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Commentary and concepts

Ideal (i) CPR: Looking beyond shadows in a cave

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ABSTRACT

Survival rates after cardiac arrest have shown minimal improvement in the last 60 years. However, in some forward-thinking cities and hospitals, out-of and in-hospital cardiac arrest survival rates exceed 20% and 40% respectively. These beacons of hope can enlighten us, providing a clearer vision of what it takes to provide *Ideal* cardiopulmonary resuscitation. To make progress in a field that has seemingly stagnated for too many decades, we must be open to new ideas and develop bundles of care that work in communities with varying EMS systems and various existing infrastructure to bring the best practices to the rest of the country.

"How could they see anything but the shadows if they were never allowed to move their heads?"

Plato, The Allegory of the Cave

In 2015 the world's experts from the International Liaison Committee on Resuscitation (ILCOR) updated the European Resuscitation Council (ERC) and American Heart Association (AHA) cardiopulmonary resuscitation (CPR) Guidelines [1,2]. Despite the hard work, there were very few changes from the 2010 Guidelines and no fundamental differences between the European and American Guidelines. The "key" changes consisted of highlighting the critical importance of interactions between the emergency medical dispatcher and bystanders who can be directed to provide early CPR and the timely deployment of a public access defibrillator; and providing precise targets for chest compression depth (at least 5 cm but no more than 6 cm) and rate (100–120 compressions/minute). Unfortunately, national survival rates between 2010 and 2015 showed little improvement. For example, Europe and North America, survival with favorable brain function after out-of-hospital cardiac arrest remains staggeringly low, only ~7%. Average in-hospital cardiac arrest survival rates, where patients are medically supervised, are ~20% [3,4].

In this modern age of drug discovery, molecular biology, and robots, it is remarkable that after more than a half-century, closed-chest manual CPR still remains the primary European and American-recommended method to promote blood flow to the heart and brain. The current hands-only resuscitation methods combined with defibrillation are often insufficient to restore life. Newer approaches are needed to transform resuscitation care if we are ever going to increase overall survival rates with favorable brain function for all cardiac arrest patients above 20%, the highest values reported by EMS systems that rely on hands-only CPR [5]. While some experts believe that we should abandon manual chest compressions altogether and focus solely on early defibrillation [6], we strongly recommend starting with high quality manual CPR followed by a comprehensive of system of care approach as described herein. This includes using multiple different types of techniques, tools, and machines, as needed, to help treat to this complex disease state. There are many sites where overall survival from out-of-hospital cardiac arrest with restoration of good brain function is nearly 20% or higher [7–9]. In Anchorage Alaska, for example, overall survival with good brain function is nearly 25% at present. Similarly, in-hospital cardiac arrest rates exceed 40% in some forward-thinking institutions [10]. These beacons of light can provide a clearer vision of what it takes to provide *Ideal* (*i*) *CPR*.

From the start, CPR has been a physiological struggle. It is truly extraordinary that external chest compressions provide any meaningful circulation to the brain and heart and a chance for functional survival. Under normal biological conditions circulation is a self-contained and internally regulated process. It involves an exquisite series of complex interactions between contractile myocytes, specialized cardiac electrical pathways, smooth muscle conduits, myriads of nerves, multiple blood reservoirs and compartments and scores of circulating hormones and other modulators that all work together synergistically on a beat by beat basis. As we search for light and wisdom while trying to improve outcomes after cardiac arrest what can we

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learn from those who treat other multi-organ complex disease states with high mortality rates such as HIV, heart failure, sepsis, trauma, and cancer? First and foremost, we need to stop hunting for a single silver bullet in the shadows and embrace advances that are in plain sight. Second, we need to use tools, in addition to defibrillation, to improve overall survival rates. It is time for resuscitation scientists to adopt a "bundle of care" approach that embraces the synergy of multiple interventions mimicking our natural biological circulation and stress-response systems. Every treatable complex disease state requires multiple synergistic and often simultaneous therapies for abatement, containment, or cure. Think of the combination of pharmacological, surgical, radiation, and adjuvant therapies needed to treat many cancers or the multi-drug therapy needed to keep HIV infection at bay. In each of these complex disease states, each component has been shown to have individual merit but they are often more effective when used together.

So, what could comprehensive progress in cardiac arrest care look like in 2017? Let's try to better define the scientific rationale and tools needed to provide *iCPR*.

One promising vision, first described by Lick et al is a program called Take Heart America (THA) [8], a sudden cardiac arrest initiative that weaves together multiple interventions simultaneously and has a track record of improving outcomes in communities that adopt its approach. In 2010 these investigators demonstrated that survival rates could be increased from 8.5% to 19% by simultaneously implementing state-of-the-art methods and technologies with demonstrated clinical benefit, focusing on CPR quality, and harnessing the potential synergies between multiple interventions at once. THA has recently updated their recommended bundle of care to include current best practices from high-performing communities (http://takeheartamerica.org/). Four key areas of care focus on rapid restoration of blood flow, optimization of blood flow to the heart and brain, rapid defibrillation when indicated, and, after restoration of a perfusing rhythm, identification and correction of the cause of the arrest, and protection from recurrence future cardiac arrest. A centerpiece of this program is the imperative to track outcomes from the time of collapse to the time of hospital discharge. A gap analysis of the major components of the THA bundle of care helps communities identify the missing pieces of care that drive continuous quality improvement and better outcomes. At its essence, the THA program has a different focus from the current European and American Guidelines: implementation of care bundles to improve survival.

Building upon this THA vision that was first articulated in 2005, what are some of the key tools and approaches used to deliver *iCPR*?

1. Implement dispatcher-assisted CPR: This just-in-time CPR "No,No,Go" approach has been highly successful in some communities to increase the likelihood that a patient will receive bystander CPR before professional responders arrive at the scene [11].
2. Support public access defibrillation programs: Widespread availability and knowledge of the location of automated external defibrillators (AED) is beneficial, even though this approach is expensive and has been, in general, underutilized except in high population density locations [12].
3. Focus on high quality manual CPR with feedback tools to guide the quality of CPR: This approach helps assure CPR is performed correctly: The quality of CPR by professional and trained rescuers without such tools is poor in more than 50% of all cases based upon multiple published studies [13–15]. When high quality manual CPR is delivered by trained first responders, they should use a compression:ventilation ratio of 30:2 and delivered the 2 breaths quickly to minimize interruptions in compressions. **4.** Incorporate CPR adjuncts into the resuscitation protocols, including those that enhance blood flow to the heart and the brain. These adjuncts include an impedance threshold device (ITD) combined with high quality CPR or active compression decompression (ACD) CPR, and use of automated CPR devices. While some may consider the ITD controversial, when used with the high-quality CPR as recommended by the AHA and ILCOR, it can significantly improve outcomes [13,16]. Likewise, though multiple studies have failed to show a survival with favorable brain function benefit when comparing manual versus automated CPR [17], automated CPR devices do offer the benefit of indefatigable, high quality CPR and are likely to be most beneficial during patient transport, prolonged resuscitation attempts, and limited-personnel environments [12]. Importantly, such devices should be applied rapidly, without stopping manual compressions for more than 5–10 s as such interruptions, combined with a decrease in the frequency of shock delivery once placed, may offset survival gains associated with improvements in CPR quality.
5. Provide Therapeutic Temperature Management (TTM): The science behind TTM is supported by multiple decades of laboratory investigations as a method to preserve damaged cells and organ function by reducing metabolic demand and the initiation of multiple cell-injury pathways that are triggered by ischemia and anoxia. Multiple clinical studies have found a strong association between use of TTM and improved neurological outcomes in patients after cardiac arrest, the first one published in 1959 [18]. TTM using intravenous cooled saline should probably not be used as it can cause pulmonary edema and rearrest.
6. Cardiac catheterization after resuscitation has been associated with an increase in the likelihood of survival for over a quarter of a century [19]. Recent studies have demonstrated the importance of cardiac catheterization to minimize door-to-reperfusion times after cardiac arrest and successful resuscitation, both in patients with a ST-segment elevation myocardial infarction (STEMI) as the primary cause and in patients with a non-STEMI plus refractory ischemia or hemodynamic or electrical instability [2].
7. Consider extracorporeal membrane oxygenation (ECMO): ECMO has been shown to improve in-hospital cardiac arrest survival rates in suitably equipped and experience centers [20]. More recently ECMO has shown promise for patients after in-hospital and out-of-hospital cardiac arrest when it is used rapidly and in highly selective patients [21]. This approach is used in pediatric in-hospital arrest that have the requisite expertise [22]. It is admittedly an intensive and aggressive therapy but, when used correctly as part of a bundle of care, it can result in another important step forward in terms of increasing neurological sound survival rates. A recent report from Minnesota showed that 50% of patients in refractory ventricular fibrillation who underwent 'salvage' ECMO therapy walked out of the hospital functionally intact [21,23].
8. Collect and analyze data: In the age of big data, the opportunities associated with predicative analytical modeling, machine learning, geographic information systems and computers in general in resuscitation is enormous? These new approaches already allow us to: alert lay rescuers that a nearby patient is in cardiac arrest, locate an AED nearby, provide just-in-time CPR feedback, provide real-time CPR guidance and feedback, remotely diagnosis and triage patients, predict who is most likely to suffer from an in-hospital cardiac arrest, re-arrest or arrest in transport, and identify and close gaps in overall systems of care [1,2]. The enormous advances provided by computers, advanced software, and mobile communication devices, along with opportunities to harness social media to educate and optimize care are no longer in their infancy.

While not shown in isolation or by themselves to increase neurologically-intact survival, these advances remain core to the concept of *iCPR*.

In many ways, we are in the middle of one of the most exciting periods in the history of resuscitation. Change is never easy, but we now have the newer tools, therapies, methods, and devices noted above, along with a number of additional advances on the horizon, yet to be rigorously assessed in humans, including use of sodium nitroprusside combined with ACD CPR + ITD for the treatment of refractory cardiac arrest [24], elevation of the head and heart in conjunction with advanced CPR methods [15,25], and use of perfusion injury protection strategies to attenuate the potential harm associated with reperfusion after prolonged periods of no-flow [26]. *iCPR* continues to evolve but already offers the promise of >30% overall survival from out-of-hospital cardiac arrest and >50% for in-hospital arrest, regardless of the presenting rhythm.

How do we make progress in a field that has seemingly stagnated for too many decades? We must be open to new ideas and develop bundles of care that work in communities with varying EMS systems and various existing cardiac arrest infrastructure to bring the best practices from Anchorage and Seattle and Minnesota to the rest of the country. While the evaluation of single out-of-hospital cardiac arrests tools and therapies one at a time has been the mainstay in the past, and clearly work in some patients, we must look beyond the shadows, leave the cave, and follow those beacons of light that have already shown us the way forward as we strive to optimize care and outcomes after cardiac arrest. Many advances that incorporate multiple therapeutic advances in concert are already available today. Without waiting for more clinical trials and the next 'big breakthrough', existing strategies have the potential annually to restore today full life to tens if not hundreds of thousands more cardiac arrest patients worldwide.

Statement of authorship

All authors have participated to the conception, design and writing of this manuscript. This manuscript represents valid work and that neither this manuscript nor one with substantially similar content under our authorship has been published or is being considered for publication elsewhere.

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Conflict of interest

Dr. Lurie is a co-inventor of the active compression decompression CPR device, the impedance threshold device and head up CPR devices.

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Copyright constraints

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