Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Experimental paper

Impact of drone-specific dispatch instructions on the safety and efficacy of drone-delivered emergency medical treatments: A randomized simulation pilot study

Emma E. Davidson[a,b], Jason A Correll[e,f], Adam Gottula[c,f], Laura R. Hopson[c], Thomas B Leith[c,e], Noor K. Majhail[b,d], Emily J. Mathias[c], James M Pribble[c], Nathan B. Roberts[c], Isabella G. Scott[b,d], James A. Cranford[c], Nathaniel Hunt[c], Christine M. Brent[c,*]

Abstract

Introduction: Medical drones have potential for improving the response times to out-of-hospital emergencies. However, widespread adoption is hindered by unanswered questions surrounding medical dispatch and bystander safety. This study evaluated the impact of novel drone-specific dispatch instructions (DSDI) on bystanders' ability to interact effectively with a medical drone and provide prompt, safe, and high-quality treatment in a simulated emergency scenario.[1] We hypothesized DSDI would improve bystanders' performance and facilitate safer bystander-drone interactions.

Methods: Twenty-four volunteers were randomized to receive either DSDI and standard Medical Priority Dispatch (MPD) instructions or MPD alone in a simulated out-of-hospital cardiac arrest (OHCA) or pediatric anaphylaxis.,[23] Participants in the DSDI group received detailed instructions on locating and interacting with the drone and its enclosed medical kit. The simulations were video recorded. Participants completed a semi-structured interview and survey.

Results: The addition of DSDI did not lead to statistically significant changes to the overall time to provide care in either the anaphylaxis or OHCA simulations. However, DSDI did have an impact on bystander safety. In the MPD only group, 50% (6/12) of participants ignored the audio and visual safety cues from the drone instead of waiting for it to be declared safe compared to no DSDI participants ignoring these safety cues.

Conclusions: All participants successfully provided patient care. However, this study indicates that DSDI may be useful to ensure bystander safety and should be incorporated in the continued development of emergency medical drones.

Keywords: Drone, Out-of-hospital cardiac arrest, Dispatch instruction, CPR, Anaphylaxis, Epinephrine auto-injector

Introduction

An emerging technology likely to revolutionize prehospital care of acute medical emergencies is the medical drone, which has the potential to rapidly deploy time-sensitive medical supplies to the scene of an out-of-hospital medical emergency.[1,2] Current research suggests drones are capable of reducing the time to intervention in out-of-hospital emergencies by rapidly delivering critical medical supplies faster than typical ground emergency medical services (EMS).[3–15] The first real-world utilization of this strategy was reported by Schierbeck et al. in 2021, after a drone delivered an Automatic External Defibrillator (AED) to an out-of-hospital cardiac arrest resulting in effective defibrillation of a patient.[16] However, as

* Corresponding author at: Department of Emergency Medicine, University of Michigan Medical School, 1500 East Medical Center Drive, Ann Arbor, MI 48109, USA.

E-mail address: martinek@med.umich.edu (C.M. Brent).

[1] Drone-specific dispatch instructions.

[2] Medical priority dispatch[3] Out-of-hospital cardiac arrest.

https://doi.org/10.1016/j.resplu.2024.100652

Received 8 February 2024; Received in revised form 21 April 2024; Accepted 23 April 2024

drones continue to improve in capability and speed, questions regarding safety of bystander interaction and communication remain unanswered. This limits their widespread adoption as an adjunct to traditional ground based EMS.

Typical activation of the EMS system begins with a bystander calling 911 and interacting with a trained emergency medical dispatcher (EMD). Communication center EMDs provide instructions to bystanders awaiting EMS arrival according to Medical Priority Dispatch System (MPDS) protocols.[17,18] These pre-arrival instructions can have a significant impact on patient outcomes by increasing rates of bystander intervention and thus shortening time to treatment in medical emergencies.[3,19–22] For example, during telecommunicator CPR, the EMD will guide the caller in initiating CPR.[17,23–25].

Similarly, the success of drone-based medical care is dependent on bystanders interacting with the medical drone to provide time-sensitive intervention to the patient prior to EMS arrival. It is unknown if standard MPDS protocols already utilized by EMS would be sufficient to facilitate this interaction in a safe manner, or if drone-specific pre-arrival instructions will be necessary for bystanders to safely locate and utilize the supplies delivered via medical drones without being subjected to bodily harm, such as contact with a spinning rotor blade.

This study investigated the impact of pre-arrival, drone-specific dispatch instructions (DSDI) on the ability of bystanders to effectively interact with a novel medical delivery drone and provide prompt, safe, and high-quality emergent medical interventions in a simulated emergency scenario, either an adult out-of-hospital cardiac arrest (OHCA) or pediatric anaphylaxis. We hypothesized the provision of DSDI would lead to improved performance by bystanders in out-of-hospital emergency situations and would facilitate safer bystander-drone interactions.

Methods

Participant selection

The study screened potential participants residing within the general geographic region of southeast Michigan through an institutional portal, UMHealthResearch. Participants were screened on a first-come, first-served basis. Eligibility criteria specified all participants were (1) over the age of 18 years, (2) able to arrange independent travel, and (3) had the self-determined capacity to ambulate independently for at least 100 yards. Bystanders with formal medical training or extensive knowledge of unmanned aerial vehicles were excluded. The institutional review board approved the research protocol and consent process.

DSDI script design

Study team members with the input of MPDS-qualified emergency medical dispatchers designed the DSDI to provide specific instructions on interacting with the drone and medical kit. The script was based on existing MPDS protocols for OHCA and anaphylaxis that integrate with routine operations. The team piloted the script within the author group and made further refinements prior to deployment in the simulations. See Appendix B for scripts used in each scenario; 2 with standard MPDS instructions, and 2 with MPDS plus DSDI.

Simulation design

The simulation was conducted between May and July 2022. The drone landing site was situated approximately 100 feet from the simulation space. The drone utilized in this study was a non-flying prototype of a fixed-wing, vertical take-off and landing-capable medical drone with a height and wingspan of approximately 1.25 m (Appendix A). It features standard green and red navigation lighting on the wingtips as well as extra safety lighting and an aural warning system intended to inform the bystander when it is and is not safe to approach the drone. During simulated landing, these lights flash and a voice command directs: “Landing. Stay Back.” When it is safe to approach the drone, the navigation lights turn white, and another voice command directs: “Medical emergency drone safe. Pull handle. Swing open door. Grab handle and remove medical kit.” The medical kit is housed within the fuselage of the drone. Safety behaviors were assessed by analyzing if the participants heeded these audio and visual safety directions.

Before beginning the simulation, participants were given a brief introduction to the manikin (Laerdal Resusci-Anne or Laerdal Resusci-Junior)(Laerdal, Stavanger, Norway), actors, and simulation environment. Participants were informed that they will participate in a simulation that requires them to react to a medical emergency and that there would be a cellular phone, on which a simulated 911 call would connect the participant with a simulated emergency medical dispatcher, who would provide them with further instruction. No additional information regarding the simulated emergency, the drone or medical kit was provided.

Participants were randomized to a scenario where they either received DSDI, or were without DSDI (Appendix B). All participants received standard MPDS instructions and interacted with the drone’s built-in safety cues while those randomized to DSDI also received extra drone-specific instructions integrated into the simulation. The participants were expected to initiate bystander care, call 911, find the medical drone, remove the medical kit from the drone, return to the patient, and provide the required emergency intervention. The scripts and scenarios were created and reviewed before the simulations to ensure consistency across all participants.

Data collection and analysis

We employed a convergent parallel mixed methods approach, in which qualitative and quantitative data sets were collected simultaneously, analyzed separately, and then merged.[26] This approach allowed triangulation of findings from each arm for support of validity and a deeper understanding of outcomes. Safety behaviors were assessed in the simulation by analyzing if the participants followed the drone’s audio and visual safety directions.

All simulations were video recorded and time intervals were evaluated. To maximize inter-rater reliability, time values reported were calculated through video review of simulations using well-defined definitions of each action (e.g., “exit room” was defined as time participant reached the door frame). Two team members independently recorded time values. The average value between the two reported values was used for data analysis.

The quantitative data consisted of a web-based survey completed by all participants immediately after the simulation. The survey (Appendix C) was deployed on Qualtrics XM (Qualtrics, Provo, UT, and Seattle, WA). Prior research focusing on bystander interface with medical drones was utilized in the design of this survey.[1,2,27,28] The survey was piloted within the author group and an unrelated group with advanced training in survey research, and iteratively refined. Survey data were analyzed using Excel (Microsoft, Redmond, WA) and IBM SPSS Statistics for Windows, version 28 (IBM Corp, Armonk, NY). Between-groups comparisons used independent-samples *t*-tests, and unstandardized effect sizes were calculated. An alpha level of 0.05 was used for all analyses, and all hypothesis tests were two-sided.

The semi-structured interview (Appendix D) was conducted by one of two members of the author team (NH, EM) immediately after the simulation. The semi-structured interview script was piloted within the author group and refinements were made. The interview included questions targeting participants' perceptions regarding their interactions with the simulated medical dispatch. Interviews were audio-recorded using Zoom™ (Zoom Video Communications Inc, San Jose, CA), and commercially transcribed. Descriptive coding for thematic analysis was conducted using Dedoose (Dedoose version 9.0.54, Los Angeles, CA: Socio Cultural Research Consultants, LLC.www.dedoose.com).[29] Coding was done by consensus between the two coders. Key themes were iteratively developed and refined through discussion with the research team. Saturation, as defined by the absence of new codes and themes, was achieved.[30]

Results

Participant characteristics

Table 1 displays participant demographics. The OHCA and anaphylaxis groups were dissimilar in gender, while the anaphylaxis with DSDI group had a higher mean age.

Quantitative data

Table 2 presents mean total time to and between critical actions for OHCA and anaphylaxis simulations. Fig. 1 displays participant adherence to safety measures between DSDI and non-DSDI groups.

Survey results

Survey results showed participants who received DSDI generally felt they received just the right amount of information on how to interact with the drone and medical kit, although 2/12 participants felt they received extra information (Fig. 2). Importantly, no one felt they needed more information. Conversely, in the non-DSDI groups, 25% felt there were gaps in the dispatcher instructions regarding medical kit use and 33% felt there were gaps regarding drone interactions. Additionally, those who received DSDI generally had a more favorable opinion of the dispatcher's helpfulness during the interactions (Fig. 3) than those who did not receive DSDI (Fig. 4). This was most noticeable while locating the drone, locating the medical kit, and removing/using the medical kit.

More participants in both of the DSDI groups rated the interactions with the simulated dispatcher as helpful or very helpful with respect to interacting with the drone and locating/retrieving the medical kit than in the non-DSDI groups. However, less participants who received DSDI stated they felt the dispatcher instructions were helpful when using the medical devices on the simulated patient than participants in the non-DSDI group.

Interestingly, all but one participant in the non-DSDI group reported receiving step-by-step instructions on the drone and medical kit, despite receiving no information regarding the drone or assistance in finding medical supplies within the medical kit. All participants in the DSDI group correctly identified the receipt of DSDI.

Qualitative data

Semi-structured interview and video observation results

Participants voiced generally positive opinions of dispatch interactions and the concept of DSDI. The basic interaction with the dispatcher was largely perceived to be helpful by participants in both DSDI and non-DSDI simulations; the calmness and expertise of the dispatcher was felt to be comforting and supportive, as demonstrated when a participant in the anaphylaxis and DSDI group stated, *"It was very explicit, so that was good. It was very calm. That's good. And just walking me through it and telling me the colors and every-*

Table 1 – Participant demographics.

	Total (Epi & AED)	Total AED	AED with DSDI	AED without DSDI	Total Epi	Epi with DSDI	Epi without DSDI
Participant Characteristics	(n = 24)	(n = 12)	(n = 6)	(n = 6)	(n = 12)	(n = 6)	(n = 6)
Gender							
Female	13 (54%)	3 (25%)	2 (33%)	1 (17%)	10 (83%)	5 (83%)	5 (83%)
Age							
Age, (yrs) (mean (SD))	44.6 (16.7)	43.2 (15.4)	42.7 (17.2)	43.7 (15.0)	46.0 (18.6)	55.5 (16.3)	36.5 (16.6)
18–37 years old	10 (42%)	5 (42%)	3 (50%)	2 (33%)	5 (42%)	1 (17%)	4 (67%)
38–57 years old	6 (25%)	4 (33%)	1 (17%)	3 (50%)	2 (17%)	1 (17%)	1 (17%)
58 + years old	8 (33%)	3 (25%)	2 (33%)	1 (17%)	5 (42%)	4 (67%)	1 (17%)
Education							
High School	4 (17%)	1 (8%)	0	1 (17%)	3 (25%)	1 (17%)	2 (33%)
Some College	5 (21%)	3 (25%)	2 (33%)	1 (17%)	2 (17%)	1 (17%)	1 (17%)
College Graduate	11 (46%)	6 (50%)	3 (50%)	3 (50%)	5 (42%)	3 (50%)	2 (33%)
Graduate/ Professional	4 (17%)	2 (17%)	1 (17%)	1 (17%)	2 (17%)	1 (17%)	1 (17%)
Training							
Previous CPR training	15 (63%)	9 (75%)	3 (50%)	6 (100%)	6 (50%)	3 (50%)	3 (50%)
AED training	6 (25%)	5 (42%)	1 (17%)	4 (67%)	1 (8%)	0	1 (17%)
Previous AED Use	0	0	0	0	0	0	0
Epi training	6 (25%)	5 (42%)	1 (17%)	4 (67%)	1 (8%)	1 (17%)	0
Previous Epi Use	0	0	0	0	0	0	0

Table 2 – Mean total time (MM:SS) to and between critical actions for OHCA and anaphylaxis simulations between groups with and without drone-specific dispatch instructions.

OHCA				
	With DSDI (*n* = 6)	Without DSDI (*n* = 6)	*d*	*p*
911 call – begin CPR	1:26 (within AHA minimum guidelines)	1:21 (within AHA minimum guidelines)	0:50	.28
Begin CPR – exit room	2:01	2:04	0:03	.52
911 call – exit room	3:27	3:26	0:01	.70
Exit room – drone contact	0:41	0:29	0:11	.17
Drone contact – remove medical kit	0:06	0:03	0:03	.02
Exit room – remove medical kit	0:47	0:32	0:15	.07
Exit room – re-enter room	1:07	0:45	0:22	.01
Re-enter room – turn on AED	0:19	0:22	0:03	.36
Turn on AED – use AED	1:08	1:01	0:07	.53
Begin CPR – use AED	4:36	4:14	0:22	.21
911 call – use AED	6:03	5:35	0:27	.09
Anaphylaxis				
	With DSDI (*n* = 6)	Without DSDI (*n* = 6)	*d*	*p*
911 call – exit room	2:49	2:58	0:09	.04
Exit room – drone contact	0:39	0:33	0:06	.26
Drone contact – remove medical kit	0:07	0:05	0:02	.21
Exit room – remove medical kit	0:46	0:38	0:08	.16
Exit room – re-enter room	1:04	0:53	0:11	.08
Re-enter room – open medical kit	0:16	0:10	0:06	.20
Open medical kit – remove Epinephrine autoinjector	0:12	0:20	0:08	.01
Remove Epinephrine autoinjector – use Epinephrine autoinjector	0:39	0:40	0:01	.92
911 call – use Epinephrine autoinjector	5:02	4:54	0:08	.42

d = absolute difference between "With DSDI" and "Without DSDI" groups.
p = *p*-value from independent-groups *t*-test.

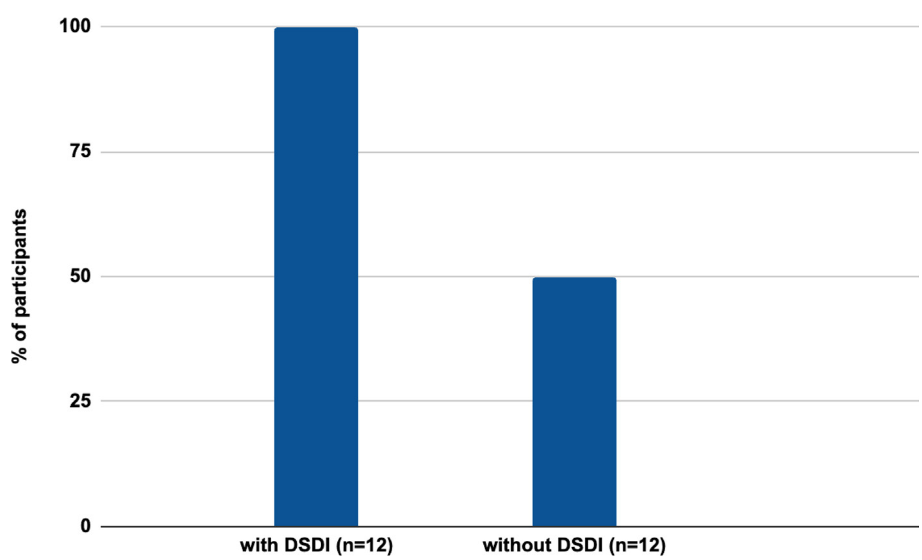

Fig. 1 – Adherence to Safety Measures in the DSDI vs non-DSDI Groups.

thing, what to look for and don't go near". The benefit of an experienced dispatcher to guide participants through a complex situation using clear, sequential instructions helped to minimize the cognitive load of the participants. A participant in the anaphylaxis scenario without DSDI stated, "*I think it was great. It was just enough. It wasn't too much to where I was overloaded in that moment trying to figure it out. It was very clear and concise"*. Although the dispatcher generally helped participants feel in control, the demands of the scenarios occasionally outcompeted the dispatcher. Subjects expressed that the cognitive load, at times, led them to tune out either the dispatcher or the drone safety cues. A participant in the OHCA with DSDI group stated, "*That was good. Although I stopped, when I was trying to read what to do with the pads, I almost stopped listening to them because I was trying to figure it out myself...*". Although cognitive overload was present in both groups, participants without DSDI felt they needed more information from the dispatcher, and they sug-

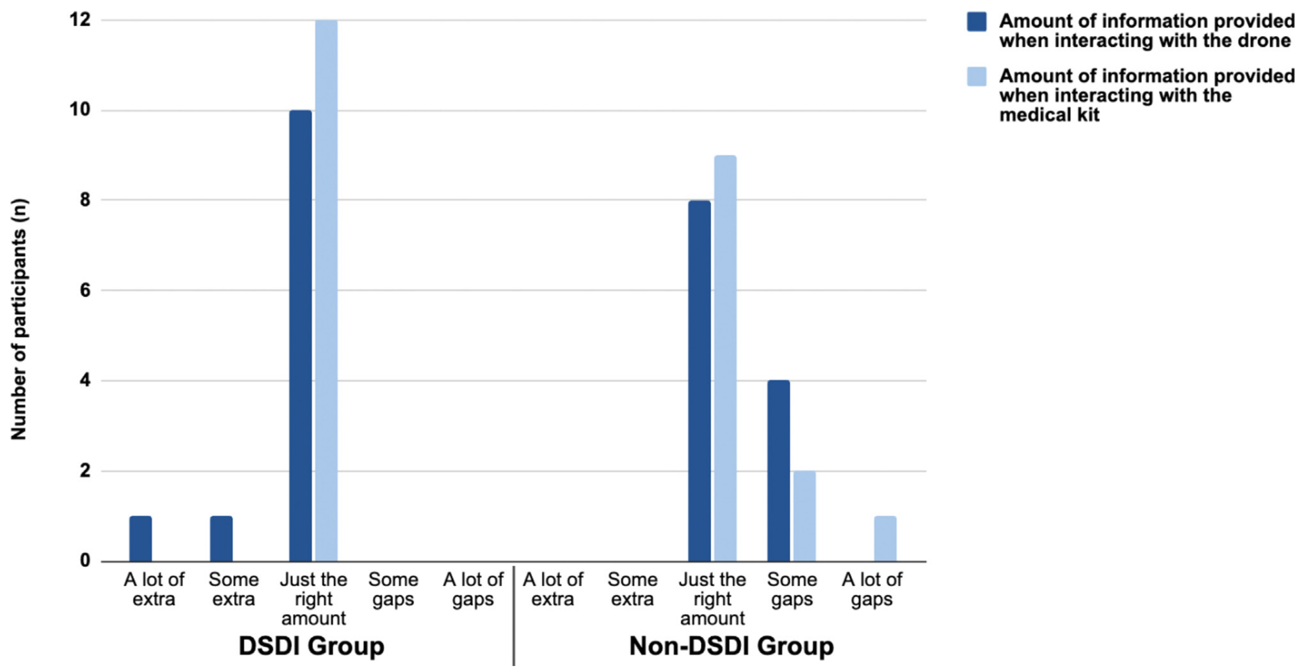

Fig. 2 – Survey Responses: How do you feel about the amount of information provided by the 911 operator?

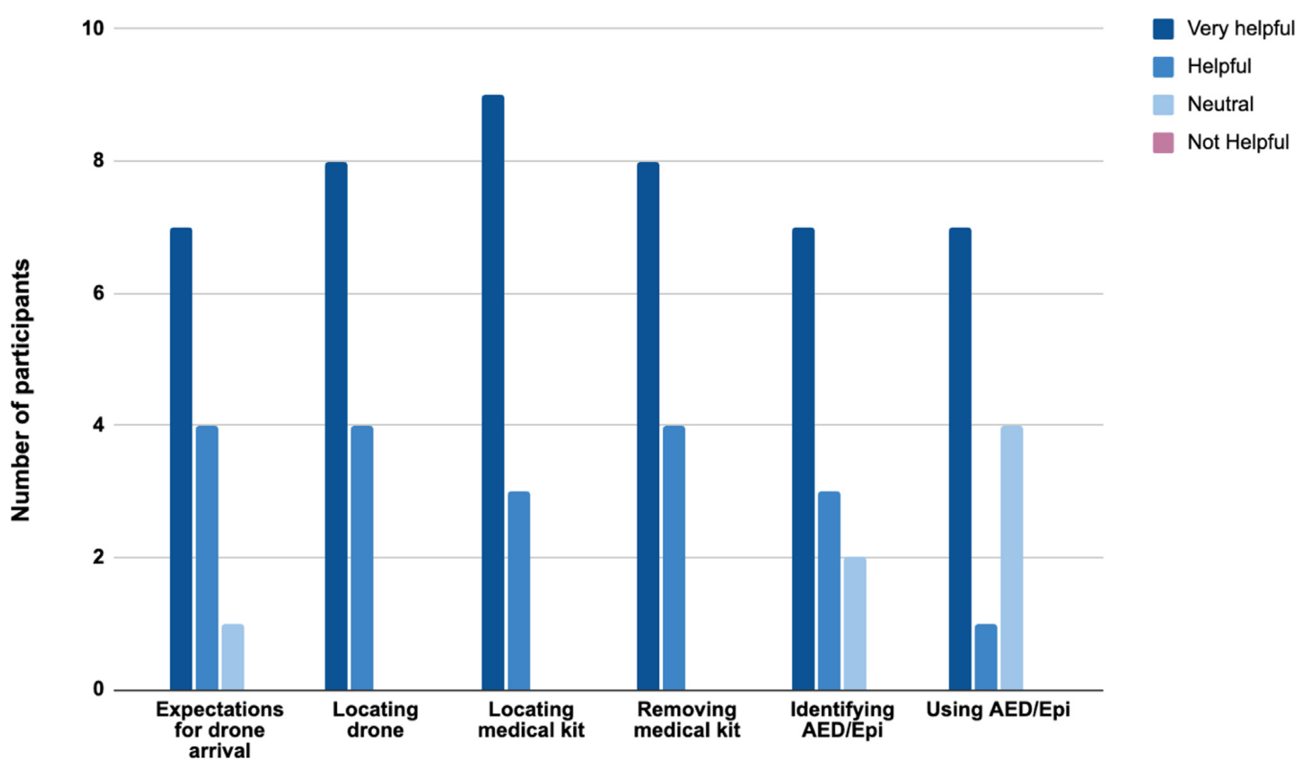

Fig. 3 – Survey Responses in DSDI Group: How helpful or not helpful were your interactions with the 911 operator with the following tasks:

gested during the interview that the dispatcher provide this information, as seen when a participant in the OHCA without DSDI group stated, "*So, maybe the 911 person would say open the drone when you get there*".

Recommendations for general improvements to dispatcher interactions emerged as a theme from the dispatch communication. A participant in the OHCA without DSDI group stated *"it took me a long time to realize, okay, here's all the other supplies. I'm not seeing the pads and then pull tab off the one end, just that everything's here and then that pull tabs over here. . .Well, as I said if these are a standardized kit, that might be something that they should mention. The green tag's going to be underneath where the power button is."* Specifically,

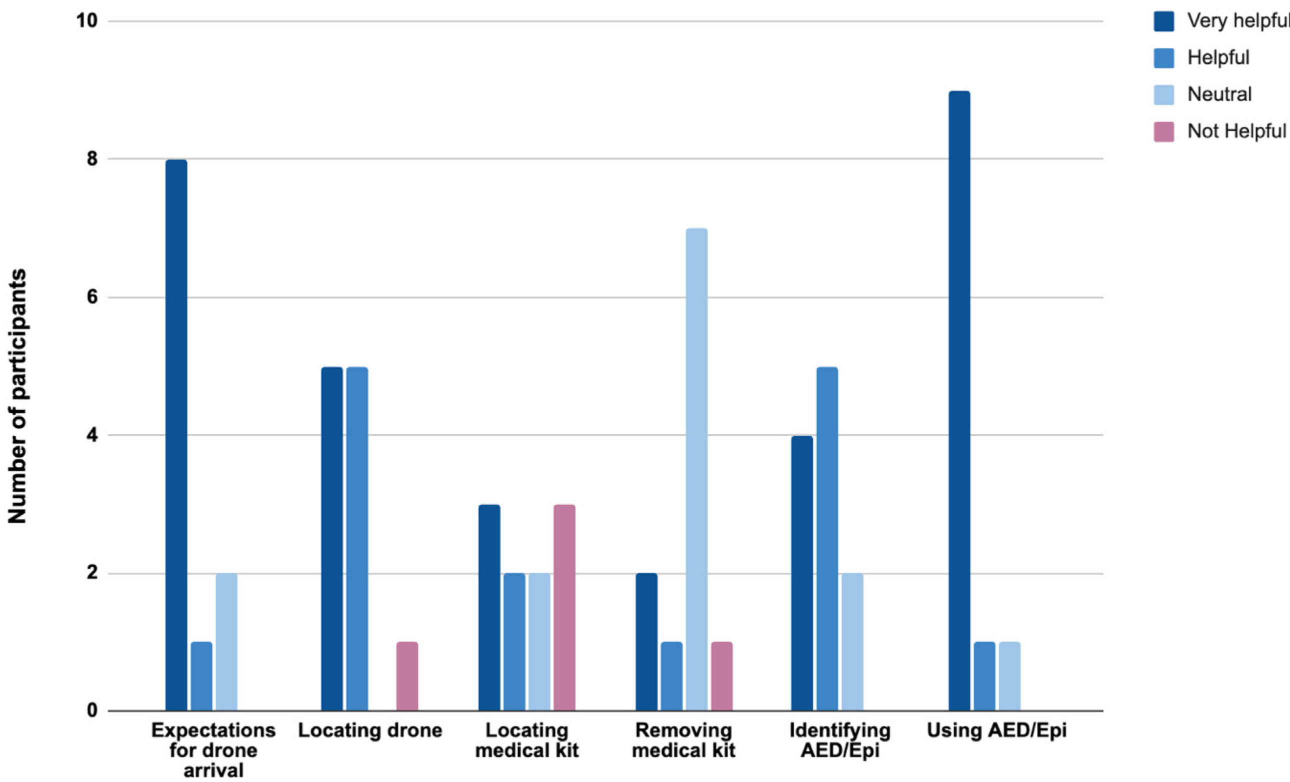

Fig. 4 – Survey Responses in Non-DSDI Group: How helpful or not helpful were your interactions with the 911 operator with the following tasks:

participants wanted clearer instructions from the dispatcher regarding the need to open a door on the drone to access the medical kit (6/12 participants without DSDI), and one participant in the DSDI group stated that further markings or highlighting on the drone itself would be useful to indicate that the medical kit was inside of it, as several participants thought that the medical kit would be dropped from the drone. Additionally, 19 out of the 24 participants voiced that the appearance of the drone was different than what they were initially expecting, and one participant further stated that it would be beneficial for the dispatcher to give anticipatory guidance on the appearance of the drone and what to look for.

Discussion

In this study, we analyzed bystander interaction with a novel medical drone and medical kit following standard MPDS instructions with and without additional DSDI. There were a few small but statistically significant differences in time intervals noted with DSDI when compared to the non-DSDI groups. The instructions provided to the DSDI group allowed them to more rapidly accomplish the tasks within each scenario, but these statistically significant time differences were determined to not be clinically significant and would not likely make a difference in overall patient outcome in this specific, relatively straightforward scenario. However, in a more complex and real-world scenario, this small but statistically significant difference may indicate the ability of DSDI to provide a clinically significant difference in patient outcomes due to a reduced time to intervention when several other factors are also at play. When utilized in a real medical emergency, bystanders will likely feel more stressed and anxious about the patient outcome, thus hindering their focus to retrieve and implement the necessary medical intervention. In addition, it may take more time to find the drone wherever it lands, compared to just down the hallway of the simulation room. The additional DSDI instructions would also be beneficial to assist the bystanders in knowing where and how to retrieve the medical kit amidst the loud sounds of a functional and flying drone, while also ensuring their safety. In this simulation, all participants were able to effectively administer the required medical intervention in a timely manner. This supports prior research that showed bystanders are willing and able to utilize a medical drone and kit to respond to an out-of-hospital emergency while also suggesting this model could be utilized in limited resource areas with minimal to no capabilities for dispatcher pre-arrival instructions.[1,2] The suggestions that were offered independently by participants in the non-DSDI group were quite similar to the DSDI group, suggesting that DSDI would be appreciated by bystanders. These data clearly reflect an interest in and appreciation for DSDI among study participants. In addition, the data reflects the novelty of the concept and system; participants were unaware of what to expect in dispatcher instructions, so even brief instruction to go outside, find the drone, and return with its medical kit was considered to be step-by-step instructions by most participants. Some participants potentially even considered the audio safety cues from the drone itself to be considered drone-specific instructions.

However, the clinically significant differences in the safety of participants between the two groups will be critical to implementing drones in EMS. The large difference in the ability of participants to follow safety protocols between the DSDI and non-DSDI groups suggests that DSDI should be developed and integrated into dispatch pre-arrival protocols to ensure safety during implementation of a drone-based emergency response system for bystander intervention prior to EMS arrival.

The findings of our study emphasize the importance of addressing the cognitive load of bystanders in highly stressful situations. Interestingly, participants who did not receive DSDI reported more favorable responses to dispatch instructions while using the AED, despite instructions at this point being the same for both groups. Video review suggested this was related to incidental conflict between AED audio instructions and the EMD's verbal instructions, as participants struggled to focus on both. A potential explanation is participants misidentifying the normal MPDS telecommunicator CPR instructions at this point as DSDI during their SSI responses. A potential solution is for the dispatcher to simply refer the participant to the audio instructions from the AED. This supports the concept that cognitive overload with respect to dispatch instructions is an important factor in the development of a functional drone-based bystander response system with DSDI. Understanding how to mitigate this conflict is important for long-term success of DSDI implementation.

The small sample size resulted in randomization failure, and limited generalizability, as demonstrated by the male predominance (75%) in the OHCA group, and the female predominance (83%) in the anaphylaxis group. All but one participant (11/12) in the non-DSDI group responded to all survey questions. The participant group was more highly educated than the average United States population. The drone in the simulation was a stationary prototype, which may have influenced participants' perception of the drone's safety and account for some non-DSDI participants approaching the drone prematurely. This simulation was performed entirely indoors, so participants did not endure any environmental conditions that could have altered their interactions with the drone or the dispatcher. Participants did not walk far or search for the drone, which may take more time in a real-world scenario. Thus, further studies utilizing an airworthy prototype are needed to investigate the impact of refined DSDI on the safety of interactions between bystanders and flying drones, as well as the ability to reduce time to intervention and improve patient outcomes during a broader and more complex range of high fidelity simulated emergency medical scenarios to enhance the scope and applicability of the findings.

Conclusions

In this simulation study, emergency medical drones were used to deliver time-sensitive medical interventions that can be administered by bystanders. The results demonstrated that bystanders were able to effectively administer the required medical interventions during OHCA and prehospital pediatric anaphylaxis emergencies. While there was no clinically significant difference in time to intervention between the groups that received DSDI and those that did not, participants who received DSDI exhibited better adherence to drone safety cues and articulated significant appreciation towards the dispatcher's instructions. This study highlights the importance of incorporating DSDI with the use of emergency medical drones in areas that can support pre-arrival instructions. Further development and integration of DSDI into MPDS pre-arrival protocols should be prioritized to ensure the safety of bystanders when interacting with unmanned drones during medical emergencies.

CRediT authorship contribution statement

Emma E. Davidson: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation. **Jason A Correll:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Adam Gottula:** Writing – review & editing. **Laura R. Hopson:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Thomas B Leith:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Noor K. Majhail:** Writing – review & editing, Investigation. **Emily J. Mathias:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **James M Pribble:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Nathan B. Roberts:** Writing – review & editing, Writing – original draft, Investigation. **Isabella G. Scott:** Writing – review & editing, Investigation. **James A. Cranford:** Writing – review & editing, Validation, Formal analysis, Data curation. **Nathaniel Hunt:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Christine M. Brent:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Christine M. Brent reports financial support was provided by Toyota Motor Corporation. James M. Pribble reports financial support was provided by Toyota Motor Corporation. Laura R. Hopson reports financial support was provided by Toyota Motor Corporation. Emily J. Mathias reports financial support was provided by Toyota Motor Corporation. Nathaniel Hunt reports financial support was provided by Toyota Motor Corporation. Christine M. Brent reports a relationship with the Medical Control Authority of Michigan that includes: board membership. Co-author employed by Emergent Health Partners – E.E.D. Co-author employed by Emergent Health Partners – I.G.S. Co-author employed by Emergent Health Partners – N.K. M. Corresponding author employed as EMS Medical Director – C. M.B. Co-author employed as EMS Medical Director – N.H. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The study team acknowledges Kristine Kasten (KK) for assistance in understanding MPDS protocols and developing drone-specific dispatch instruction materials and Tyler Nix for his assistance with background research and literature review. We acknowledge Jonah Matthisson and Isabell Lott for assistance in running the simulations.

We thank Toyota Motors North America Research and Development for providing the simulation recording technology.

Funding

This work was supported by Toyota Motor North America Research and Development. The study sponsors were not involved in the study design, collection of data, analysis, and interpretation of data, or in the writing or submission of the manuscript. REDCap electronic data capture and participant registry tools (i.e., UMHealthResearch) leveraged in the study were hosted at the Michigan Institution for Clinical & Health Research (grant support (CTSA: UL1TR002240)).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100652.

Author details

[a]*University of Michigan School of Nursing, 426 North Ingalls Street, Ann Arbor, MI 48109 USA* [b]*Emergent Health Partners, LLC, 1200 State Circle, Ann Arbor, MI 48108 USA* [c]*Department of Emergency Medicine, University of Michigan Medical School, 1500 East Medical Center Drive, Ann Arbor, MI 48109 USA* [d]*College of Literature, Science and the Arts, University of Michigan, 500 S State St, Ann Arbor, MI 48109 USA*[e]*University of Michigan Medical School, 1515 E Medical Center Dr, Ann Arbor, MI 48109 USA* [f]*Department of Anesthesiology, Division of Critical Care, University of Michigan Medical School, 1500 East Medical Center Drive, Ann Arbor, MI 48109, USA*

REFERENCES

[1]. Zegre-Hemsey JK et al. A feasibility study to assess delivery of automated external defibrillators via drones in simulated cardiac arrest-users' experiences and the human-drone interaction. Circulation 2019;140.

[2]. Sanfridsson J et al. Drone delivery of an automated external defibrillator - a mixed method simulation study of bystander experience. Scand J Trauma Resusc Emerg Med 2019;27:40.

[3]. Mell HK et al. Emergency medical services response times in rural, suburban, and urban areas. JAMA Surg. 2017;152:983–4.

[4]. Cui ER, Fernandez AR, Zegre-Hemsey JK, et al. Disparities in emergency medical services time intervals for patients with suspected acute coronary syndrome: findings from the north carolina prehospital medical information system. J Am Heart Assoc. 2021;10(15):e019305.

[5]. Mueller LR, Donnelly JP, Jacobson KE, Carlson JN, Mann NC, Wang HE. National characteristics of emergency medical services in frontier and remote areas. Prehospital Emerg Care off J Natl Assoc EMS Physicians Natl Assoc State EMS Dir. 2016;20 (2):191–9. https://doi.org/10.3109/10903127.2015.1086846.

[6]. Cui ER, Beja-Glasser A, Fernandez AR, Grover JM, Mann NC, Patel MD. Emergency medical services time intervals for acute chest pain in the United States, 2015–2016. Prehospital Emerg Care off J Natl Assoc EMS Physicians Natl Assoc State EMS Dir. 2020;24(4):557–65. https://doi.org/10.1080/10903127.2019.1676346.

[7]. Alanazy ARM, Wark S, Fraser J, Nagle A. Factors impacting patient outcomes associated with use of emergency medical services operating in urban versus rural areas: a systematic review. Int J Environ Res Public Health. 2019;16(10):E1728. https://doi.org/10.3390/ijerph16101728.

[8]. Carrillo-Larco RM, Moscoso-Porras M, Taype-Rondan A, Ruiz-Alejos A, Bernabe-Ortiz A. The use of unmanned aerial vehicles for health purposes: a systematic review of experimental studies. Glob Health Epidemiol Genom. 2018;3:e13.

[9]. Malta Hansen C, Kragholm K, Pearson DA, et al. Association of bystander and first-responder intervention with survival after out-of-hospital cardiac arrest in North Carolina, 2010–2013. JAMA. 2015;314(3):255–64. https://doi.org/10.1001/jama.2015.7938.

[10]. Hansen CM, Kragholm K, Granger CB, et al. The role of bystanders, first responders, and emergency medical service providers in timely defibrillation and related outcomes after out-of-hospital cardiac arrest: Results from a statewide registry. Resuscitation. 2015;96:303–9. https://doi.org/10.1016/j.resuscitation.2015.09.002.

[11]. Bogle BM, Rosamond WD, Snyder KT, Zègre-Hemsey JK. The case for drone-assisted emergency response to cardiac arrest: an optimized statewide deployment approach. N C Med J. 2019;80 (4):204–12. https://doi.org/10.18043/ncm.80.4.204.

[12]. Boutilier JJ, Brooks SC, Janmohamed A, et al. Optimizing a drone network to deliver automated external defibrillators. Circulation. 2017;135(25):2454–65. https://doi.org/10.1161/circulationaha.116.026318.

[13]. Pulver A, Wei R, Mann C. Locating AED enabled medical drones to enhance cardiac arrest response times. Prehosp Emerg Care. 2016;20(3):378–89. https://doi.org/10.3109/10903127.2015.1115932.

[14]. Derkenne C, Jost D, Miron De L'Espinay A, et al. Automatic external defibrillator provided by unmanned aerial vehicle (drone) in Greater Paris: A real world-based simulation. Resuscitation. 2021;162:259–65. https://doi.org/10.1016/j.resuscitation.2021.03.012.

[15]. Chu J, Leung KHB, Snobelen P, et al. Machine learning-based dispatch of drone-delivered defibrillators for out-of-hospital cardiac arrest. Resuscitation. 2021;162:120–7. https://doi.org/10.1016/j.resuscitation.2021.02.028.

[16]. Schierbeck S, Svensson L, Claesson A. Use of a drone-delivered automated external defibrillator in an out-of-hospital cardiac arrest. N Engl J Med. 2022;386(20):1953–4. https://doi.org/10.1056/NEJMc2200833. PMID: 35584161.

[17]. Hardeland C, Olasveengen TM, Lawrence R, et al. Comparison of medical priority dispatch (MPD) and criteria based dispatch (CBD) relating to cardiac arrest calls. Resuscitation. 2014;85(5):612–6. https://doi.org/10.1016/j.resuscitation.2014.01.029.

[18]. International Academy of Emergency Medical Dispatch. Medical Priority Dispatch System QA Guide v13. Salt Lake City: Priority Dispatch Corporation; 2016.

[19]. Tanaka Y, Taniguchi J, Wato Y, Yoshida Y, Inaba H. The continuous quality improvement project for telephone-assisted instruction of cardiopulmonary resuscitation increased the incidence of bystander CPR and improved the outcomes of out-of-hospital cardiac arrests. Resuscitation. 2012 Oct;83(10):1235–41. https://doi.org/10.1016/j.resuscitation.2012.02.013. Epub 2012 Feb 23 PMID: 22366353.

[20]. Ballesteros-Peña S, Fernández-Aedo I, Vallejo-De la Hoz G, Etayo Sancho A, Alonso PA. Quality of dispatcher-assisted vs. automated external defibrillator-guided cardiopulmonary resuscitation: a randomised simulation trial. Eur J Emerg Med. 2021 Jan 1;28 (1):19–24. https://doi.org/10.1097/MEJ.0000000000000715. PMID: 32925478.

[21]. Banerjee P et al. Every one-minute delay in EMS on-scene resuscitation after out-of-hospital pediatric cardiac arrest lowers ROSC by 5. Resusc. plus 2021;5 100062.

[22]. Sutter J, Panczyk M, Spaite DW, et al. Telephone CPR instructions in emergency dispatch systems: qualitative survey of 911 call centers. West J Emerg Med. 2015;16(5):736–42. https://doi.org/10.5811/westjem.2015.6.26058.

[23]. Wise SL, Freeman CL, Edemekong PF. EMS Pre-Arrival Instructions. In: *StatPearls*. StatPearls Publishing; 2021. Accessed August 11, 2021. http://www.ncbi.nlm.nih.gov/books/NBK470543/.

[24]. CriteriaBasedDispatchGuidelines-Rev2010.pdf. Accessed August 19, 2021. https://www.emsonline.net/assets/CriteriaBasedDispatchGuidelines-Rev2010.pdf.

[25]. Harve H, Jokela J, Tissari A, et al. Can untrained laypersons use a defibrillator with dispatcher assistance? Acad Emerg Med off J Soc Acad Emerg Med. 2007;14(7):624–8. https://doi.org/10.1197/j.aem.2007.03.1353.

[26]. Creswell, J. W. author & Plano Clark, V. L. Designing and conducting mixed methods research. (SAGE, 2018).

[27]. Ornato JP et al. Feasibility of bystander-administered naloxone delivered by drone to opioid overdose victims. Am J Emerg Med 2020;38:1787–91.

[28]. Glei DA, Goldman N, Ryff CD, Weinstein M. Can we determine whether physical limitations are more prevalent in the US than in countries with comparable life expectancy? SSM - Popul. Health 2017;3:808–13.

[29]. Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology 2006;3:77–101.

[30]. Saunders B et al. Saturation in qualitative research: exploring its conceptualization and operationalization. Qual. Quant. 2018;52:1893–907.