Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Rosamond WD, Johnson AM, Bogle BM, et al. Drone delivery of an automated external defibrillator. N Engl J Med 2020;383:1186-8. DOI: 10.1056/NEJMc1915956

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SUPPLEMENTARY METHODS

Design

Between March and June 2019, we conducted a randomized trial of 35 tests comparing the delivery time of an automated cardioverter-defibrillator (AED) by drone to the site of a simulated out-of-hospital cardiac arrest with time that a bystander could search for and retrieve an AED acquired from a fixed location. We conducted trials in five zones across the University of North Carolina at Chapel Hill (UNC) campus, with seven trials in each zone. We used a life-sized manikin (Laerdal Resusci Anne) accompanied by two participants for each test. The UNC institutional review board approved the trial protocol and consent forms. Participants were randomized at the time of the simulated out-of-hospital cardiac arrest to either dial a mock 9-1-1 telecommunicator and wait for a drone to deliver the AED ("caller"), or to search for and retrieve an AED from the surrounding area ("seeker"). The caller followed a script to describe the out-of-hospital cardiac arrest and ask for help. The telecommunicator followed a script that: (1) directed the caller to ask the seeker to search for an AED and bring it to the site, (2) informed the caller that a drone would be dispatched with an AED to the site, and (3) instructed the caller how to approach the drone upon landing and retrieve the AED.

Participants and data collection

Seventy participants were recruited from three age strata (ages 18-34, 35-49, and 50-65). Participants were paired by sex and age group into 35 tests. Participants were blinded to the location of the simulated cardiac arrest event prior to the trial's initiation and were not provided with the location of AEDs in the area. Timing data were collected using a standardized digital clock (Exact Time App). The start of each test was recorded when the site manager indicated the onset of the simulated cardiac

arrest to the participants. Stop times were recorded for both the caller and seeker when their respective AED was placed next to the manikin, or 10 minutes had passed, whichever came first.

Trial setting

Each of the five zones presented different environmental challenges to drone navigation and bystander acquisition of an AED from fixed locations and had varying density of fixed AEDs (Supplementary Appendix Table S1). The locations of drone launch sites were not visible from the event site and differed by zone, ranging from 780 to 1290 feet from the event site. The locations of fixed AEDs in each zone were determined from a list provided by campus facilities services. We used ArcGIS (ArcMap desktop version 10.6) to plot the location of AEDs and event sites and to demarcate a 600-foot radius region around each event site.[1,2] We validated the AED list within the 600-foot radius via manual search. AED and event site global positioning system (GPS) coordinates were determined using a smartphone application.

As indicated in Supplementary Appendix Table S1, some AEDs were only publicly accessible during business hours (e.g., in the student union), and some were otherwise restricted. A DJI Matrice 600 Pro drone was used for all tests and was modified to carry a standard 2.5-pound Philips HeartStart AED (Supplementary Appendix Figure S1). The AED was affixed to a plate under the aircraft with two Velcro straps. The drone flew autonomously using a preprogrammed flight path, flying over buildings and wooded areas where possible to reduce exposure to pedestrians. Per regulations stipulated from UNC's Drone Policy, the UNC institutional review board, and the Federal Aviation Administration (FAA), a licensed drone pilot maintained visual contact with the drone at all times with the capacity to override the drone's autonomous flight mode if necessary.

Pre- and Post-trial interviews

Each participant was surveyed pre-test and post-test. Pre-test surveys queried previous experience with cardiopulmonary resuscitation (CPR), AEDs, drones, comfort with drones, and safety concerns. Post-test surveys queried the participant's test experience with the drone or searching and retrieving an AED. Seventeen participants in the caller role were selected for additional in-depth, semi-structured post-test interviews; selection was designed to ensure representation from all age-sex strata. Interviewees were asked to share their experiences, concerns, and perceptions participating in the simulation. Interviews were audio-recorded and supplemented with notes. Qualitative data were analyzed and organized thematically. Data were reviewed by a second team member, and areas of disagreement were discussed until consensus.

Statistical analysis

Summary statistics include median time intervals with interquartile ranges. Between-group differences in median time intervals were determined, and 95% confidence intervals were calculated by Hodges-Lehmann Estimation.[3] Data from pre- and post-test interviews are reported as frequencies and counts. A five-point Likert scale was used for participants' rating of confidence and comfort levels with various aspects of study participation.

SUPPLEMENTARY RESULTS

We conducted 35 tests, 18 with women and 17 with men. These included 15, 11 and 9 tests across the three age strata (18-34, 35-49, and 50-65 years), respectively. In seven of the 35 tests, only one participant was present and performed both roles as a caller and seeker sequentially. In all, there were 63 unique participants (30 women and 33 men). The median time (minutes: seconds) from onset of the

simulated out-of-hospital cardiac arrest to drone delivery of an AED ranged from 4:18 in zone C to 5:00 in zone E (Table, main text). Median time from arrest onset to bystander search and retrieval of an AED ranged from 2:56 in zone D to 7:00 in zone E. The difference in median AED delivery time between drone delivery and the ground search method ranged from -2:56 (Zone E) to +1:42 (Zone D).

The relative performance of drone delivery versus ground search delivery of an AED to the arrest site varied by trial zone characteristics (Supplementary Appendix Figure S2). In zone A, there is only one AED within 600 feet of the arrest, located in a building 512 feet away. In this zone, drone delivery outperformed the ground search (4:47 versus 7:00). However, in zone D where there are seven accessible AEDs within 600 feet of the event site and the average distance to an AED was shortest of all the zones (254 feet), the median AED delivery time favored ground search compared to drone delivery (2:56 and 4:38, respectively).

Median ground search and delivery time was longer among women (6:16, IQR=4:35 to 8:11) than men (4:27, IQR=3:11 to 7:51), and over 2.5 minutes longer for participants aged 50-65 than ages 18-34. In 71% (n=25) of tests, the drone delivered the AED within five minutes, compared to 51% of ground searches. In all tests, the drone delivered an AED within eight minutes, but for 26% of tests, the ground search exceeded eight minutes. Excluding trials where a single participant was the caller and seeker did not influence findings.

The median time from drone launch to landing was similar to the time for the seeker to find an AED (2:25 versus 2:45, respectively) (Table, main text). Because the drone was able to land consistently within ten feet of the site, the median AED transfer time from drone to manikin was 22 seconds. By comparison, the seeker's median return time was approximately 1 minute longer.

Participant perceptions

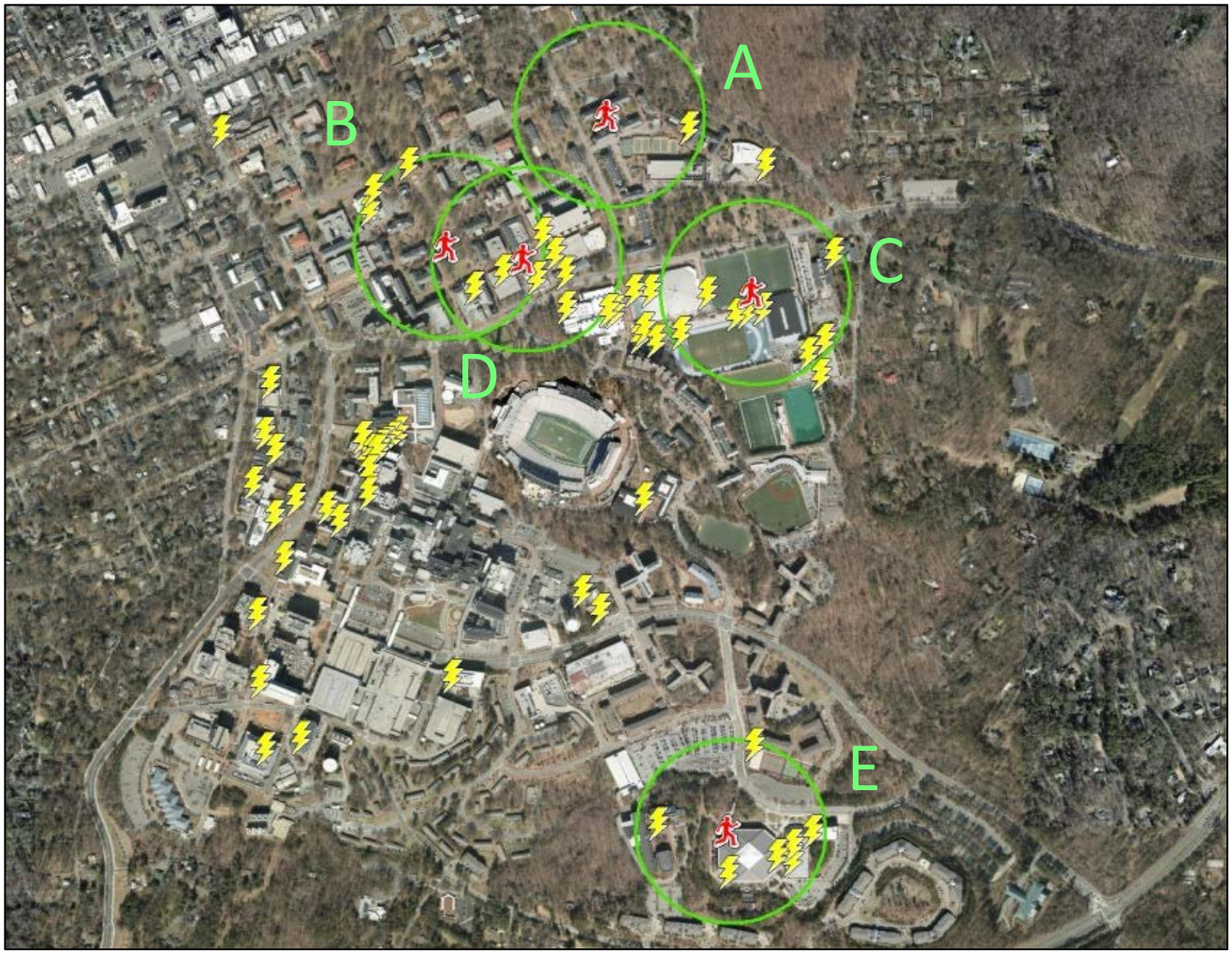
Interacting with the drone was well accepted by participants. Only 34% reporting having had prior interaction with a drone (Supplementary Appendix Table S2). After participating, 89% reported feeling comfortable during drone approach, and 72% had no safety concerns during approach and landing. The vast majority (85%) of callers found it easy to remove the AED from the drone. In contrast, nearly half of seekers reported difficulty in finding an AED.

Qualitative analysis suggests participants favored use of a drone-delivered AED over searching for an AED. Multiple seekers expressed concern with leaving the manikin to search for an AED, and multiple callers expressed relief at being able to continue CPR. All callers reported a positive experience and willingness to use a drone-equipped system in a real-life emergency. Caller concerns were rare but included some difficulty removing the AED from the drone, fear of the drone landing too close, and uncertainty of the drone's approaching direction.

REFERENCES

1. Lerner EB, Fairbanks RJ, Shah MN. Identification of out-of-hospital cardiac arrest clusters using a geographic information system. Acad Emerg Med 2005;12:81-4.
2. Cunningham CJ, Lowe JR, Johnson A, et al. Public Access defibrillation: utilization and missed opportunities. Australasian J Paramedicine 2019;16.
3. Hodges JLJ, Lehmann EL. Rank Methods for Combination of Independent Experiments in Analysis of Variance. Annals of Mathematical Statistics. 1962;33:6.

Supplementary Figure S1. DJI Model M600 drone fitted with AED and Laerdal Resusci Anne at simulated cardiac arrest event site.



Supplementary Figure S2. Location of simulated cardiac arrest sites (red) in zones A-E (green) and fixed AEDs (yellow).

Supplementary Table S1. Characteristics of trial zones, including distance from simulated cardiac arrest event site to AEDs and drone launch site.

		AED density [1]				**Average distance**		**Drone**
Zone	**Simulated cardiac arrest event site**	*Accessible to public at all times*	*Accessible to public during business hours only*	*Restricted access at all times*	**TOTAL**	**to AED in zone (ft)**[2]	**Distance to closest AED (ft)** [3]	**flight distance (ft)** [4]
A	Courtyard of dormitory complex	0	1	0	1	512 ft	512 ft	1290 ft
B	Main campus quadrangle	1	3	1	5	488 ft	316ft	1178 ft
C	Intermural athletic fields	3	4	0	7	353 ft	116 ft	1125 ft
D	Plaza adjacent to Student Union	1	6	0	7	254 ft	138 ft	780 ft
E	Sidewalk next to sports arena	1	4	3	8	441 ft	269 ft	945 ft

[1] Number of accessible fixed AEDs located within a 600 ft radius of simulated cardiac arrest event site;

[2] Average distance in feet to fixed AED within 600 ft radius of simulated cardiac arrest event site;

[3] Straight line distance in yards to closest AED from simulated cardiac arrest event site;

[4] Flight distance in feet from launch site to simulated cardiac arrest event site.

Supplementary Table S2. Pre- and Post-Trial Interview Questions, by study role, n (%)

	Caller (N=35)	Seeker (N=35)
Pre-trial Interview		
Ever interacted with a drone	12 (34.3%)	16 (45.7%)
Ever trained in AED use	22 (62.9%)	24 (68.6%)
Comfortable or very comfortable using technology	34 (97.1%)	34 (97.1%)
Confident or very confident knows what AED looks like	32 (91.4%)	33 (94.2%)
Confident or very confident knows how to use an AED	22 (62.9%)	27 (77.1%)
Post-trial Interview (Caller)		
Felt comfortable or very comfortable as drone approached	31 (88.6%)	
Unconcerned or very unconcerned for my safety as drone approached	25 (72.4%)	
Felt it was easy or very easy to remove the AED from the drone	30 (85.7%)	
Post-trial Interview (Seeker)		
Asked for help		26 (74.3%)
Had someone offer help		4 (11.4%)
Felt it was easy or very easy to find an AED		18 (51.4%)