Cardiopulmonary resuscitation (CPR) involving external chest compression and positive-pressure ventilation was first described >50 years ago in a landmark publication that launched the fundamental approach to present-day CPR. Since this initial description, modern-day CPR has given rise to initiatives related to CPR research, education and training, advocacy, and industry.

These ever-increasing efforts are founded on an appreciation that CPR can positively affect survival from cardiac arrest, a common cause of death in most societies. To be clear, the foundational assertion of CPR's benefit is not derived from multiple, high-quality randomized human trials. Rather, evidence has accumulated from experimental (animal) studies and observational human investigations. CPR possesses many of the epidemiological criteria often cited as the basis for causation: biological plausibility, temporality, and dose response. With regard to the epidemiological trait of consistency, there is not uniform agreement across all investigations regarding the association between CPR and outcome; however, the preponderance of studies observes a beneficial relationship. Moreover, community-specific efforts from around the globe to increase bystander CPR correspond to community improvements in survival. Thus, the initial discovery of CPR's clinical benefit has been borne out by strong, albeit imperfect science supporting CPR as an essential link in the chain of survival.

The original report, however, belies some of the current-day challenges involving CPR, challenges involving both community implementation related to bystander CPR and scientific discovery related to professional CPR. The original report proclaims that “anyone, anywhere can now initiate cardiac resuscitation procedures,” suggesting that most patients experiencing cardiac arrest could and should receive bystander CPR. Unfortunately, less than half of patients experiencing cardiac arrest receive bystander CPR before the arrival of professional rescuers in most US communities. Fortunately, there are accessible strategies that provide the tools for community-based bystander CPR improvement.

Strategies such as telecommunicator CPR provide an efficient approach that can substantially boost bystander CPR rates. Other approaches have incorporated CPR training into the secondary school curriculum, targeted training to high-risk geographies or families, or used smart technology to summon free-ranging volunteers to patients potentially experiencing cardiac arrest. These strategies complement the cornerstone of traditional instructor-based CPR training.

If these multifaceted approaches provide a roadmap for success, why do communities often struggle to achieve best practices? Explanations can vary, but 1 common theme is the challenge to convene the range of stakeholders required for community implementation. A successful community CPR program requires leadership, cooperation, and persistence, and is rarely high profile or rewarded. Yet, successful communities experience health benefits that translate to lives saved.

The recent Institute of Medicine report features community implementation of resuscitation best practices, in general, and specifically implementation of bystander CPR to improve outcomes. Bystander CPR needs to be an all-access therapy that indeed can be applied by anyone, anywhere a cardiac arrest occurs.

And then there is the challenge of scientific discovery. The original report describes “a method that is simple to apply… whereby pressure on the sternum forces blood out….and relaxation allows the heart to fill.” To be sure, these concepts and descriptions were immensely progressive and still serve as a useful paradigm for CPR science. However, research increasingly suggests that the mechanism of benefit underlying CPR may be multifaceted and that CPR itself may be considered a complex technique where variations in the technique can influence the likelihood of resuscitation.

Although the time-honored perfusion model may help explain CPR benefit, other mechanisms may also contribute. For example, CPR may promote posts ischemic conditioning, a process by which low-flow or interrupted flow as a consequence of CPR protects against the apoptotic pathophysiology that occurs as a result of cardiac arrest. Indeed, there may be multiple mechanisms by which CPR affects physiology. And importantly, different mechanisms may be more or less important for individual patients.

Which brings us to the challenge of what constitutes ideal CPR? For many years CPR was a checkbox intervention—a yes-no categorical measure that for many of us was the filler between the next therapy—be it drug treatment, airway management, or shock. Fortunately, there has been an evolution in CPR measurement, enabled, in part, by advances in technology. Defibrillators can now measure some components of CPR. These measurement tools have provided the basis to determine information about compression rate, depth, extent
of release, release velocity, duty cycle, and interruptions in compressions, and ventilation rate, as well. Some patterns appear from these observational data involving professional-rescuer resuscitation. For example, longer interruptions in compressions to analyze the heart rhythm and deliver a shock—sometimes termed the “perishock pause”—are associated with a lower likelihood of resuscitation. In this edition of Circulation, there is a new finding from Brouwer and colleagues that provides additional insight into the relationship between CPR and resuscitation outcome. Researchers detailed interruptions in compressions among 300 patients undergoing ventricular fibrillation arrest. The study observed an independent association between longer longest pause in CPR and a lower likelihood of resuscitation. The relationship was independent of the perishock pause, suggesting that long interruptions regardless of whether a shock is delivered can adversely affect survival.

A limitation to most studies that evaluate CPR interruptions is that there is often little insight into the reason for the length of interruption. The longer interruption itself may independently affect physiology and be the cause of poor outcome. Alternatively, the interruption could simply be a marker of some other adverse circumstance. Studies that help characterize the reason for CPR pauses may help distinguish true cause-and-effect.

The current study is important, in part, because it characterized CPR in a manner that has not previously been rigorously evaluated. The distinct methodology that classified longest pause underscores the potential myriad of methodological approaches to evaluate CPR. As with most instructive research, this study provides for more questions than answers even as it advances our understanding.

So how should we assess CPR? Progress to date is commendable and a consequence of detailed registry evaluation that combines clinical information with real-time CPR measurement by professionals. Such data resources are essential if we are to continue to learn more. As we look ahead, however, we need to consider issues of how we measure and categorize individual CPR components, the interrelated potential of the individual components, the time-varying nature of both CPR and the patient, and the current lack of a time-sensitive, high-fidelity, physiological surrogate to determine patient-specific treatment effectiveness.

As the current study highlights, there are different approaches, each logical, to measure related CPR components. The current study used longest pause, whereas previous studies have assessed compression fraction; these are distinct, yet related, and ongoing investigation will hopefully define the most useful set of CPR measurements. A related challenge is the general approach to measure and model CPR components. Analyses often evaluate the average of a 1-minute interval—for example, what was the average compression depth during a given minute—and yet there may be 100 individual compressions during this single minute. Is the amount of variability around the average important, and if and how should we measure and incorporate individual compression-based details?

Moreover, guidelines highlight individual CPR components, consistent with our clinical understanding, and yet we increasingly appreciate that these measures are often interrelated. For example, duty cycle has demonstrated provocative effects in animal studies but its role in human resuscitation is not well-understood. Duty cycle is related to compression depth such that, ideally, an evaluation of compression depth and outcome would also simultaneously incorporate duty cycle to understand the individual and collective contributions of these CPR components. Future efforts that simultaneously evaluate primary and interaction second-order effects of multiple CPR components may uncover important outcome relationships.

And, of course, there is the challenge of how best to incorporate the dimension of time given the dynamic time-dependent course of resuscitation. Because a patient’s physiology changes over time and with treatment, the optimal CPR composition could potentially also change. Future analytical methods that more fully integrate the time structure of resuscitation may also advance our understanding.

These challenges to advancing CPR science highlight the need for a real-time, dynamic physiological measure that can guide CPR and other treatments during resuscitation. Such a measure might be related to flow, but again therapeutic mechanisms of resuscitation may not be gauged simply by flow. For now, professional rescuers generally strive to apply a singular set of CPR metrics instead of tailoring CPR and other treatments to the physiology of a given patient. In many instances, this one-size-fits-all strategy may suffice, but the goal to match treatment more precisely to a patient’s physiological needs provides 1 paradigm to advance the science of CPR.

The Brouwer investigation highlights CPR’s important prognostic role and advances our understanding, while providing a useful context in which to consider the challenges related to community implementation and scientific discovery as we endeavor to achieve the full lifesaving potential of CPR.

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References


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