RESEARCH ARTICLE

Predicting Survival from In-Hospital CPR: An Update

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Cardiac Arrest

Cardiovascular disease is the number one cause of death in the United States and is estimated to cost $200 billion annually (1). Each year it kills more Americans than chronic respiratory disease, diabetes, stroke, Alzheimer's Disease, influenza and pneumonia combined (2). The presence of cardiovascular disease increases one's risk of experiencing cardiac arrest, defined as the cessation of cardiac mechanical activity (3). Despite medical advances, it is estimated that 1 of every 7.5 people in the United States will die of sudden cardiac death (4). The incidence of cardiac arrest is even greater, as some people survive sudden cardiac arrest (5).

The literature divides cardiac arrest into two subgroups - cardiac arrest that occurs outside of a hospital, and that which occurs during a hospitalization. Risks of out-of-hospital cardiac arrest (OHCA) include prior heart disease, black race, and lifestyle factors such as smoking, diet, and obesity (6,7,8,9). A family history of a first-degree relative with cardiac arrest is associated with a 2-fold increased risk of experiencing cardiac arrest (10,11). As the prevalence of obesity and heart disease continue to increase, so does the risk of cardiac arrest.

In 2016 in the United States, over 350,000 cases of out-of-hospital cardiac arrest were reported (12,13). 70% of these cases occurred in patients' homes (14). About 60% of out-of-hospital cardiac arrest patients receive treatment by emergency medical services (EMS) (15). Similarly, the majority of out-of-hospital cardiac arrests in children occur at home. The age-adjusted incidence of EMS-assessed cardiac arrest in children <19 years of age has been estimated to be 8.3 per 100,000 person-years (16,17).

The incidence of cardiac arrest in hospitals is lower than that out of hospitals. The annual incidence of in-hospital cardiac arrests (IHCA) in the United States was most recently estimated to be 209,000 cases (18). A slight majority of these cases occur in critical care areas - including the intensive care unit, operating room, or emergency department. One study showed that 46% of in-hospital cardiac arrests occurred in noncritical care settings (19). Not surprisingly, the incidence of cardiopulmonary resuscitation (CPR) in hospitalized adults has increased. From 2007 to 2012, the incidence increased from 1.81 to 2.37 per 1000 hospitalizations for patients aged 18-64 years (20). Additionally, each year year 6000 children in the US receive CPR in a hospital (21,22). Globally cardiac arrest incidence ranges up to 140 per 100,000 people, with survival rates ranging from 2-11% (23,24).

Cardiopulmonary resuscitation is a potentially lifesaving intervention for cardiac arrest (23,24,25,26,27). However, studies have repeatedly shown that both the general public and some medical professionals are inaccurate in their CPR survival predictions - overestimating survival and recovery. This article seeks to take a deeper look at the latest research into cardiopulmonary resuscitation survival and attitudes towards it.

Misconceptions

There are many misconceptions regarding cardiopulmonary resuscitation - both among patients and providers. Previous research has shown that lay persons overestimate the survival rates of CPR (28). Studies have shown that these unrealistic expectations of the general public may be associated with younger age and CPR information from television (29). Television rates of successful CPR are much higher than in the real world. Marco and Larkin's study of the general public, representing 38 states, showed inaccurate estimations of resuscitation survival. The study interviewed 1831 participants in public places. The results showed a mean estimated survival rate after cardiac arrest of 54%, with a mean estimated duration of resuscitation efforts in an emergency department of 28 minutes (28).

In 2015 Shif et al. surveyed patients' surrogate decision makers in the intensive care unit (ICU). This study also revealed gross overestimations of post-resuscitation

survival rates. 50 subjects participated in an interview survey within 24 hours of the patient's ICU admission. This study revealed that 72% of participants believed survival after CPR was greater than 75%. Less than half (42%) had spoken to the patient about CPR before entering the hospital. 26% of the surrogates changed their decision on CPR during the patient's time in the ICU (30).

Misconceptions also exist within the medical community. In 2006 Jones et al looked at the knowledge and perceptions of medical professionals regarding resuscitation outcomes. They surveyed medical personnel, including medical students in years 3 and 4 of their training, as well as residents and attendings in family medicine, internal medicine, emergency medicine, anesthesia, and surgery. Their results showed that 51% of students, 47% of residents, and 36% of attendings accurately predicted IHCA survival rates. Estimations of out-of-hospital survival were more accurate; 51% of students, 52% of residents and 70% of attendings were accurate (31).

Reality

In reality, cardiopulmonary resuscitation success rates are much lower than estimated. For years studies have looked at post-resuscitation survival rates. Most recently, data from hospitals participating in the Get With the Guidelines-Resuscitation program have provided insight into post-resuscitation survival rates. The program looked at 84,625 patients experienced who cardiac arrest at 374 hospitals. The data showed that the median adult survival rate of IHCA is 17% with a pediatric survival rate of 36% (32,21).

For OHCA, survival rates were higher in hospitals that experience higher cardiac arrest volume, higher surgical volume, and have more availability for invasive cardiac services, as well as higher socioeconomic catchment areas (33). Location of event and ethnicity of patients have also been associated with outcomes; survival rates have been shown to be higher when cardiac arrest occurs in public places rather than private residences, perhaps due to the availability of support (17). Analysis of age-adjusted survival of cardiac arrests in one year in New York City showed the survival for black patients was nearly half that of white patients: 6% vs 11.3% (7).

In 2009 the American Heart Association Registry for CPR studied ethnic disparities

for in-hospital cardiac arrest survival. Data showed that 25.2% of black patients survive to discharge while 37.4% of white patients do. Analysis revealed that hospital location significantly contributed to racial variation in survival rates (34). Further studies have shown lower mortality in patients experiencing cardiac arrest in academic teaching hospitals (55.3%) vs nonteaching hospitals (58.8%) (35).

With nearly 6000 pediatric cardiac arrests in hospitals annually, research has looked closely at this population. It is estimated that only 2-6% of pediatric cardiac arrests occur in pediatric intensive care settings (36,37). In 2017 Bhanji et al. published outcomes based on data collected between 2000 and 2012, from 354 hospitals participating in the AHA's Get With the Guidelines-Resuscitation registry. Of 12,404 pediatric cases reviewed, 70% experienced return of spontaneous circulation (ROSC) > 20 minutes but that rate decreased to a 58% 24-hour survival rate. 36% survived to hospital discharge (21).

It is important to distinguish between different survival statistics when it comes to cardiopulmonary resuscitation. Successful resuscitation may be defined as ROSC, however, as shown above, this does not equate to survival to hospital discharge, much less quality of life. Further studies have evaluated the quality of life of a patient, if they survive to hospital discharge. In 2017 10.4% of patients who experienced EMS-treated OHCA survived to hospital discharge, with 8.4% reporting good functional status (17). These rates vary greatly in different geographic locations. In 132 counties in the U.S., the hospital survival rates vary drastically - from 3.4% to 22% with functional recovery rates varying from 0.8% to 20.1%. Researchers of this data identified layperson CPR rates and AED use as two factors in this variation (38).

CPR Variability

Many factors play a role in the efficacy of resuscitation efforts. The AHA Guidelines name five critical components of high quality CPR: minimize interruptions in chest compressions, provide compressions of adequate rate and depth, avoid leaning between compressions, and avoid excessive ventilation. Even with maximal quality, CPR provides only up to 30% of normal blood flow to the heart and up to 40% of normal blood flow to the brain

(39,40,41,42). Variation in any of these components may further decrease the success of CPR.

Optimal chest compression depth is at least 5cm with a rate of 100-120 compression/minute (43). However, maintaining appropriate compression depth, rate, with full chest recoil between compressions without interruption can be difficult. Event location outside of the hospital, small number of team members, competing tasks, and difficulty of performing CPR while inside a moving vehicle may decrease CPR quality (44). Even inside a hospital, variables such as provider fatigue or physical strength may play a role in suboptimal chest compressions. In 2012 research showed that post-CPR survival-to-discharge rates after an out-of-hospital cardiac arrest were decreased by 30% when the compression depth was <38mm (17). Because of this potential area for improvement, mechanical compression devices have been developed to automate CPR. In 2015 the PARAMEDIC trial enrolled 4471 patients to evaluate the efficacy of mechanical compression devices outside of the hospital. This study showed no improvement in 30-day survival in patients who received mechanical chest compressions, rather than manual compressions by a provider (45).

Further variation occurs when evaluating CPR success in terms of specific patient conditions.

Sepsis is a common diagnosis for patients hospitalized. Research has shown that patients with sepsis-associated cardiac arrest are less likely to survive to both ROSC and hospital-discharge than patients who experience cardiac arrest without sepsis (46, 47, 48). In 2017 Morgan et al. discussed that various aspects of the pathophysiology of sepsis may impact resuscitation outcomes. These aspects include intravascular volume depletion, systemic vasodilation, metabolic derangements and pulmonary hypertension. They proposed that targeting sepsis-related pathophysiology surrounding cardiac arrest treatment may improve outcomes (49).

Researchers have also looked at resuscitation survival rates in patients with cancer. Reisfeld et al. performed a meta-analysis of 42 studies, including 1707 patients with cancer who experienced in-hospital cardiac arrest. Their data showed an overall survival to discharge rate of 6.2%. Their results showed that patients were more

likely to survive to discharge with localized disease, 9.5%, rather than metastatic disease, 5.6% (50). In 2013, Kjorstad and Haugen performed a literature review, expanding 21 years. Their review included 18 articles and showed that cancer patients had a worse post-CPR survival rate that patients without cancer. The data also supported previous research, that survival decreased with increased cancer burden (51). In 2018 Journal of Clinical Oncology published a retrospective study analyzing 396 codes at a tertiary cancer center. With 90% of the patients receiving high-quality CPR, survival rates were 79% immediately after resuscitation, 48% at 24 hours, and 17% to hospital discharge. This study reiterated the need for continued code discussions throughout a patient's care, as 64% of the patients changed their preference from full code to do-not-resuscitate when in critical care settings (52).

Post-resuscitation survival rates of patients with dementia is similar to that of patients with metastatic cancer. Survival to discharge after in-hospital cardiac arrest is 3 times lower in people with dementia than those with no cognitive impairment. Out-of-hospital survival rates are even lower, with extremely low success rates in patients who have unwitnessed cardiac arrest. For older patients with comorbidities such as dementia or cancer, resuscitation efforts may be more traumatic than beneficial (53, 54, 55). The Alzheimer's Association supports the need for discussions surrounding medical interventions. Dr. Volicer published an executive summary, consolidating a 20-year literature review. In his summary Dr. Volicer recommended limits on CPR and increased physician involvement in discussions surrounding end-of-life care (56). Of the patients with dementia who initially survive resuscitation, most die within 24 hours in an intensive care unit.

Although cardiopulmonary resuscitation has been shown to have higher rates of success with cardiac arrest due to acute myocardial infarction, other cardiac causes of arrest are associated with lower survival rates, particularly congestive heart failure (57). Even with in-hospital cardiac arrest, the mortality rate is high for these patients with congestive heart failure (58). Presence of chronic illness is associated with worse CPR outcomes, including a lower rate of survival to discharge and median long-term survival. In a retrospective analysis of 358,682 patients who underwent cardiopulmonary resuscitation,7.2% of

patients with chronic disease who underwent CPR survived at least 6 months without readmission. However, when looking specifically at patients with advanced chronic obstructive pulmonary disease, congestive heart failure, malignancy, and cirrhosis, the success rate decreased to ≤ 2%. Subgroup analysis confirmed that even if these patients were discharged home, they had worse long-term survival and higher rates of hospital readmissions (59).

Environmental factors have also been shown to play a role in post-resuscitation survival rates. Survival rates among in-hospital cardiac arrest have been shown to be lower among both children and adults when the cardiac arrest occurred at nighttime (21). While some studies have shown daytime resuscitation rates >20%, the rate decreases to 15% between the hours of 11pm and 7AM. In addition to the time of day, it appears that location within the hospital also matters. Survival rates have reached 36% in cardiac arrests that occur in heavily monitored settings, such as operating rooms or postanesthesia care units during the day. On the other hand, survival rates at night in unmonitored settings have been estimated to be 9% (60). Such research suggests possible areas of significant improvement in increasing post-cardiac arrest survival rates.

Conclusion

In 2017 data showed that of OHCAs in the United States from 2005 to 2014, the general public initiated CPR in 34% of the events (61). The likelihood of a layperson initiated CPR was lower in low-income black neighborhoods or Hispanic neighborhoods, than that in affluent white neighborhoods (62, 63). Programs for CPR training have lower rates of trainings in counties with more black or Hispanic residents, lower household incomes, and those in rural areas (64).

Overall trends include an increase in the incidence of both layperson-initiated CPR and EMS-treated out-of-hospital cardiac arrest. Rates of survival to hospital discharge for both OHCA and IHCA have increased (18). Although these trends show progress, there is still a large discrepancy between the public's knowledge of cardiopulmonary resuscitation and today's survival rates. It is the physician's responsibility to guide truthful conversations with patients and families.

A survey conducted by Marco and Larkin in 2008 assessed the opinions and knowledge of the general public regarding resuscitation. Their results showed that the general public believed the most important factor surrounding resuscitation was patient and family wishes. Results also showed that advanced technology and physician communication were the most important aspects during resuscitation (28).

However, a survey of 52 junior doctors revealed that 73% of them found CPR to be stressful. The top two reasons for stress were inappropriateness of CPR for the patient and poor outcomes. 97% felt that some of the resuscitations performed were inappropriate. This survey also showed that 58% of junior physicians felt that discussing CPR with patients was difficult; 46% felt that it was difficult to discuss with relatives (65).

Increasing trends of resuscitation attempts for both OHCA and IHCA necessitate adequate training for performing CPR. Along with variability in the implementation and success of CPR, variability also exists regarding accuracy of opinions about survival rates of resuscitation attempts. Research has shown that patients' families value healthcare providers' communication regarding such situations. Medical professionals should feel empowered to discuss not only patient and family preferences regarding CPR, but also to have an honest conversation about the reality of CPR survival and long-term recovery

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