Aerial drones for blood delivery

Geoffrey Ling[1,2] *and Nicole Draghic*[2]

Aerial drone technology is now in use to improve medical care, especially blood delivery. The use of aerial drones is broader than just this and includes aerial photography, express shipping and delivery, disaster management, search and rescue operations, crop monitoring, weather tracking, law enforcement, and structural assessment. This wide use promises to accelerate and, ideally, reduce the cost of technological advances of drones. By doing so, drone use offers the opportunity of improving health care, particularly in remote and/or underserved environments by decreasing lab testing turnaround times, enabling just-in-time lifesaving medical supply/device delivery, and reducing costs of routine prescription care in rural areas.

Although most people consider aerial drones a relatively recent phenomenon, they were actually conceived of during World War I as an automatic airplane. In 1911, Elmer Sperry, the inventor of the gyroscope, began to explore radio control as a means of remotely piloting aircraft. In 1915, he was joined by Dr. Cooper Hewitt, a pioneer in radio technology, and later by Carl Norden, the inventor of the Norden bombsight, and Thomas Edison. During World War I, the US Navy and Army had programs to develop an aerial torpedo and Kettering Bug, respectively. Interestingly, Orville Wright was a consultant to the Kettering Bug program. However, neither became operational, as radio technology (and other issues) to remotely control these unmanned aerial vehicles or aerial drones was too technologically immature for this purpose.[1] The need for unmanned aerial aircraft was heightened during World War II through the very high rate of loss of reconnaissance aircraft and their pilots. However, it wasn't until the Vietnam War that drones were successfully deployed for military operations. It is not surprising that shortly after introducing aerial drones for reconnaissance, drone operators used their platforms as aircraft of convenience to rescue service members. The first reported successful use of a drone for rescue was a when Gyrodyne QH-50 Drone Anti-Submarine Helicopter was dispatched to rescue a US special operations Marine. The Marine was able to grab the QH-50 skids and was then airlifted out of enemy territory to safety.[2]

Today, in addition to military use, drones are used in a variety of applications including aerial photography, express

ABBREVIATIONS: AEDs = automated external defibrillators.

From the [1]Division of Neurosciences Critical Care, Departments of Neurology, Neurosurgery and Anesthesiology-Critical Care Medicine, Johns Hopkins Medical Institutions, Baltimore, Maryland; and the [2]Department of Clinical Neurosciences, Inova Fairfax Hospital, Falls Church, Virginia.

Address reprint requests to: Geoffrey Ling, MD, PhD, Division of Neurocritical Care, The Johns Hopkins Hospital, 600 North Wolfe Street, Phipps 455, Baltimore, MD 21287; e-mail: gling1@jhmi.edu.

Received for publication August 31, 2018; revision received October 12, 2018, and accepted October 13, 2018.

doi:10.1111/trf.15195

TRANSFUSION 2019;59;1608–1611

shipping and delivery, disaster management, search and rescue operations, crop monitoring, weather tracking, law enforcement, and structural assessment. These successful uses of drone technology have sparked another frontier: medical logistics delivery.

By 2018, drones were already in use for natural disaster/humanitarian monitoring. For instance, following Hurricane Katrina and the Haiti earthquake, they were used for damage assessment and to deliver medicine and other supplies. The utility of drones for medical care is quite obvious. Drones enable improved response times and reduced transportation costs, particularly in remote and/or underserved environments. Conversely, the need for drones can also be true for urban areas, where congestion can be an impediment to emergency medical delivery.

Time is a critical aspect of health care. The Army stresses the importance of the "golden hour": The sooner a trauma patient reaches definitive care, particularly if it is within 60 minutes after injury, the better the chance for survival. Medical drones have the potential to improve lifesaving capabilities by reducing the time to transfer lab tests, blood, and medicines over long distances or to hard-to-reach remote areas. This review article summarizes recent advancements in the medical use of drones, highlighting the increased efficiency and reduced costs across a number of uses including blood delivery, laboratory testing, medical device delivery, and medication delivery.

BLOOD DELIVERY

Several companies have established the benefits of using drones for blood product delivery.

Blood is a vital but limited asset to health care, particularly in Africa. Certainly, accidents and trauma account for the majority of transfusion needs, but so too does the high prevalence of anemia caused by malaria and pregnancy-related complications. Life-threatening malaria is characterized by severe anemia, hypoglycemia, and brain involvement. World Health Organization statistics reveal that in Africa, at least 285,000 children under the age of 5 years died of severe malaria, which accounts for 41% of deaths among this cohort.[3,4] Infrastructure challenges, difficulty recruiting volunteer donors, and the lack of a national blood transfusion service adds pressure to a fragile logistics system.[5] Therefore, it is not surprising that many areas in Africa experience chronic blood shortages. Furthermore, delivering blood to where it is needed is typically by car or ambulance, which can be delayed and constrained by poor road conditions; the rainy season annually threatens some roads with complete washout. In fact, only one-third of Africans live within 2 kilometers of a road that functions year-round.[6]

In response to the urgent unmet need for available blood products, in 2016, San Francisco Bay–based Zipline launched a drone delivery operation in Rwanda. They began by establishing a drone port and blood distribution center with 15 drones to deliver blood, plasma, and platelets to regional medical treatment facilities.

Health care providers order blood via text message. When received, drone port operators prepare the blood payload and launch the aircraft. "Zip" drones have a flight range of 75 miles and can carry 3 pounds of blood. At the point of need, the blood payload is dropped via parachute to the waiting medical providers. Results have shown reduction in blood delivery time from 4 hours to just 30 minutes.

Since 2016, Zipline has flown over 4000 missions, covering 186,411 miles, and delivered 7000 units of blood. Approximately one-third of these deliveries have been emergency lifesaving situations. Zipline now delivers more than 20% of Rwanda's blood supply outside of the capital. In addition to its impact in lifesaving emergency situations, Zipline's just-in-time drone delivery has helped transform the country's medical supply chain. To service the whole country, Zipline is preparing to open a second drone port and distribution center in Rwanda.

In April 2018, Zipline unveiled a new generation of delivery drone. It is reported to be the fastest available commercial delivery drone. In addition, Zipline has improved its process such that the time between receipt of an order and launch of a delivery has dramatically decreased from 10 minutes to 1 minute. These new drones have a 33% increase in range and payload, and they now have a range of 99 miles carrying up to 3.85 pounds.[7]

Matternet, another aerial drone company, has successfully flown 1800 flights over Swiss cities and delivered 850 blood and pathology specimens in Lugano and Bern. It recently expanded operations to Zurich. Outside of Europe, Matternet has delivered medications in Haiti, the Dominican Republic, and New Guinea. The company also works with UNICEF and Doctors Without Borders.[8]

In addition to blood products, these platforms have been used to deliver vaccines, HIV therapies, and other medications such as snake antivenom.

LABORATORY TESTING

As with blood delivery, access to medical laboratory tests in Africa is hindered by poor roads. Fortunately, drones provide fast, cost-effective access to important diagnostic laboratory tests. Recent studies demonstrate that biofluid samples can be safely transported by drones without adversely affecting laboratory results. These studies were performed in ambient temperatures with a maximum length of flight up to 40 minutes. A 2017 study examined the effects on blood chemistry and hematology following drone flights of more than 3 hours in duration and under conditions of relatively high ambient temperatures as compared to control specimens that were neither flown or subject to high temperature. Blood specimens were then analyzed for serum sodium,

potassium, chloride, bicarbonate, urea nitrogen, creatinine, and glucose as well as WBCs; RBCs; hemoglobin; hematocrit; mean corpuscular volume; RBC distribution width; platelet count; and lymphocyte, monocyte, neutrophil, eosinophil, and basophil levels. Results from both groups were similar for 17 of the 19 tests. The two differences were serum glucose and potassium levels. These were higher in the flown samples. It is thought to be most likely due to higher temperature exposure during flight.[9] Consequently, it is recommended that there be rigorous temperature management in drone payload compartments.

MEDICAL DEVICE DELIVERY

Time is crucial in out-of-hospital cardiac arrest. A victim's chance of survival decreases by 7% to 10% for every minute that passes without defibrillation.[10]

Although automated external defibrillators (AEDs) have become widely distributed in urban areas such as malls, airports, schools, and sport venues, they are not as prevalent as one might think. In fact, only 17 (34%) US states require AED installation in at least some schools; the remaining states have no legislation. Several states have laws that require AEDs in other facilities and buildings but not in schools.[11]

In areas with known delayed Emergency Medical Service response times, lack of ready access to an AED is a valid concern. Drone-delivered AEDs may be a viable alternative. A recent study compared drone versus ambulance response time in delivering an AED and found that the median time from dispatch to drone launch was 3 seconds, and the median time from dispatch to arrival of the drone was 5.21 minutes, whereas the EMS median time for AED delivery was 22 minutes.[12]

US MILITARY

Logistics challenges are expected in a war environment, particularly as it pertains to delivery of medical supplies and evacuation of casualties. To meet these challenges, the Department of Defense is also investigating drones as a battle space platform for medical logistics delivery. The Defense Innovation Unit Experimental is presently working with a number of companies exploring drone use for this purpose. In early 2018, the Defense Innovation Unit Experimental began a program to develop an aerial drone that can deliver a 5-pound package over 100 kilometers in "austere environments". In 2017, the Defense Innovation Unit Experimental started working with Airspace to develop a drone capable of identifying, tracking, and autonomously removing adversary drones.

The Defense Logistics Agency is developing a drone delivery service to support contingency operations and natural disaster relief efforts. The first goal is to develop drones capable of picking up, transferring, and delivering food to military or civilian relief personnel.

The Marines are using drones to resupply troops on the battlefield. The Marines' Hive Final Mile project consists of a mobile application for placing orders to drone operations, an automated drone launcher (the Hive) capable of launching up to 32 drones simultaneously, software for managing flight paths, and a cloud storage component for maintaining a record of all flights and orders. When complete, users will simply place orders and specify dropoff locations via an app. Software selects the appropriate type of drone based on the order, and the drone is then dispatched.

MEDICATION

While the majority of Americans live in close proximity to a pharmacy, patients with chronic conditions living in rural areas may not. This makes refilling a standing monthly prescription more time consuming and costly. After disasters such as hurricanes, access to prescription drugs might be limited or nonexistent. For example, in 2004, after Hurricane Ivan struck Mobile, Alabama, more than one-half of the pharmacies in the affected areas had depleted supplies, and at least 26% had to ration medications to patients and prioritize distribution to patients. Five days after Hurricane Maria made landfall in Puerto Rico, only approximately 29% of pharmacies were open.[13]

QuiQui is a drone company delivering pharmacy products in San Francisco's Mission District. They operate 24 hours a day with an average delivery time of 15 minutes and a flat rate delivery charge of $1.

Flirtey is a Nevada-based drone delivery service that works with ambulance and medical providers to deliver medicine to rural health care clinics. Flirtey has also gone beyond medicine dispatches and partnered with Domino's Pizza and 7-Eleven to deliver food, drinks, and other consumer products. Flirtey had the first Federal Aviation Administration–approved drone delivery in July 2015, when it delivered medical supplies to a health clinic in Wise, Virginia. The delivery took only 3 minutes, whereas delivery via car took 90 minutes.[14]

COST/TIME SAVINGS

A recent Johns Hopkins study investigated drone delivery of vaccines. They found that using drones resulted in a logistics cost savings of up to $0.21 per dose when compared to traditional delivery. These results show that drones could increase vaccine availability and decrease costs over a wide range of settings provided the drones are used frequently enough to overcome the initial capital costs of installing and maintaining the system.[15]

In rural southwest Virginia, drones delivered prescription drugs in 3 minutes versus 90 minutes by car along a winding, bumpy road.[8] In Lesotho, Matternet's drones deliver blood samples from remote clinics to hospitals for HIV/AIDS testing in 15 minutes for a delivery cost of $0.24[16]

CONCLUSION

Drones are enabling improved health care delivery by providing faster response times, reduced transportation costs, and improved medical products/services to remote and/or underserved environments.

REFERENCES

1. Keane JS, Carr SS. A brief history of early unmanned aircraft. Johns Hopkins APL Tech Dig 2013;32(3):558-71.
2. [cited 2018 Oct 12]. https://www.airspacemag.com/military-aviation/dash-goes-to-war-23369442/
3. [cited 2018 Oct 12]. http://www.who.int/malaria/areas/high_risk_groups/children/en/
4. [cited 2018 Oct 12]. https://www.worldatlas.com/articles/the-leading-causes-of-death-in-the-african-continent.html
5. Osaro E, Charles AT. The challenges of meeting the blood transfusion requirements in Sub-Saharan Africa: the need for the development of alternatives to allogenic blood. J Blood Med 2011;2:7-21.
6. Khazan OA Drone to save the world. The Atlantic, 2016. [cited 2018 Oct 12]. https://www.theatlantic.com/technology/archive/2016/04/a-drone-to-save-the-world/476592/
7. [cited 2018 Oct 12]. www.flyzipline.com/
8. Drone delivery models for healthcare. Proceedings of the 50th Hawaii International Conference on System Sciences. [cited 2018 Oct 12]. https://pdfs.semanticscholar.org/622a/d97506e882bf30ba4dab9c0748ce540ecee3.pdf
9. Amukele T, Hernandez J, Snozek C, et al. Drone transport of chemistry and hematology samples over long distances. Am J Clin Pathol 2017;148:427-35.
10. [cited 2018 Oct 12]. http://www.heart.org/idc/groups/heart-public/@wcm/@ecc/documents/downloadable/ucm_438703.pdf
11. Sherrid M, Aagaard P, Serrato S, et al. State requirements for automated external defibrillators in American schools framing the debate about legislative action. J Am Coll Cardiol 2017;69:1735-43.
12. Claesson A, Bäckman A, Ringh M, et al. Time to delivery of an automated external defibrillator using a drone for simulated out-of-hospital cardiac arrests vs emergency medical services. JAMA 2017;317:2332-4.
13. Lavery AM, Patel A, Boehmer TK, et al. Notes from the field: pharmacy needs after a natural disaster — Puerto Rico, September–October 2017. MMWR Morb Mortal Wkly Rep 2018;67:402-3.
14. [cited 2018 Oct 12]. http://fortune.com/2016/03/25/flirtey-drone-legal-delivery-urban/
15. Haidari L, Brown ST, Ferguson M, et al. The economic and operational value of using drones to transport vaccines. Vaccine 2016;34:4062-7.
16. [cited 2018 Oct 12]. https://www.flexport.com/blog/drone-delivery-economics/