EDITORIAL

Drone-Based Automatic External Defibrillators for Sudden Death?

Do We Need More Courage or More Serenity?

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Daniel B. Mark, MD, MPH
Steen M. Hansen, MD
Monique L. Starks, MD
Mary L. Cummings, PhD

The Serenity Prayer asks for the courage to change what can be changed, the serenity to accept what cannot be changed, and the wisdom to know the difference. Medicine demands large doses of all three. The greatest difficulty is deciding when the times call for more courage or more serenity. Some of our problems seem so intractable that we stop expecting progress during our professional lifetimes. Occasionally, however, advances completely unrelated to medicine give us cause to reconsider the comfort of our serenity-courage balance.

Out-of-hospital cardiac arrest is one of medicine's most vexing public health problems. Decades of research have failed to reveal any test that is sufficiently accurate to identify people who will have a sudden cardiac arrest (SCA) before the catastrophic event occurs. Huge research efforts have been expended to identify best resuscitation practices at the time of the SCA event (eg, how many inches of chest compression, at what rate, and with what ventilation strategy; airway management; and what adjuvant drug therapies) and best treatment practices in the hours and days following (including targeted temperature management and early coronary angiography). Community-wide emergency medical service (EMS) systems have been created to deliver interventions to SCA patients with a goal of arriving within 8 minutes of the 9-1-1 call at least 90% of the time. However, despite improvements in prehospital systems of care and bystander resuscitative efforts, absolute survival for out-of-hospital SCA has remained at or below 10%.[1–3]

Glimmers of the possibility of much higher survival rates have appeared in the form of observational reports of automatic external defibrillator (AED) use. The first AED was approved by the US Food and Drug Administration in 1998. Early work showed that when SCAs occurred in well-populated public spaces with an AED close at hand and a shock was delivered by bystanders, 30-day survival rates reached 40% (airplane) to 74% (casino, shock within 3 minutes).[4,5] The PAD trial (Public Access Defibrillator; a test of best-case static AED coverage) compared the use of AEDs plus cardiopulmonary resuscitation with cardiopulmonary resuscitation alone in 993 "community units" (shopping malls, recreational areas, hotels).[6] The AED intervention arm was intended to deliver an AED to a cardiac arrest scene within 3 minutes. Fourteen percent of the 107 subjects with definite cardiac arrest survived to hospital discharge in the cardiopulmonary resuscitation–only arm compared with 23% of the 128 in the cardiopulmonary resuscitation plus AED arm. However, even with such encouraging proof of concept, the potential of rapid AED use has proven surprisingly difficult to generalize to the community level, and bystander defibrillation rates have remained low.[1,2,7]

The 2 current options for getting an AED to the site of a cardiac arrest in a timely fashion are placing static AEDs in strategic (largely public) locations, which requires bystanders to find and retrieve the devices, and getting first responders to bring

Correspondence to: Daniel B. Mark, MD, MPH, Duke Clinical Research Institute, PO Box 17969, Durham, NC 27715. E-mail daniel.mark@duke.edu

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an AED to the site. Placement of onsite AEDs in public locations can result in improved bystander defibrillation rates, as shown in a Danish study in which the number of registered static AEDs increased from 141 in 2007 to 7800 in 2012 and corresponding bystander defibrillation rates in public locations increased from 1% to 15%.[8] However, current community-level AED coverage patterns are highly variable in terms of both geographic location and hours of accessibility.[9,10] Furthermore, most SCAs (70%–85%) occur at home where the efficacy of static AEDs has proved limited.[2,8,11] Adding options for AED delivery by first responders can reduce arrival time,[12,13] but the impact on overall outcomes has been quite small.[14]

Thus, although multiple lines of evidence support the expectation that very rapid AED use can produce a much greater increment in survival than any prior therapeutic strategy tested so far, no one has yet managed to effectively realize this potential at the community level. Three factors must be considered when trying to engineer a "chain-of-survival" process to deliver AEDs to SCA victims in a 3-minute time window: recognition, deployment, and use. The first step is rapid determination that an SCA has taken place. This alone is extremely challenging because >50% of out-of-hospital arrests are unwitnessed and these patients are often not resuscitated.[5,12–14] Even when a witness is present, delays in recognition of the nature of the emergency are common.[15] The second step is getting an AED to the scene within 3 minutes, and the third step is using the AED.

One novel and potentially revolutionary solution to this problem is an AED-equipped drone, which in theory can be flown to a witnessed out-of-hospital arrest within several minutes of a 9-1-1 call. One such AED-equipped drone prototype, reported to have the ability to achieve speeds >60 mph and using global positioning system and cell phone technology to reach the target location, was demonstrated in 2014 in the Netherlands.[16] The primary advantage that a drone-delivered AED offers relative to traditional EMS/rescue delivery is reduced travel time. Drones can fly very rapidly in a straight line from the dispatch site to a target location without hindrance from winding roads, meandering motorists, or gridlocked traffic jams. In addition, unlike static public-access AEDs, the drone-delivered AED can be brought quickly to where it is needed without a frantic, inefficient search as precious seconds tick by.

In a world where Amazon is developing drone-based package delivery and drones are already being used in rural Africa to deliver time-sensitive lifesaving medicines, differentiating science fiction from the technology of tomorrow is not so easy. At least 4 formidable challenges still must be overcome to move drone delivery of AEDs within 3 minutes of a 9-1-1 call from a "cool idea" to an integral part of the chain of survival in communities: regulation, drone technology improvements, deployment strategy across a region, and integration into current EMS command and control structures.

Three groups have now published studies addressing the third of these 4 challenges by combining empirical historical arrest data with mathematical modeling (optimization and queuing) techniques to examine different deployment patterns for drone-delivered AEDs. In this issue of *Circulation*, Boutilier and colleagues[17] from the University of Toronto examined this topic using 8 years of data on 54 000 out-of-hospital arrests in the Toronto Regional RescuNET (8 regions in southern Ontario; total population, 7.1 million; total area, 26 000 km^2). Proposed drone stations across the region were selected from all existing fire, paramedic, and police stations, and the drones were assumed to fly ≈60 mph at a height of 197 ft with 10 seconds required for takeoff and landing. To reduce the time to arrival of an AED by 3 minutes relative to historical EMS/first responder arrival times, Boutilier et al[17] predicted that 81 bases and 100 drones would be needed. If all the drones were coordinated through an integrated central command/dispatch center, the projected number of bases and drones was reduced by 30% to 40%, but this efficiency was achieved in part by reducing coverage for more remote portions of the service region. The number of drones required to achieve the desired performance was sensitive to decisions about how to handle "drone busy time," when a call comes in and the closest drone is already out on another call or is being recharged after returning from an earlier call. Should there be a backup drone at that site (or >1 drone for densely populated metropolitan areas), or should bases cross-cover each other? Tradeoffs also affected how quickly a drone could reach arrests in the more remote rural areas of the county.

Thus, the problem of how to deploy drones across a geographic region to deliver AEDs to a cardiac arrest minutes faster than EMS/first responders seems tractable. However, at present, the regulatory hurdles are probably the most formidable. The Federal Aviation Administration regulates all unmanned aerial vehicle (or drone) use in the United States and strictly limits drone use to operator line of sight. Some countries follow the United States in this manner, whereas others (eg, Canada, United Kingdom) are currently somewhat more permissive. The Federal Aviation Administration will require extensive proof of safety before authorizing any community or organization to set up a network of AED delivery drones.

To be cost-effective, highly reliable all-weather AED delivery drones need to be developed that are small, very fast, and capable of carrying an AED (eg, 2–3 lb), which is a typical payload of many commercially available small drones. However, complex tradeoffs exist between onboard weight, performance (eg, speed, maximum travel range), and cost. To move AED-equipped drones beyond demonstration prototypes will require the addition of onboard collision avoidance technologies and radar to be able to operate in all weather conditions (including high winds, rain, snow, and fog). Any additional sensors or improved batteries add weight, which then reduces speed and range.

In addition, each community will have to decide not only how to deploy the drones but also how to integrate them into the existing EMS networks, who pilots the drones, who maintains them, how much backup redundancy is needed, and how all of this gets paid for. Moving the human pilot's role to direct control from line-of-sight operation will require the development of an expert workforce to oversee the flights of multiple drones at any time and to ensure the safety of the drones and people on the ground.

Once these technical, logistic, and regulatory issues are solved, we will still need large-scale studies to prove that drone delivery of an AED within 3 minutes of a 9-1-1 call can materially affect population-level survival after cardiac arrest and is economically feasible. Thus, for most of us, the serenity-courage balance for drone-delivered AEDs will continue to demand more serenity, for now. Many of the technical advances needed and regulatory assurances required by the Federal Aviation Administration will likely be driven by companies desiring to use drones for package delivery and other commercial applications. Although the path forward is not easy, we hope that some of the most courageous among us will invest the difficult years of work it will likely take to see whether drone delivery of AEDs can be the SCA game changer we desperately need.

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AFFILIATIONS

From Duke Clinical Research Institute, Duke University Medical Center, Durham, NC (D.B.M., S.M.H., M.L.S.); Department of Clinical Epidemiology, Aalborg University Hospital, Denmark (S.M.H.); and Duke Robotics, Duke Pratt School of Engineering, Durham, NC (M.L.C.).

FOOTNOTES

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