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Editorial

Resuscitation highlights in 2017

The International Liaison Committee on Resuscitation (ILCOR) celebrated its 25th anniversary last year and this came at a time when the science underpinning cardiopulmonary resuscitation (CPR) continued to grow [1]. The number of submissions to *Resuscitation* continues to rise and the editors have highlighted some of the key papers published in the Journal in 2017.

Epidemiology and outcome

The relationship between neighbourhood socio-economic status and rates of bystander CPR was studied in Paris, France [2]. Of 4009 out-of-hospital cardiac arrest (OHCA) patients, 19.4% received bystander CPR and there were lower rates of bystander CPR in neighbourhoods with low versus higher socio-economic status (OR 0.85; 95% CI 0.72–0.99). Although similar findings have been reported from the United States (US), this was the first European study to document this association.

An analysis of the Korean nationwide OHCA registry focused on 511 OHCAs that occurred in schools [3]. The highest incidence was at a university with a large proportion of cases occurring outdoors (29.7%) or in a sports facility (30.7%). Overall survival with good neurological outcome was 19.6%.

Although an increasing number of OHCA victims survive to hospital discharge, there are few data on factors associated with longer-term survival. In an analysis of 1591(5.6%) patients who survived to hospital discharge in Canada, by one year, 12.6% of patients had died and 37.3% had been readmitted [4]. By 3 years, the mortality rate was 20% and all-cause readmission rate was 54.1%. Older age and a history of cancer were associated with higher risk of 3-year mortality. Shockable rhythm at presentation (hazard ratio [HR] 0.62, 95% CI 0.45–0.85), coronary revascularisation (HR 0.37, 95% CI 0.28–0.51) or insertion of an implantable cardioverter defibrillator (ICD) (HR 0.28, 95% CI 0.20–0.41) were associated with lower 3-year mortality. Prior cardiac conditions and other arrest characteristics were not associated with long-term mortality.

In an analysis of 13,860 patients with non-EMS witnessed OHCA in the Danish cardiac arrest registry, 25% of patients who were defibrillated by prehospital personnel were initially in a non-shockable rhythm [5]. Conversion from a non-shockable to a shockable rhythm during resuscitation was common and associated with three-fold higher odds of 30-day survival compared with sustained non-shockable rhythms. Compared with sustained non-shockable rhythms, converted shockable rhythms and initial shockable rhythms were associated with increased 30-day survival (adjusted OR 2.6, 95% CI 1.8–3.8; and OR 16.4, 95% CI 12.7–21.2, respectively).

Rapid response systems

A systematic review of outcome among adult patients attended by rapid response teams (RRT) included 29 studies and 157,383 RRT activations [6]. Limitations of medical treatment resulted from 8.1% of RRT reviews and 23% resulted in a transfer to an intensive care unit (ICU). Of patients transferred to an ICU, 29% died during that admission. The median hospital mortality was 26%, and the median 30-day mortality rate was 29%.

The frequency of medical emergency team (MET) activation before paediatric CPR was evaluated using the Get-With-The-Guidelines-Resuscitation (GWTG-R) registry (2007–2013) [7]. Of 215 children from 23 hospitals requiring CPR for bradycardia or cardiac arrest, 48 (22.3%) had a preceding MET evaluation. Children with a MET evaluation before CPR were older and were more likely to have metabolic/electrolyte abnormalities, sepsis, or malignancy. Among patients who did not have a MET called and with information on vital signs, 55/141 (39.0%) had at least one abnormal vital sign that could have triggered a MET call, demonstrating opportunity for more use of MET teams.

An interrupted time series study analysed the trajectories of monthly complication rates for 4.69 million patients in 218 hospitals in Victoria, Australia following the introduction of a national standard for recognising deteriorating patients [8]. This initiative was associated with a reduction in the rates of in-hospital cardiac arrests (IHCAs) and acute coronary syndromes (ACS) in acute hospitals. Greatest benefit was seen in the elderly, female and surgical patients. This is the second large jurisdictional study from Australia to demonstrate benefit of system-wide introduction of a rapid response system [9].

Basic life support

2017 Saw the first output from the ILCOR transition to continuous evidence evaluation [10]. Working with knowledge synthesis experts from Li Ka Shing Knowledge Institute, St. Michael's Hospital, content experts from ILCOR reviewed the science relating to the effectiveness of different

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compression to ventilation methods for cardiac arrest [11]. The review synthesised evidence relating to dispatcher-assisted CPR and compression to ventilation ratios for bystanders. The summaries of these findings were then considered by the ILCOR BLS/AED and Paediatric Task Forces. These led to the publication of 6 consensus on science and treatment recommendations on the ILCOR website (www.ilcor.org) which were published in the annual summary presented in *Resuscitation* [12] and *Circulation* [13]. The recommendations from ILCOR have been incorporated in to the 2017 update of the European Resuscitation Council Guidelines for CPR [14].

High quality cardiopulmonary resuscitation

High-quality CPR remains a central tenet of effective resuscitation. An observational study from Denmark which captured CPR quality data from an AED which provided audio-feedback found that bystanders delivered moderate to good quality CPR. This provides real world data about the potential benefits of CPR feedback and prompt devices [15]. There was nevertheless scope for improving chest compression depth and minimising pauses in chest compressions.

Amongst 6475 bystander witnessed victims of OHCA in Korea, a higher proportion survived if they received bystander CPR from dedicated trained responders rather than lay person bystanders (adjusted OR 1.59(1.20–2.11)). In Sweden, bystander-witnessed OHCA victims who received initial CPR from off-duty medically-educated personnel, had better outcomes than those receiving bystander CPR from laypersons.[Nord 2017,88] Whilst receiving bystander CPR in itself remains critically important to outcome from OHCA [16,17], these data highlight the importance of CPR training for delivering the best outcomes.

Defibrillation

An analysis of 19519 ventricular fibrillation/pulseless ventricular tachycardia (VF/pVT) patients in the Swedish OHCA registry (1990–2015) found that 30-day survival decreased with more shocks regardless of witnessed status and the time period [18]. Factors associated with an increased 30-day survival included CPR before arrival of EMS, female sex, cardiac cause and year of OHCA (increasing survival over years).

The interaction between the defibrillation waveform (mono– vs bi–phasic) and time to defibrillation was investigated among 71566 patients in the all-Japan OHCA registry [19]. For both biphasic and monophasic defibrillation, the delivery of more shocks was associated with a decreased rate of return of spontaneous circulation (ROSC) in the field. However, an increased number of biphasic-only defibrillation shocks improved the one-month CPC (1, 2) survival rate. The authors concluded that a biphasic waveform has a more favourable effect on long-term survival than a monophasic waveform when ≥ 2 defibrillations are delivered.

Recent non-randomised case series in patients with refractory VF suggest benefit from delivering two shocks in rapid succession (termed double sequential defibrillation, or 'DSD'). A retrospective, observational analysis of London Ambulance Service patients with VF refractory to ≥ 6 standard shocks compared the outcome of those who subsequently received DSD versus continued single shocks [20]. During the 18-month study period, 45 patients were treated with DSD: a third obtained pre-hospital ROSC and 7% survived to hospital discharge. Similar ROSC and survival rates were observed in those who received exclusively standard defibrillation, leading the authors to conclude there was no clear benefit from DSD use by EMS in the treatment of refractory VF.

Major regional discrepancies in both AED density and survival were documented in an analysis of data from 51 French districts (29.3 million inhabitants) [21]. Mean survival rate was two-fold higher with AED density above the median (7.9% versus 17.8%, $P < 0.001$) and four-fold higher with BLS-education above the median (5.0% versus 20.9%, $P < 0.001$). However, only the rate of population BLS education remained independently associated with survival (OR 1.64, 95% CI 1.17–2.31; $P = 0.0045$). The authors concluded that population BLS education provides an important benefit regardless of the density of AEDs in a community.

Can drones carrying AEDs improve survival from OHCA? They are easily deployed and fast, and have a relatively low operational cost but barriers to their widespread deployment remain [22].

Advanced life support

Airways, ventilation and waveform capnography

There was little new about how we should manage the airway in 2017 and the optimal strategy for airway management during CPR remains a stepwise approach that is based on patient factors, and the skills of the rescuer [23,24]. There is increasing interest in the use of videolaryngoscopy for tracheal intubation during cardiac arrest. An analysis of two Japanese multicentre prospective observational studies between 2010 and 2016 that included 10, 927 emergency department intubations (4426 for cardiac arrest) observed that videolaryngoscopy was used for 2% of intubation attempts in 2010 and 40% in 2016 [25]. The first attempt success rate increased from 68% in 2010 to 74% in 2016 ($P_{trend} = 0.02$). A small (82 intubations) pilot RCT of video (King videolaryngoscope) versus direct laryngoscopy for intubation by paramedics in OHCA reported similar first attempt and overall success rates with both techniques [26]. Once a tracheal tube is placed, the recommended ventilation rate is $10\,min^{-1}$ without interrupting chest compressions. A systematic review identified very low-quality evidence to support this recommendation [27]. Low ventilation rates are likely to be sufficient to maintain an adequate ventilation to perfusion ratio during CPR as the cardiac output generated during CPR is also markedly reduced. Finally, if all else fails, reassuringly, eight out of 10 inexperienced rescuers were able to insert an emergency cricothyroidotomy on a fresh cadaver using a pocket knife and a ballpoint pen [28].

Waveform capnography to confirm tracheal tube position in all patients who are intubated during CPR is now widely accepted and part of current guidelines [23]. Two studies looked at whether ventilation rate could be accurately measured with waveform capnography in the presence of chest compression artefact: one study reported that its algorithm performed well with an error of below $1.8\,min^{-1}$ [29], whereas the other reported that 42% of waveforms were distorted and errors in the ventilation rate were as high as 50% [30]. An observational study of 207 defibrillation attempts in 62 patients documented that all defibrillation attempts were successful when the mean end-tidal carbon dioxide ($ETCO_2$) value was greater than 45 mmHg in the minute preceding the shock, and no shock was successful when this value was less than 7 mmHg [31]. Defibrillation was defined as effective if VF/pVT was terminated with a subsequent organised rhythm within 60 s. If, as is thought likely, that high-quality CPR increases end-tidal carbon dioxide values, this study supports the previous observations that high-quality CPR preceding a shock improves defibrillation shock success [32].

Drugs during CPR

The evidence for any drug therapy during CPR remains uncertain. A systematic review and network meta-analysis comparing the effectiveness of antiarrhythmic drugs for OHCA identified 8 RCTs involving 4464 patients [33]. The analysis found that amiodarone and lidocaine were associated with improved survival to hospital admission but for important patient outcomes such as survival to hospital discharge and neurologically intact survival, no antiarrhythmic was better than any other or than placebo.

A retrospective cohort study of 1525 individuals treated with intravenous (IV) drugs and 275 with tibial intra-osseous (IO) drugs during CPR for OHCA reported that, after risk adjustment, IO treatment was associated with lower ROSC (OR = 0.67, 95% CI 0.50–0.88) and lower survival to hospital admission (OR = 0.67, 95% CI 0.51–0.91) [34]. Whether other IO sites (humeral or sternal) would have similar outcomes is unknown.

Sodium bicarbonate is still used by many during CPR. Observational OHCA data from Canada between 2005 and 2016 identified that 5165 (37.3%) out of 13865 patients had been given sodium bicarbonate [35]. In a 1:1 propensity matching cohort of 5638 patients, sodium bicarbonate was associated with worse survival to discharge (adjusted OR 0.64, 95% CI 0.45–0.91) and worse neurological outcome at discharge (adjusted OR 0.59, 95% CI 0.39–0.88).

Mechanical devices

An analysis of the Swedish cardiac arrest registry noted marked variation in the use of mechanical chest compression devices, ranging from 0.8% to 79% (average 32%) amongst 24,316 patients treated for OHCA [36]. Unadjusted 30-day survival was 6.3%. Adjusted odds ratio for 30-day survival in the group receiving mechanical CPR was 0.72 (95% CI 0.62–0.84).

The PARAMEDIC cluster randomised trial of the LUCAS mechanical device reported similar survival but worse neurological outcomes in patients allocated to receive mechanical CPR (6% versus 7%, adjusted odds ratio 0·86, 95% CI 0·64–1·15) [37]. In a follow-up study, twelve months after cardiac arrest there was no difference in generic health-related quality of life measures (SF-12 and EQ-5D), emotional wellbeing (HADS and PTSD-CL) [38]. Cognitive function, measured by MMSE, was statistically lower in the LUCAS arm (26.9 versus 28.0 (adjusted mean difference −1.5 (95% CI −2.6 to −0.4)), but the difference was smaller than the amount considered to be a clinically important difference. A within trial cost effectiveness analysis, based on quality adjusted life years (derived from EQ-5D-3L), assessed at 12 months and extrapolated to the lifetime horizon reported that mechanical CPR represented poor value for money compared to standard chest compressions [39].

The LUCAS IN Cardiac arrest (LINC) investigators presented a post hoc analysis of outcomes in patients in initially shockable rhythms [40]. The rationale for this analysis was the finding in the PARAMEDIC trial that outcomes were worse in the group receiving mechanical chest compressions. The two trial protocols differed – in LINC, patients received an initial shock before rhythm analysis and received chest compressions for 3 min cycles. In PARAMEDIC, the first shock was delayed until after initiation of mechanical CPR and chest compression cycles were of 2 min duration. The LINC analysis found no difference in the rate of ROSC, survival or neurological outcomes, despite a slight (1 min on average) delay in the initiation of first shock in the mechanical CPR group.

Extracorporeal CPR (ECPR)

Current guidelines based on limited studies include considering the use of ECPR in specific circumstances [23]. A review of the international Extracorporeal Life Support Organisation (ELSO) database over 12 years (2003–2014) reported a 10-fold increase in ECPR cases from 35 per year to over 400 per year [41]. Survival to hospital discharge remained stable at 29% over this time. Another report from the ELSO database looked at 217 cases of OHCA receiving ECPR between 2010 and 2016 [42]. The median age was 52 years (range 18–87); 73% were male. Complications included haemorrhage (31.3%), limb complications (11.1%), circuit complications (8.8%), infection (7.4%), and seizures (5.5%). Survival to hospital discharge was 27.6% (95% CI 22.1–34.0%). A single centre observational study of 112 ECPR cases identified 25 with brain death (22.3% of total and 30.4% of deaths) [43]. Of these brain-dead individuals, 20 were eligible for organ donation, 14 became donors (23 kidneys, 12 livers, 4 lungs in 39 recipients) with 90% of recipients having good transplant function.

Paris, France is one of the few places where pre-hospital ECPR is undertaken. After refining the ECPR protocol (ECPR initiation after 20 min of resuscitation, stringent patient selection, limiting adrenaline and deploying the ECPR team with the initial response team) survival with good neurological function at ICU discharge or day 28 increased from 8% to 29% [44]. Whether some of the additional survivors would have survived without ECPR is not possible to say [45]. The Paris group have started a RCT of ECPR (NCT02527031) that should provide further information about the role of pre-hospital ECPR.

Ultrasound during CPR

Cardiac ultrasound during CPR remains a promising intervention. A study of 60 cardiac ultrasound scans during CPR for IHCA by anaesthesiologists with basic level training reported that subcostal images acquired both during pauses in chest compression for rhythm checks and pauses for bag-mask ventilation were of similar quality with 67% and 64% being useful respectively [46]. Another single centre study of 23 scans during CPR reported that a focused ultrasound scan increased the duration of pulse checks pauses from a mean of 13 s (95% CI 12–15) to 21 s (95% CI 18–24) and no finding prompted a change in the patient's care [47].A systematic review suggested that the combination of the absence of spontaneous cardiac movement on cardiac ultrasound and the presence of other unfavourable measures for ROSC could be useful in deciding when to stop CPR [48].

Paediatric resuscitation

An analysis of infants hospitalised in a quaternary referral neonatal intensive care unit (NICU) showed that the incidence of CPR was low (< 3%). Infants receiving inotropic therapy prior to CPR and adrenaline administration during CPR were less likely to survive to hospital discharge [49].

The impact of public access defibrillation (PAD) on outcome after paediatric OHCA was assessed in a nationwide, population-based, propensity score-matched study of the all-Japan OHCA registry (2011–2012) [50]. The use of PAD was associated with an increased neurologically favourable survival among those who received bystander CPR.

A Korean national observational study of bystander CPR (BCPR) for paediatric OHCA (2012–2014), showed that 49% received BCPR; this was by family members in 57.4% (458) of cases and family members were more likely than strangers to perform BCPR except in communities with the lowest educational level [51].

The impact of pre-hospital advanced airway management (AAM) on outcome from paediatric OHCA (1–17 years) was evaluated using the All-Japan Utstein Registry (2011–2012) [52]. The primary outcome was one-month neurologically favourable survival defined as a Glasgow-Pittsburgh cerebral performance category (CPC) score of 1–2 (corresponding to a Paediatric CPC score of 1–3). Pre-hospital AAM was not associated with an increased chance of neurologically favourable survival compared with bag-mask-only ventilation. While there may be unmeasured confounders and selection bias, the study again questions the benefit of advanced interventions early in resuscitation.

Lack of benefit from AAM in paediatric OHCA (< 18 years of age) was also confirmed by a study of the Cardiac Arrest Registry for Enhanced Survival (CARES) database in the US (2013–2015) [53]. Non-traumatic OHCAs from 17 state-wide registries and approximately 55 additional US cities were included. Bag-mask ventilation was associated with a higher rate of survival to hospital discharge compared with tracheal intubation and insertion of a supraglottic airway (SGA).

The accuracy of the Broselow tape as a weight estimation tool and a drug-dosing guide was evaluated in a systematic review and meta-analysis [54]. The Broselow tape lacked sufficient accuracy as a weight estimation and drug-dosing tool in comparison with other techniques. The frequent rate of incorrect usage of the tape indicated the need to also improve training.

Trauma and hypothermia

An evaluation of long-term mortality among survivors in a large regional drowning registry (1974–1996), showed that the risk of subsequent mortality in the long-term was the same as the general population and was independently associated with age and neurologic status at hospital discharge [55].

The potential use of drone technology to save lives from drowning has been evaluated by a group from Sweden [56]. With the knowledge that submersions < 10 min may be associated with favourable neurological outcomes if bystanders rescue and resuscitate, this randomised simulation study used a submerged manikin placed in shallow (< 2 m) water on a Swedish beach. A search party of 14 surf-lifeguards was compared to a drone transmitting video to a tablet. Twenty searches were performed, and a drone transmitting live video to a tablet was found to be feasible, and faster compared with the search parties.

The importance of bystander CPR following drowning was investigated in a multivariate analysis of the Cardiac Arrest Registry for Enhanced Survival (CARES) database (2013–2015) [57]. Bystander CPR, witnessed drowning and younger age were associated with neurologically favourable survival. Shockable rhythms were uncommon and not associated with improved outcome.

ILCOR published an update on the 2003 Utstein style for reporting data from drowning-related resuscitation [58]. The new guidelines should help improve the clarity of reporting the epidemiology and outcomes reporting for drowning and quality of observational studies based on registry data.

The 30-day survival from cardiac arrest caused by traumatic injury in England and Wales was evaluated in a population-based analysis of the Trauma Audit and Research Network (TARN) [59]. During 2009–2015, traumatic cardiac arrest (TCA) occurred in 705 (0.3%) of 227,944 patients. Blunt injuries were present in 85.2% and 86.8% had a severe traumatic brain injury or major haemorrhage. Overall short-term survival was 7.5%. The authors concluded that early and aggressive management of patients in TCA should be initiated using protocols to target reversible causes and that resuscitation in this patient group is not futile.

The factors associated with paramedic decisions to attempt resuscitation in traumatic OHCA and to attempt resuscitation for ≤10 min in patients who die at the scene were evaluated in an Australian study [60]. Resuscitation was attempted in 28% of 2334 cases of traumatic OHCA (2008–2014). Arrests occurring in rural regions had significantly lower chances of attempted resuscitation relative to those in urban regions. Resuscitation attempts ≤10 min represented 34% of cases in which resuscitation was attempted but the patient died at the scene. The large proportion of cases with resuscitation attempts ≤10 min may downplay survival in those patients who receive full resuscitation attempts.

Post-resuscitation care

Post-cardiac arrest syndrome

Patients with the post-cardiac arrest syndrome (PCAS) have a sepsis-like inflammatory response which often requires treatment with vasopressors. In a sub-analysis of 163 patients enrolled in the Targeted Temperature Management (TTM) study, inflammatory and endothelial biomarkers were associated with the need for vasopressors as documented by the cumulative vasopressor index (CVI) [61].

Targeted temperature management

The TTM study concluded that in comatose post-cardiac arrest patients the use of hypothermia at a targeted temperature of 33 °C conferred no benefit compared with a targeted temperature of 36 °C [62]. Although all patients in the TTM study were treated with active temperature control there is a concern that many clinicians have interpreted the results to mean that temperature control is not required. In a retrospective cohort study of 76 post ventricular fibrillation (VF) cardiac arrest patients from Melbourne, Australia, following a change in target temperature from 33 °C to 36 °C fewer patients received active cooling (100% vs. 70%, $p < 0.001$); they spent less time at target temperature (87% vs. 50%, $p < 0.001$) and fever rates increased (0% vs. 19%, $p = 0.03$) [63]. In a survey of 268 large teaching and university hospitals in 14 European countries, 33% had changed their target temperature for treating comatose post-cardiac arrest patients from 32–34 °C to 36 °C and this change was more common in Northern Europe [64].

Haemodynamics

Several observational studies have a documented an association between higher mean arterial pressure (MAP) and better outcome among post-cardiac arrest patients. In a study of 122 comatose OHCA patients, after risk adjustment, higher mean MAPs were associated with lower odds of death (odds ratio (OR) 0.60 per 5 mmHg increase; 95% CI 0.40–0.89; p = 0.01) [65]. The relationship between mean MAP and the odds of death and severe neurological dysfunction became attenuated in older patients.

After ROSC cerebral blood flow is often reduced. The critical closing pressure (CrCP) in the cerebrovascular bed is the lower limit of arterial blood pressure below which vessels collapse and flow ceases. In a study that compared 11 comatose post-cardiac arrest patients with 10 control patients, CrCP was significantly higher with high cerebrovascular resistance and low cerebral blood flow velocities [66]. These data imply the need for higher target MAP in post-cardiac arrest patients. In another study of the same patients, these investigators also documented reduced variability of cerebral blood mean flow velocity among non-survivors [67]. The authors suggest that these changes are most likely caused by impaired intrinsic myogenic vascular function and autonomic dysregulation.

Post-cardiac arrest oxygen and carbon dioxide

Although current guidelines suggest aiming for normocarbia in ventilated post-cardiac arrest patients, some recent evidence from observational studies has suggested that optimal outcomes are associated with mild hypercarbia. However, a systematic review and a meta-analysis of eight studies showed a U-shape association between post-cardiac arrest carbon dioxide values and survival – normocarbia was associated with increased hospital survival (OR 1.30 95% CI 1.23–1.38) [68].

In an observational study using data from the Resuscitation Outcomes Consortium (ROC), abnormal arterial oxygen and carbon dioxide values measured within the first 24 h after resuscitation from out-of-hospital cardiac arrest were associated with increased hospital mortality [69].

Coronary revascularisation

The indications for early coronary angiography in patients resuscitated from OHCA who do not have ST elevation (STE) on their ECG remain unclear. In a meta-analysis of seven observational studies and one randomised controlled trial (RCT), the use of early angiography was associated with decreased short term (OR = 0.46, 95% CI = 0.36–0.56, $P < 0.001$) and long term (OR = 0.59, 95% CI = 0.44–0.74, $P < 0.001$) mortality [70]. Despite the use of several statistical methods in an attempt to eliminate confounders, these observational studies are subject to considerable bias. Ultimately, the role of urgent angiography in these comatose OHCA survivors who do not have STE can be determined reliably only with the results of RCTs. The ARREST (A Randomised tRial of Expedited transfer to a cardiac arrest centre for non-ST elevation ventricular fibrillation out-of-hospital cardiac arrest) trial is one such study, and following a successful pilot study [71], recruitment to a large-scale RCT is about to start.

Prognostication

Prognostication among comatose post-cardiac arrest patient remains a hot topic and several papers on this subject were published in *Resuscitation* in 2017. Recently guidelines have encouraged the use of neuroprognostication protocols such as that used by investigators treating patients in the TTM study [72]. Three hundred and thirteen (33%) unconscious patients underwent prognostication at a median 117 h after arrest. Related care recommendations were: continue in 117 (37%); not escalate in 55 (18%); and withdraw in 141 (45%). Withdrawal of life-sustaining therapy (WLST) eventually occurred in 196 (63%) at median day 6 (IQR 5–8).

Clinical seizures after cardiac arrest are associated with a poor prognosis but multiple observational studies have established very clearly that good neurological outcome is still possible despite the occurrence of seizures. In a post-hoc analysis of the TTM study, clinical seizures were documented in 268 patients (29%) [73]. Early and late seizures were equally predictive of poor outcome, which contrasts with other studies that have suggested a worse prognosis associated with early seizures. Myoclonic seizures were the most common (240 patients, 26%) and the most predictive of a poor outcome (sensitivity 36.1%, false positive rate 4.3%). Two patients with status myoclonus regained consciousness, one with a good neurological outcome, generating a false positive rate of poor outcome of 0.2% (95% CI 0.0–1.0). There are now several cases in which a good outcome has occurred despite documented status myoclonus. Some of these cases may represent early-appearing Lance-Adams syndrome (LAS), a generalised action myoclonus that does not preclude awakening. Among a cohort of 458 post-cardiac arrest patients, 7 (1.5%) developed early LAS and within 72 h after cardiac arrest all these cases showed preserved brainstem reflexes and localised to pain [74]. The authors conclude that early after cardiac arrest, myoclonus together with a reactive, epileptiform EEG, preserved evoked potentials and brainstem reflexes suggests LAS.

Brain computed tomography (CT) and diffusion-weighted magnetic resonance imaging (DW-MRI) are both used to help with prognostication in comatose post-cardiac arrest patients although ease of access means that the former is used more commonly. In cohort of 39 comatose post-cardiac arrest patients who underwent early imaging with both CT and MRI, there was no significant difference in predicting poor neurological outcome between average grey matter to white matter ratio (GWR) on brain CT and the presence of high signal intensity on DW-MRI; however, the combination improved the sensitivity for predicting a poor outcome [75].

European Resuscitation Council (ERC) guidelines recommend early head CT in comatose OHCA survivors who do not have an indication for immediate coronary angiography [76]; however, some local protocols include early head CT for all comatose OHCA patients. In a cohort of 213 patients who survived at least 24 h after OHCA, only 54% underwent head CT in the first 24 h; acute abnormalities were found on 38% of HCT and a third of these abnormal scans resulted in management changes [77].

The ERC guidelines recommend multimodal prognostication but only a few studies have evaluated the performance of more than one mode for predicting outcome after cardiac arrest. In another sub-study, the TTM investigators have evaluated the combination of head CT and peak neuron specific enolase (NSE) for prognostication of poor outcome [78]. Perhaps surprisingly, only 356/939 (37.9%) of the patients enrolled in the TTM study underwent head CT. Initial CT ≤ 24 h after CA was normal in 174/218 (79.8%), whilst generalised oedema was diagnosed in 21/218 (9.6%). Between days 1–7, generalised oedema was seen in 65/143 (45.5%), acute/subacute infarction in 27/143 (18.9%) and bleeding in 9/143 (6.3%). Generalised oedema predicted poor outcome with 33.6% sensitivity (95% CI 28.1–39.5) and 98.4% specificity (95% CI 94.3–99.6); however, the combination of peak NSE > 38 ng/L and generalised oedema on CT predicted poor outcome with 46.0% sensitivity (95% CI 36.5–55.8) with no false positives.

Investigators from the Post Cardiac Arrest Service at the University of Pittsburgh studied the initial neurologic examination, quantitative analysis of head CT and continuous EEG (cEEG) in 240 patients to determine if this combination would improve outcome prediction after cardiac arrest [79]. The combination of head CT with cEEG was superior to any individual test for predicting mortality and neurological outcome. Addition of clinical variables further improved prognostication for mortality but not neurological outcome.

The role of regional cerebral oxygen saturation (rSO_2) measured using near infrared spectroscopy (NIRS) for the prediction of outcome during and after cardiac arrest remains uncertain. A study of rSO_2 values in six ICU patients who were dying after WLST showed that there was a continuous and patient specific decrease in rSO_2 in all patients with a simultaneous decrease in MAP; however, there was a broad range in the absolute rSO_2 value at the moment of clinical death [80]. These findings imply that in the cardiac arrest setting trends in rSO_2 values are far more important than absolute values.

Education and quality improvement

Innovative approaches which provide an engaging user experience offer great potential to engage the younger generation in CPR training [81]. Yeung et al. conducted a randomised trial comparing the Lifesaver app, an immersive, interactive CPR training game to standard face to face training or a combination of both [82]. The combination of Lifesaver and face to face was the best performing intervention although differences were small, showing the potential for innovative technologies.

Seizing every opportunity to deliver CPR training will increase the pool of trained bystanders who can deliver CPR. Promising new approaches reported were reported in *Resuscitation* during 2017. Ultra-brief (30 s–2 min) videos showing chest compression-only CPR was able to improve CPR performance in attendees at a basketball game [83] and those waiting in an emergency department to be seen [84]. A self-instruction hands-only CPR kiosk proved effective at training over 23,000 individuals over as 32 month period at a US airport [85].

Conflicts of interest

JPN is Editor-in-Chief of Resuscitation and Chair of the European Resuscitation Council. He is a co-investigator for two National Institute of Health Research (NIHR) funded studies: AIRWAYS-2 and PARAMEDIC-2.

JPO, MJAP, GDP and JS are Editors of Resuscitation

JPO serves as Cardiac Co-Chair for the National Institutes of Health-sponsored Resuscitation Outcomes Consortium (ROC). He serves as the Virginia Commonwealth University Principal Investigator for the National Institutes of Health-sponsored Neurological Emergency Treatment Trials Network (NETT).

GDP is Co-Chair of the International Liaison Committee on Resuscitation. He is Chief Investigator for the NIHR funded PARAMEDIC-2 trial.

JS is Co-Chair of the Advanced Life Support Task Force of the International Liaison Committee on Resuscitation.

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