Extracorporeal membrane oxygenation for inhospital cardiac arrests: the rise of the machines

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Published rates of inhospital cardiac arrest (IHCA) in Australia vary from 0.66 to 3.77 per 1000 admissions.[1-3] Although they are relatively infrequent, IHCAs are associated with an inhospital mortality of 68%–82% in Australia.[3-6] Despite the promulgation of protocols for basic life support (BLS) and advanced life support (ALS), and considerable organisational commitments to train staff in such skills, there has been little improvement in the outcome of IHCAs over several decades.[7] It is likely that suboptimal end-of-life care planning and recognition of and response to earlier deterioration may contribute to these poor outcomes.[8,9] However, there is also a need for a paradigm shift to improve the outcome of cardiac arrests in patients with high levels of premorbid function, particularly if conventional BLS and ALS fail. We review the existing paradigm of cardiopulmonary resuscitation (CPR) for IHCAs, before discussing a potential role for extracorporeal membrane oxygenation (ECMO) for this condition.

The current paradigm for CPR

The current paradigm for CPR involves the provision of elements of BLS and ALS, the cornerstones of which are early and effective chest compressions and early defibrillation of cardiac rhythms amenable to electrical cardioversion.[10] The components of modern BLS were developed around 1960 in response to reversible cardiac arrests occurring in a monitored environment shortly after induction of anaesthesia.[11,12] However, BLS was rapidly deployed for all forms of IHCA, irrespective of their potential reversibility. It is perhaps not surprising that the inhospital mortality of IHCAs in ward patients is around 75%, and that this has remained largely unchanged for 50 years.[7]

There are several reasons why the outcomes of IHCAs remain poor. First, even with effective technique, external cardiac compression may only deliver a cardiac output less than one-third of normal values.[13] Second, although early defibrillation is desirable for shockable rhythms, less than one-third of IHCAs in Australian publications fall into this category.[3,4,6,9] In some instances, the absence of a shockable rhythm may be due to the fact that patients are not monitored and the arrest is not witnessed.[6]

Modern algorithms of ALS emphasise the importance of minimising interruptions to cardiac compressions to check cardiac rhythm.[10] Such interruptions may be exacerbated by the use of automated external defibrillators (AEDs) which take time to analyse the cardiac rhythm.[14] In observational studies, the use of AEDs may be associated with worse IHCA outcomes, particularly for non-shockable rhythms.[14-16] There is also uncertainty about the effectiveness of some medications used in BLS–ALS algorithms, adrenaline in particular.[17] Although adrenaline may theoretically improve coronary blood flow and the likelihood of cardioversion, there are concerns about potential detrimental effects on myocardial function and ventricular arrhythmias in patients who achieve the return of spontaneous circulation.[17]

Conceptually, IHCAs may result from several mechanisms. First, in a proportion of patients, there may be suboptimal end-of-life care planning, such that BLS and ALS are applied to patients with high levels of premorbid comorbidity and low levels of premorbid function.[8,9] In such patients, the application of BLS or ALS is unlikely to be beneficial. Second, a proportion of IHCAs may represent the end result of progressive clinical deterioration and suboptimal recognition of and response to clinical deterioration.[9,18,19] Finally, in some patients the cardiac arrest may be sudden and unexpected.[9,19]

Despite the relative ineffectiveness and low level of evidence for BLS and ALS, there is massive organisational investment to ensure that these therapies can be delivered. Thus, in many hospitals, all staff are required to undergo annual training in these techniques, despite little evidence that such training can sustain BLS and ALS competency or deliver better outcomes.[20] In addition, there is a need to purchase, maintain, replace and regularly check equipment and medications, and to replace expiring stock.

The role of ECMO for CPR in IHCA

In addition to improving end-of-life care planning and earlier detection of clinical deterioration, there is a need to develop techniques and strategies to improve the outcomes of IHCAs for patients with high levels of premorbid function and potentially reversible acute cardiorespiratory deterioration. One such strategy may be the use of ECMO.

There are least four international reports describing the use of ECMO for patients who have had an IHCA, most of whom did not respond to conventional BLS or ALS (Table 1).[21-24] All these studies are observational and one is prospective. The number of patients with an IHCA who were treated with

Table 1. Summary of studies of ECMO for IHCA

Feature	Haneya and colleagues[21]	Kagawa and colleagues[22]	Avalli and colleagues[23]	Wu and colleagues[24]
Patients having IHCA	59	38	24	59
Country of origin	Germany	Japan	Italy	Taiwan
Study period	Jan 2007 – Jan 2012	Apr 2006 – Oct 2009	Jan 2006 – Feb 2011	Jan 2004 – Dec 2006
Study design	Retrospective	Retrospective	Retrospective	Prospective
Age, years				
Median (IQR)	62 (52–75)	68 (58–73)	67 (61–73)	61.5
Mean (SD)	64 (14)	–	–	57.4 (12.5)
Male, *n* (%)	44 (75%)	22 (58%)	16 (67%)	50 (85%)
Primary rhythm, *n* (%)				
VT or VF	13 (22%)	10 (26%)	12 (50%)	29 (49%)
PEA	34 (58%)	26 (69%)	12 (50%)*	17 (29%)
Asystole	12 (20%)	2 (5%)	*	13 (22%)
Hospital location, *n* (%)				
Intensive care	27 (31.8)	–	6 (16)	†
Operating room	5 (5.8)	–	3 (8)	33 (56%)†
Cardiac catheterisation laboratory	22 (25.9)	13 (34)	5 (13)	†
Ward	5 (5.8)	–	3 (8)	‡
Other	–	11 (29)	–	26 (44%)‡
ED	–	6 (16)	12 (55)	‡
CCU	–	8 (21)	–	–
Complications, *n* (%)	ECMO-related, 17 (29%)	Leg ischaemia, 7 (18%); bleeding, 26 (68%); pneumonia, 9 (24%); sepsis, 3 (8%); AKI, 14 (37%); pressure area, 2 (5%)	Leg ischaemia, 4 (17%); fasciotomy 2 (8%)	N/A
Short-term survival, *n* (%)	Inhospital survival, 25 (42%)	30-day survival, 13 (34%)	28-day survival, 11 (46%)	Inhospital survival, 17 (29%)
Neurological outcome, *n* (%)	N/A	Favourable, 10 (26%)	N/A	14 (23.7%)

ECMO = extracorporeal membrane oxygenation. IHCA = inhospital cardiac arrest. IQR = interquartile range. VT = ventricular tachycardia. VF = ventricular fibrillation. PEA = pulseless electrical activity. ED = emergency department. CCU = coronary care unit. AKI = acute kidney injury. N/A = not available. * PEA and asystole combined. † Intensive care unit, operating room and cardiac catheterisation laboratory combined. ‡ Ward, ED and other combined.

ECMO during CPR ranged between 24 and 59. Many of these patients had pre-existing comorbidities and in three of the studies, one-quarter of the patients were aged over 73 years. The proportion of patients with shockable rhythms ranged between 22% and 50%, and the hospital location where the IHCA occurred varied widely (Table 1). Despite all these potentially unfavourable factors, and the fact that ECMO was used as a salvage therapy, the short-term patient survival ranged from 29% to 46%. Moreover, in the two studies that reported neurological outcomes, a favourable outcome was seen in 10 out of 13 survivors (77%) and 14 out of 17 survivors (82%). Given the urgent and challenging nature of applying ECMO during CPR, it is perhaps not surprising that at least one-quarter of patients experienced ECMO-related complications (Table 1).

Recently, Stub and colleagues reported on the characteristics and outcomes of 15 patients with IHCAs occurring in an Australian hospital who were treated with a complex algorithm which included ECMO.[25] The initial rhythms were ventricular fibrillation (VF), ventricular tachycardia (VT), asystole and pulseless electrical activity (PEA) in six (VF), two (VT), three (asystole), and four patients (PEA), respectively. A return of spontaneous circulation was achieved in all 15 patients, and nine out of 15 patients (60%) survived to hospital discharge.[25]

Where to from here?

The studies outlined above show that it is technically feasible to apply EMCO for patients who have had an IHCA and who are refractory to conventional BLS or ALS. However, there are several barriers to widely deploying this technique. First, sufficient numbers of staff will need to be trained to provide the service reliably, and primed circuits and other equipment will need to be portable enough to reach remote areas of the hospital. There are obvious cost and resource implications for using the technique more widely and careful patient selection will be paramount in optimising patient outcomes and resource use.

In a recent article in the Journal, Straney and colleagues reported that there were more than 11 000 intensive care unit admissions related to IHCA in Australia and New Zealand between 2000 and 2011, with more than 1000 occurring during 2011.[26] It is likely that these patients represent a minority of all IHCAs. Surprisingly, there is little detailed data available on the epidemiology of IHCAs for ward patients in Australia and New Zealand. Such data would be essential for guiding the design of studies and strategies aimed at assessing the utility of ECMO for IHCA in appropriate centres in our two countries.

Competing interests

None declared.

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