



Bystander interventions for out-of-hospital cardiac arrests: substantiated critical components of the chain of survival

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Early bystander cardiopulmonary resuscitation (CPR) and defibrillation are both vital components in the chain of survival following out-of-hospital cardiac arrest (OHCA) (1,2). Fortunately, bystander CPR rates in industrialized countries have recently increased from 30% to 50% (3-8). A Swedish analysis reported that CPR performed prior to emergency medical services (EMS) arrival was associated with a 30-day survival rate following OHCA more than twice as high as that associated with no CPR before EMS arrival (5). Further, bystander interventions (bystander CPR and defibrillation) were also associated with an increased likelihood of 1-month neurologically intact survival following OHCA according to an analysis of a Japanese nationwide registry (7). As neurological assessments fluctuate for at least 90 days following cardiac arrest, the American Heart Association (AHA) has recommended that longer-term end points (i.e., 90 days) coupled with neurocognitive and quality-of-life assessments should be considered (9). The AHA further suggests that researchers utilize either Cerebral Performance Categories or modified Rankin Scale for global outcomes of neurological assessment in patients following cardiac arrest (9). However, little is known regarding the impact of bystander intervention on long-term (i.e., >90 days following OHCA) neurologically intact survival (3,10).

Bystander interventions and long-term outcomes

Recent research (11) published in *the New England Journal*

of Medicine demonstrated that, among patients in Denmark surviving 30 days following OHCA, bystander intervention was associated with significantly lower risk of brain damage or nursing home admission as well as all-cause mortality than no bystander intervention. The authors of this investigation, Kragholm and colleagues (11), report these findings following retrospective analysis utilizing the Danish Cardiac Arrest Registry. From 2001 through 2012, 34,459 patients aged ≥ 18 years in which resuscitation was attempted were included for analysis. Of these, 2,855 patients (8.3%) survived 30 days following OHCA. Further, during this period, the percentage of 30-day survivors increased from 3.9% [2001] to 12.4% [2012] ($P < 0.001$). Of the 2,855 surviving patients, 276 (9.7%) died during the 1-year follow-up period, and a further 300 30-day survivors (10.5%) were either diagnosed with anoxic brain damage or admitted to nursing homes. During the study period, rates of bystander CPR (without defibrillation) and bystander defibrillation (regardless of bystander CPR performance) increased from 66.7% to 80.6% and from 2.1% to 16.8%, respectively (all $P < 0.0001$). In adjusted analyses, bystander CPR was associated with a risk of brain damage or nursing home admission that was significantly lower than that associated with no bystander CPR [hazard ratio (HR) = 0.62; 95% confidence interval (CI), 0.47–0.82] as well as a lower risk of all-cause mortality at 1 year (HR = 0.70; 95% CI, 0.50–0.99). Interestingly, risk of brain damage or nursing home admission was significantly reduced in patients receiving bystander defibrillation compared with

that in those who received no bystander CPR (HR =0.45; 95% CI, 0.24–0.84). The investigation by Kragholm *et al.* (11) supports the idea that bystander intervention may improve long-term functional outcomes and highlights the necessity to implement and improve strategies that facilitate bystander initiation of CPR as well as increase public access to automated external defibrillators (AEDs). However, the only limitation of the study is its retrospective design, in which the confounding factors cannot be fully accounted for (12). Even though all known confounders can be accounted for, there may be numerous unknown confounding factors that may disrupt the causal relationship between bystander CPR and long-term outcome. In epidemiology, such a situation can be accounted for by using causal mediation analysis in which the causal relationship can be tested for its robustness. While known and measured confounders can be added to the model, other unknown factors can be evaluated with sensitivity analysis (13).

Initiatives in Denmark

Despite proven effectiveness, the proportion of patients receiving bystander CPR following OHCA is still relatively low in most countries (14–16). Historically, strategies utilized to increase rates of bystander CPR have included comprehensive public education campaigns, as well as implementation of telecommunication programs to provide instructions for bystander CPR at the scene of OHCA (17). In Denmark, reduced frequency of bystander CPR (<20%) and relatively poor 30-day survival (<6%) were identified nearly 15 years ago, leading to several national initiatives to increase bystander CPR attempts and advanced care (3). Multiple nationwide initiatives have been implemented since 2004, including widespread mandatory and voluntary CPR training; widespread dissemination of AEDs; introduction of health care professionals at emergency dispatch centers to facilitate dispatcher-assisted CPR; as well as the development of an AED registry, enabling health care professionals to guide bystanders to the nearest AED (3,11). These nationwide initiatives have resulted in improvements not only in overall survival, but in functional intact survival 1 year following OHCA (11). However, it must be emphasized that the investigation conducted by Kragholm *et al.* (11) was observational in nature, and could not determine whether the relationship between bystander intervention and 1-year outcome was causal, despite efforts to account for potential confounders. Moreover, their findings may not be generalizable to other OHCA patients

in different countries or EMS systems. The findings of this nationwide, observational investigation (11) indicate that multiple nationwide initiatives are required for meaningful long-term outcomes following OHCA.

Initiatives in Japan

In Japan, expanded use of AEDs by both EMS personnel and lay persons was deployed in 2004 (7,8,14,18,19). Further, CPR training programs have been conducted primarily by local fire departments, at the recommendation of both the Fire and Disaster Management Agency of Japan and the Ministry of Health, Labor and Welfare (18–21). In 2015, local fire departments trained ~1.4 million citizens through conventional 3 h CPR training programs consisting of chest compressions, mouth-to-mouth ventilation, and AED use (21). Additionally, the Japanese Red Cross, local nonprofit organizations, and even driver training programs have begun offering CPR training. In total, an estimated 3 million people receive annual CPR training in Japan (14). Further, emergency telephone dispatchers in Japan are trained and instructed to relay CPR instructions to bystanders prior to EMS arrival (18). In 2006, the standard telephone-assisted CPR protocol was converted from conventional CPR to chest-compression-only CPR, with dispatchers encouraging bystanders to provide chest-compression-only CPR if rescue breathing was difficult to administer (22). Following the dissemination of chest-compression-only CPR for the lay rescuer throughout Japan, rates of bystander-mediated CPR (conventional CPR, chest-compression-only CPR, and rescue breathing-only CPR) significantly increased from 42.9% (8,108/18,897) in 2006 to 55.8% (13,672/24,496) in 2015 among witnessed OHCA events with presumed cardiac origin ($P<0.0001$) (14,21). Further, significant increases were noted in the rates of both 30-day neurologically intact survival attributed to chest-compression-only (0.6% in 2005 to 28.3% in 2012) as well as any bystander-mediated CPR per 10 million individuals (from 9.0% in 2005 to 43.6% in 2012); all $P\leq 0.01$ for trend (14). Owing to these initiatives in Japan, nationwide dissemination of chest-compression-only CPR administered by bystanders was associated with significantly improved 30-day neurologically intact survival.

Initiatives in the USA

In the USA, the HeartRescue Project initiated a multifaceted, statewide quality-improvement program

in 2010, with a total study population of 41.1 million individuals spread over five participating states (6,23,24). The primary goal of this initiative was to improve collective OHCA survival by 50% over 5 years. The project endeavored to provide necessary education for community members, EMS staff, first responders, as well as hospital administrators and staff. For community members, training in chest-compression-only CPR was offered at major civic events. This training was further provided to patients with cardiovascular disease and their family members preceding hospital discharge. Medical EMS dispatchers received additional training to better recognize caller descriptions of cardiac arrest as well as to both provide callers with accurate and understandable CPR instruction and encourage the transport of specific patients to specialized medical centers. First responders were instructed in proper AED use as well as high-performance CPR. Following this statewide educational intervention of resuscitative training, the proportion of patients receiving bystander CPR and defibrillation by first responders significantly increased, associated with enhanced likelihood of neurologically intact survival in North Carolina (6). Unfortunately, less than one-third of patients who experience sudden cardiac arrest in the USA will receive bystander CPR (4). Important disparities in CPR education across the USA were recently identified by Blewer *et al.* (15). In this cross-sectional, nationally representative survey completed by 9,022 adults in the USA, Blewer *et al.* (15) reported that 18% of surveyed individuals responded as being currently trained in CPR; lower socioeconomic status was further associated with lower probability of CPR education. These findings indicate the necessity of targeted CPR training strategies, tailored specifically to discrete populations in order to maximize potential public health benefit. Recently, Geri *et al.* (10) reported that bystander CPR following OHCA was positively associated with 5-year survival (30% increase relative to no bystander CPR) consequently producing both greater quality-adjusted life years (QALYs), as well as enhanced incremental cost-effectiveness ratio of bystander CPR (USD 48,044 per QALY) in greater King County, WA. Further, the majority of patients surviving 5 years demonstrate improved likelihood of survival at 10 years following OHCA (25). Therefore, the beneficial results of bystander CPR witnessed in greater King County are dependent on the concerted efforts to promote bystander CPR.

“Kids Save Lives” statement

To increase rates of bystander CPR, the following strategies have been implemented in industrialized nations: traditional classroom training; telephone-assisted CPR; school-based instruction; online education; geospatial alert systems; and targeted neighborhood or individualized training (3,6-8,10,11,14,17-24,26). Indeed, specific environment and circumstance will likely determine which strategy would be optimal to increase rates of bystander CPR (10). For example, providing resuscitative training in schools demonstrates measurable effects and, by a “multiplier effect,” may increase both lay bystander CPR rate as well as OHCA survival rate (27). In 2015, the World Health Organization endorsed the “Kids Save Lives” statement, drafted through the collaborative efforts of the European Patients Safety Foundation, the European Resuscitation Council, the International Liaison Committee on Resuscitation and the World Federation of Societies of Anesthesiologists (27). In Denmark, one of the most active countries in promoting national initiatives to increase rates of bystander CPR, school CPR training was not successfully implemented although legislation mandates that students be trained in CPR before graduating middle school (3,26). Accordingly, additional efforts are required to successfully implement CPR training in all schools. Specifically, several factors require emphasis for further improvements including: (I) incorrectly believing fellow schools were conducting training; (II) increasing awareness of mandated legislation; (III) requiring the presence of school CPR training coordinators; (IV) identifying teachers competent to conduct training; and (V) improving ease of access to necessary training material (26). In my opinion, educating schoolchildren in CPR should be mandated by law in all countries likewise Denmark (27), requiring significant support for effective implementation.

Conclusions

Recent investigation from Denmark (11) strongly supports the hypothesis that early bystander interventions (bystander CPR and defibrillation) following OHCA are critical elements of the chain of survival. In accordance with multiple nationwide initiatives, every effort should be made to increase the rate of bystander-initiated interventions, ultimately increasing the rate of meaningful, long-term neurological outcomes following cardiac arrest.

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Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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