact on patient outcome. Chest compressions can achieve up to one-third of the normal cardiac output and are important for maintaining coronary and cerebral perfusion. Chest compressions also serve to empty the right ventricle and reduce the degree of ventricular interaction that could otherwise impede achieving a return of spontaneous circulation after defibrillation.

The 2005 Guidelines emphasize the importance of minimizing interruptions to chest compressions. This included a change in compression–ventilation ratio from 15:2 to 30:2 in order to reduce interruptions in chest compression.

**Ventilation**

Controversy is on-going about the need for ventilations early in the course of a non-asphyxial cardiac arrest. The American Heart
Association (AHA) recently published an advisory statement on compression-only CPR for bystanders responding to out-of-hospital cardiac arrest. This recommendation has not been accepted universally, with the European Resuscitation Council, among others, advocating that bystanders continue to provide ventilations if they are trained and willing to do so. The compression-only CPR is less relevant to in-hospital resuscitation attempts as in this group of patients, many will have suffered from periods of tissue hypoxia prior to cardiac arrest and there is an expectation that responders will be trained and able to provide ventilation.

Early tracheal intubation should be a priority during in-hospital resuscitation as it will allow asynchronous compressions and ventilations to be delivered. If tracheal intubation is not possible, or the resuscitation team do not contain staff with these advanced skills, a supraglottic airway device such as a laryngeal mask or I-Gel airway can be used as an alternative. It is often possible to perform asynchronous compressions/ventilations with such a device.

A landmark study by Aufderheide and Lurie demonstrated the potentially harmful effects of hyperventilation during resuscitation. They conducted an observational study on ventilation rates in real life resuscitation attempts and showed that the average ventilation rate was 30 ± 3.2 breaths/min (range, 15–49 breaths/min). The effects of these rates on outcome were then tested in a porcine cardiac arrest model. Hyperventilation (rate, 30 breaths/min) was associated with increased intra-thoracic pressures, reduced coronary perfusion pressure and reduced survival (14% in hyperventilation group and 85% in the normal ventilation group; rate, 12 breaths/min).

**Improving CPR quality**

The Utstein consensus conference on education in resuscitation developed the concept of the formula of survival. This formula attributes the probability of a patient surviving from cardiac arrest as a product of the quality of the resuscitation guidelines combined with strategies to aid education and implementation. The current evidence indicates that the quality of CPR applied in clinical practice is sub-optimal. Technological advances mean that it is now possible to receive feedback during actual performance of CPR. Devices ranging in complexity from a simple pressure sensor and metronome (e.g. CPREzy, Laerdal) to devices using a microprocessor and combinations of an accelerometer, end-tidal CO2 and transthoracic impedance measurement (e.g. Q-CPR, Zoll M series) to provide real-time feedback on performance have been developed (Fig. 3). The integration of real-time
audio/visual feedback on the quality of CPR during actual resuscitation attempts has been associated with improvement in chest compression rate and depth in the pre-hospital setting\textsuperscript{26} and reduced variability in performance during in-hospital resuscitation attempts.\textsuperscript{27} The use of post-event debriefing in simulator-based CPR training significantly improves team performance.\textsuperscript{28} Edelson \textit{et al.}\textsuperscript{29} have developed a performance debriefing system (resuscitation with actual performance integrated debriefing—RAPID) for use following a resuscitation attempt. This system uses the data exported from a defibrillator, which captures a continuous recording of an entire resuscitation attempt (capturing ECG rhythm, ventilation rate, compression rate and depth, ETCO\textsubscript{2} and an audio recording of the event). Using historical controls, they showed that post-event feedback through a weekly cardiac review was associated with improved knowledge and adherence to guidelines; quality of CPR had significant patient survival (44.6\% to 59.4\%, \(P = 0.03\)). The role of feedback devices during and following CPR is likely to increase as technological advances reduce the cost and improve the efficacy of these devices.
Defibrillation

Data from the large US CPR registry have re-enforced the importance of timely defibrillation for patients in ventricular fibrillation (VF) or ventricular tachycardia (VT). Investigators showed that delayed defibrillation (>2 min) was associated with significant reduction in survival to hospital discharge and a higher chance of major disability and reduced functional status.\(^{30}\) The use of semi-automatic and automatic external defibrillators in hospital can help reduce the time taken to deliver a shock.

A combination of advances in defibrillator technology, along with the recognition of the harmful effects of interrupting chest compressions to deliver a shock, prompted ILCOR to recommend a single shock strategy for patients in VF/VT. Chest compressions and ventilations are resumed immediately after shock delivery and continued for 2 min before pausing again to check a rhythm or a pulse. Even if defibrillation is successful, it is rare for a pulse to be palpable immediately and delays in trying to find a pulse may further compromise the myocardium if a perfusing rhythm has not been restored. If a perfusing rhythm has been restored, giving chest compressions has not been shown to increase the likelihood of VF recurring and in the presence of post-shock asystole, a period of chest compressions may induce VF—a more treatable rhythm. Defibrillation is no longer recommended if there is any uncertainty whether the rhythm is asystole or fine VF as a shock is unlikely to result in a perfusing rhythm. In this case, continue CPR and re-assess in 2 min. Evidence is emerging, suggesting that this approach to defibrillation is improving patient outcomes.\(^{31}\)

The critical importance of interruptions in chest compressions in the seconds before and after a shock has been highlighted in recent studies. Two studies in humans have shown deleterious effects from even short interruptions prior to a shock. Eftestol et al.\(^{32}\) used VF waveform prediction models to show that increasing pre-shock pauses (as brief as 5 s) were associated with a reduction in the probability of return of spontaneous circulation. Edelson et al.\(^{33}\) showed that shock success (defined as removal of VF for at least 5 s following defibrillation) was associated with shorter pre-shock pauses (1.86 increase in adjusted odds ratio for every 5 s decrease in pre-shock pause).\(^{33}\) Data from an experimental porcine study found that a delay in resuming chest compressions after defibrillation (post-shock pause) is associated with reduced return of spontaneous circulation and neurologically intact survival at 48 h.\(^{34}\)

The recommended approach for defibrillation is an important determinant of the duration of interruption in chest compression.
The European and Resuscitation Council (UK) guidelines for defibrillation differ from those produced by the AHA. The AHA guidelines prioritize minimizing the duration of the pre-shock pause by advocating that charging takes place during chest compression for health care professionals. In contrast, the European/UK guidelines recommend that charging occurs after cessation of chest compression. The different strategies are outlined in Fig. 4.\textsuperscript{35}

In a manikin study using a modern biphasic defibrillator (with a charge time of 2 s), there was a significant difference in the duration of pre-shock pause associated with the ERC approach (median 7.0 s [IQR 6.5–8.5]) as opposed to the AHA approach (1.5 s [0.8–1.5]).\textsuperscript{36} When these findings were extrapolated to the time taken for an older monophasic defibrillator to charge, the pre-shock pause for the ERC approach increased to 12.4 s [12.7–16.2]. The AHA approach has been in clinical use since 2005, and has not been associated with an increase in reports of defibrillation-related injuries. We have suggested that some of the safety concerns associated with defibrillation may be overplayed and recommend that the European/UK advice is scrutinized closely in the 2010 Guideline revision.\textsuperscript{35}

**Drugs**

There is no level I evidence demonstrating improved survival to hospital discharge for any of the drugs recommended in the treatment of cardiac arrest. A recently completed study examining drugs versus no drugs during out-of-hospital cardiac arrest failed to show any difference in survival to hospital discharge.\textsuperscript{37} Pending further definitive studies, the consensus recommendations are that for both the shockable...
and non-shockable side of the algorithm adrenaline (1 mg i.v.) should be given every 3–5 min. In practical terms, this means that it is given every other cycle. If a patient remains in shock refractory VF (>3 shocks), amiodarone 300 mg i.v. can be given immediately prior to the fourth shock. In asystole or pulseless electrical activity with a ventricular rate <60 bpm, 3 mg i.v. atropine is recommended. Thrombolysis may be considered on a case-by-case basis if initial treatment of cardiac arrest due to pulmonary embolus has failed.

Post-resuscitation care

The decision to admit a patient to intensive care following cardiac arrest, like many decisions in critical care, is challenging. There are no outcome prediction models with sufficient sensitivity or specificity upon which to base an individual treatment decision. The decision-making process should focus on the best interests of the patient taking account of the patient/relative wishes, an estimate of whether the patient is likely to survive this illness and what the duration of quality of life could be expected to be if they do survive. ILCOR have recently produced a consensus on science and treatment recommendation for post-resuscitation care. Pre-arrest factors associated with poor outcomes are increasing age, serious underlying illness and cardiac arrest location (out-of-hospital as opposed to in-hospital). Arrest-related factors include time from collapse to advanced life support, whether bystander CPR was performed, the cause of the cardiac arrest and initial rhythm (VF/VT have better outcomes) and the duration and quality of CPR performed. Epidemiological data from the UK Intensive Care National Audit and Research Centre Case Mix Programme Database from 25 000 patients admitted to intensive care and requiring mechanical ventilation after cardiac arrest reported that 42.9% survived to leave the intensive care unit, while 28.6% survived to hospital discharge. Most survivors (79.9%) were finally discharged to their normal residence implying a good neurological outcome in the majority of survivors. Long-term follow-up studies of cardiac arrest survivors demonstrate that more than 80% are alive at 12 months.

When a decision is taken to admit a patient to intensive care following cardiac arrest, the aims of that admission should be to stabilize the patient, treat any on-going issues and minimize the consequences from the ischaemia/reperfusion injury that follows cardiac arrest. Therapeutic hypothermia improves survival and neurological status in comatose survivors of cardiac arrest. Following a landmark study that demonstrated improved survival to hospital discharge (number needed to treat = 7), the International Liaison Committee...
recommended that unconscious adult patients with spontaneous circu-
lution after out-of-hospital cardiac arrest should be cooled to 32–34°C for 12–24 h when the initial rhythm was VF and that for any other rhythm, or cardiac arrest in hospital, such cooling may also be benefi-
cial. The precise timing for initiating therapeutic hypothermia remains to be determined, but the general consensus is that it should be started as early as possible. If required, shivering should be treated with sedatives and muscle relaxants. Re-warming should be controlled, aiming to increase core temperature by 0.25–0.5°C per hour and taking care to avoid an overshoot hyperthermia, which may be detrimental.

In addition to therapeutic hypothermia, it is becoming increasingly recognized that a number of other interventions during the post-
resuscitation care phase may influence the likelihood of a patient subsequently surviving. A single centre’s experience of developing an aggressive post-resuscitation care bundle comprising therapeutic hypothermia, percutaneous coronary intervention, control of haemody-
namics, blood glucose, ventilation and seizures found neurologically intact survival rise from 26% to 56% post-implementation.

**Conclusion**

The concept of the chain of survival continues to provide a framework to focus on opportunities to improve quality of care in resuscitation. Emerging evidence demonstrates scope for strengthening each link of the chain of survival. This includes better recognition of the critically ill patients at risk of cardiac arrest; improved quality of CPR; defibrilla-
tion strategies, which minimize pre- and post-shock pauses and develop-
ment of post-resuscitation care bundles.

**Funding**

G.D.P. is supported by a DH NIHR Clinician Scientist Award and Research for Patient Benefit Programme and the Intensive Care Foundation.

**References**


