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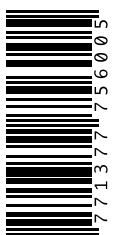
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Cardiac Arrest Management

The treatment of cardiac arrest has made significant progress over the last 10–15 years. This period marks a significant turning point, because the treatment of out-of-hospital cardiac arrest (OHCA) had often been considered an exercise in futility, with no improvement in outcome for the previous 30 years (Berdowski et al. 2010). In recent years, several investigators have documented marked improvements in survival after OHCA, particularly in those cases with an initial shockable rhythm (ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT) (Wissenberg et al. 2013; Daya et al. 2015; Chan et al. 2014).

Several interventions are likely responsible for the improving survival rates following OHCA. Bystander cardiopulmonary resuscitation (CPR) is associated with survival rates that are 2–3 times higher than those cases without bystander CPR (Hasselqvist-Ax et al. 2015; Rajan et al. 2016). Emergency medical services dispatchers are now better trained to efficiently ask the right questions to enable prompt recognition of cardiac arrest and then to instruct the caller to perform compression-only CPR (telephone CPR) (Bobrow et al. 2016). For shockable rhythms, reducing the delay to attempted defibrillation also improves outcome. Implementation of public access defibrillation (PAD) programs and dispatch of community first responders trained to use automated external defibrillators (AEDs) will reduce the time to defibrillation (Blom et al. 2014). Text alerts can be used to direct first responders to retrieve the nearest AED and then take it to the scene of a cardiac arrest (Zijlstra et al. 2014).

Once return of spontaneous circulation (ROSC) has been achieved, post-resuscitation

management impacts significantly on the ultimate neurological outcome. European guidelines for the management of post-cardiac arrest patients were published in 2015 and describe the interventions that will optimise outcome (Nolan et al. 2015). Those patients who achieve ROSC and have ST-elevation (STE) on their ECG will require urgent coronary catheterisation because most of these will benefit from percutaneous coronary intervention (PCI) to restore coronary perfusion (Dumas et al. 2010). The immediate management of those without an obvious non-cardiac cause and without STE is controversial. Some experts advocate urgent coronary catheterisation in all such patients (Dumas et al. 2016). Current European guidance is that these patients should also be discussed with interventional cardiologists and considered for urgent coronary catheterisation (Nolan et al. 2015). Some centres will immediately catheterise cardiac arrest survivors without STE, but only if they had presented with a shockable rhythm.

Immediate management of those without an obvious non-cardiac cause and without STE is controversial

Cerebral autoregulation is disturbed in 35% of post-cardiac arrest patients and is particularly associated with pre-arrest hypertension (Ameloot et al. 2015a). The optimal target mean arterial pressure (MAP) post cardiac arrest is likely to vary between patients, but to avoid secondary brain ischaemia it has been suggested that the optimal MAP is likely to be in the range 85–105 mmHg, which is somewhat higher than the 65–70 mmHg that is widely used (Ameloot et al. 2015b).

Until recently, in the immediate period after ROSC (certainly prehospital and often

in the emergency department) it has been common practice to ventilate the lungs of comatose post-cardiac arrest patients with 100% oxygen. This not unreasonably reflected concerns about harm from hypoxaemia and lack of awareness of harm from high-concentration oxygen. Animal studies have documented worse neurological outcome from the use of 100% oxygen immediately after ROSC, particularly during the first hour (Balan et al. 2006), and some observational studies using data from intensive care unit (ICU) registries have documented an association between hyperoxaemia and worse outcome among post-cardiac arrest patients. In a randomised controlled trial (RCT) the use of routine supplemental oxygen among patients with STE myocardial infarction (but not cardiac arrest), resulted in an increase in size of myocardial infarction compared with patients given oxygen only if hypoxaemic (Stub et al. 2015). A RCT of oxygen titrated to 90–94% versus 98–100% as soon as possible after ROSC and continued until ICU admission (EXACT phase 3 trial) will inform the optimal oxygenation strategy after ROSC (Nolan et al. 2017). European guidelines recommend the use of a protective lung ventilation strategy in post-cardiac arrest patients, but this was based mainly on data extrapolated from patients with acute respiratory distress syndrome (Nolan et al. 2015). However, a recent observational study of OHCA patients using propensity matching has documented an association between the use of time-weighted average tidal volumes of $< 8 \text{ mL kg}^{-1}$ predicted body weight and better neurological outcome (Beitler et al. 2017). Mild hypercapnia may also be associated with better neurological outcome in post-cardiac arrest patients, possibly because it may increase blood flow to ischaemic brain. A phase 2 study comparing mild hypercapnia with normocapnia in 50 post-cardiac arrest patients documented a lesser increase in neuron-specific enolase (NSE)

values in the hypercapnia group (Eastwood et al. 2016). A RCT comparing post-cardiac arrest patients ventilated to either normocapnia or mild hypercapnia (6.6–7.3 kPa) starts recruiting soon (Targeted Therapeutic Mild Hypercapnia After Resuscitated Cardiac Arrest (TAME) [clinicaltrials.gov/ct2/show/NCT03114033]).

Mild hypothermia has been shown to improve neurological outcome from OHCA presenting with a shockable rhythm, but the two prospective studies documenting this are now considered to be of moderate to low quality (Bernard et al. 2002; Hypothermia After Cardiac Arrest Study Group 2002). The targeted temperature management (TTM) study showed no difference in neurological outcome between all-rhythm OHCA patients with ROSC who had their temperature controlled for 24 h at 33°C versus 36°C (Nielsen et al. 2013). Temperature control for comatose survivors of OHCA is still important, but within the range of 32–34°C there is no consensus on the optimal target temperature (Donnino et al. 2016). The Hypothermia or Normothermia-Targeted Temperature Management After Out-of-hospital Cardiac Arrest-trial (TTM-2 [clinicaltrials.gov/ct2/show/NCT02908308]) study will start recruiting soon and will randomise comatose OHCA survivors to temperature control at 33°C versus prevention of fever, with temperature control to a target of 37.5°C initiated only if the patient's temperature reaches 37.8°C.

The commonest mode of death in post-cardiac arrest patients who are admitted to ICU but do not survive is withdrawal of life-sustaining therapy (WLST) following determination of a poor neurological prognosis. We now recognise that in many cases these WLST decisions have been premature and that prognostic tests previously thought to be reliable are associated with unacceptably high false positive rates (Elmer et al. 2014; Cronberg et al. 2017). European guidelines for prognostication in comatose post-cardiac arrest patients advocate a multimodal approach that is delayed until at least 3 days after cardiac arrest (Sandroni et al. 2014). Those ICUs experienced in the management of post-cardiac arrest patients should have easy access to electroencephalography, including somatosensory evoked potentials, and to neurologists who can interpret the findings.

In some countries, regionalisation of post-cardiac arrest treatment has resulted in cardiac arrest centres with availability of 24/7 coronary catheterisation laboratories, intensive care teams experienced in post-resuscitation care and neurologists that can help in the interpretation of neuroprognostic tests (Spaite et al. 2014). The introduction of cardiac arrest centres where high volumes of post-cardiac arrest patients can be treated is associated with better outcomes, even when patients are transported for greater distances as they bypass local hospitals (Tranberg et al. 2017; Schober et al. 2016; Elmer et al. 2016). Investigators in London, UK are about to start recruiting

to a study patients with ROSC after OHCA of likely cardiac cause but without STE on their 12-lead ECG, and will compare the outcome of patients randomised to be transported to the nearest acute hospital with those taken to a regional cardiac arrest centre (Patterson et al. 2017). This study will help to determine if all OHCA of cardiac cause should be treated in a cardiac arrest centres and not just those patients with STE on their 12-lead ECG.

By strengthening every link in the chain of survival it is likely that survival from cardiac arrest can still be improved considerably. ■

Conflict of Interest

Jerry Nolan is Editor-in-Chief of *Resuscitation*. He has a UK National Institute of Health Research (NIHR) grant for the PARAMEDIC-2 study (adrenaline versus placebo in out of hospital cardiac arrest-OHCA) and for the AIRWAYS-2 study (i-gel versus tracheal intubation in OHCA).

Abbreviations

AED automated external defibrillator
ICU intensive care unit
MAP mean arterial pressure
NSE neuron-specific enolase
OHCA out-of-hospital cardiac arrest
PAD public access defibrillation
PCI percutaneous coronary intervention
pVT pulseless ventricular tachycardia
ROSC return of spontaneous circulation
RCT randomised controlled trial
STE ST-elevation
TTM targeted temperature management
VF ventricular fibrillation
WLST withdrawal of life-sustaining therapy

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