Usage of Unmanned Aerial Vehicles in Medical Services: A Review

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Abstract: The usage of drone technology has increased in a vast range of disciplines, including medical services. Drones can aerially deliver medical supplies and laboratory test samples during health emergencies such as the COVID-19 pandemic. It can also be used as a delivery device for an automated external defibrillator which might significantly increase the survival chances of out-of-hospital cardiac arrest victims. Significant cost savings compared with ground transportation and speed of delivery will probably drive drone implementation in various areas in the next few years.

Introduction

Unmanned aerial vehicle (UAV), also known as a drone is an aircraft operated without a human pilot on board [1]. This technology has already been deeply studied in the XX century. Their development is deeply associated with the military, where they had their initial use in World War II as targets for weapon accuracy practice [2]. Nowadays UAVs are revolutionizing civil society with technology that is advanced enough to be introduced to everyday life. Drones are used not only for public missions such as border surveillance or military training [3] but also in medicine and healthcare.

Through drones, the modern healthcare industry can improve the delivery of medical supplies to remote areas, provide access to automated external defibrillators (AED) for patients with cardiac arrest, provision disaster assessments, and deliver aid packages, vaccines, and medicines, blood [4]. In and after the era of COVID-19 UVAs were used in social distance inspection and Personal Protective Equipment (PPEs) delivery but also delivery of test kits, vaccines, and laboratory samples [5]. Because drones are generally resistant to dull, dirty, and dangerous missions [3], they are well suited for surveillance of disaster sites and areas with biological hazards [6]. The purpose of this review is to describe the most common healthcare applications of UVA technology and summarize current attempts to make pilotless aircrafts an inherent element of medical services and rescue. The main categories investigated in this article are: transporting and delivering medical supplies, samples, and biological material like blood or organs, delivering automated external defibrillators, searching for rescue operations, and drone usage during the COVID-19 pandemic.

Transportation

Biological Samples and Blood Products. Several reports have already demonstrated that using UVA technology for biological sample transportation does not affect the laboratory results if the temperature is ambient or cold and the time of flight is no longer than 40 minutes [7-9]. In the case

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of longer flights, lasting around 3 hours, particular attention needs to be paid to samples containing glucose and potassium, where 8% and 6.2% bias, respectively, were shown. Those changes were perceived as consistent with the magnitude of the temperature difference. Long drone flights of biological samples require stringent environmental controls to ensure consistent results [10]. However, there was no evidence of other significant effects on other blood components. Where the difference between the ambient and the unit temperature was approximately 20°C, there was no evidence of red blood cell hemolysis. Also, no significant changes in apheresis platelet count and pH were registered, which suggests that drone transportation is a viable option for the transportation of blood products [9]. Additionally, studies conducted on Borneo Island proved that drone transportation is more cost-effective than an ambulance. By estimating the Incremental Cost-Effectiveness Ratio we can conclude that the significantly shorter transport time of the drone offsets its cost per minute[11].

Organ and tissue transportation is also a field where UVA technology is promising. If made more efficient, the impact of transportation-related factors impacting transplantation outcomes could be substantially diminished. In April 2019, the company MissionGO cooperated with the University of Maryland Medical Center and for the first time delivered a kidney that was successfully transplanted.[12]. The model recently used for establishing parameters relevant for organ transportation was a six-rotor drone. Before and after the flight there was no drone-travel-related damage revealed[13].

Natural Disasters and Search and Rescue (SAR) Operation. Most natural disasters and mountain rescue victims are injured, lost or ill. According to the Wilderness Medical Society Practice Guidelines for Prevention and Management of Avalanche and Non-avalanche Snow Burial Accidents, it is crucial to reach the patient during the first hour of the rescue operation [14]. That is why the potential use of drones in searching for victims was investigated by the drone-snowmobile technique. This method is promising because a larger area can be searched faster compared to the classical line search technique [15]

Additionally, by using UVA technology it is possible to quickly respond to natural disasters by evaluating the damage and collecting real-time information. In Nepal after the earthquake in 2015 and in the Philippines after the typhoon in 2013 drones were used for mapping the most destroyed and needing help areas and determining road conditions [16].

Delivery of ADS. Out-of-hospital cardiac arrest (OOHCA) occurs often enough to alarm public health services and conduct additional research on the successful delivery of an automated external defibrillator(AED), especially since the use of AED significantly increases survival. Studies in Stockholm County showed that twenty locations were potential placements for a drone. The difference in response time of ambulances between urban and rural areas is substantial, which gives an opportunity to use UVA systems designed by using the Geographic Information System [17].

Another study was conducted in Salt Lake City County, where the current estimated travel time of an ambulance was compared to the estimated travel time of a network of AED-enabled medical drones. 96.4% of demands can be reached within 5 minutes using currently available emergency medical support vehicles and facility locations. Nevertheless, more factors need to be considered drone networks as a potential help in reducing the travel time of the AED [18].

In Wales the project Concept of Operation was developed, to identify the requirements associated with deploying the drone to deliver ADS beyond visual line-of-sight (BVLOS). Studies

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showed successful transportation of an ADS by parachute payload drops, final delivery of 4.5 km was completed in 2:50 minutes [19].

Nearby bystanders are their reactions play a considerable role in rescue and resuscitation. The simulation study evaluated the efficiency of a drone in providing the early location of a possible drowning victim in comparison with standard procedure. The median time from start to contact with the manikin was 4:34 min, which gives a shorter time than for the search party of surf lifeguards. A drone transmitting live video on a tablet may be used for providing an earlier location of submerged victims and is time-saving in comparison to traditional search parties [20].

Studies over bystander experience showed three main categories: technique and preparedness, support through conversation with the dispatcher, and aid and decision-making. None of the participants hesitated to retrieve the AED and all of them found the interaction with the AED drone less difficult than performing CPR or handling their own mobile phone during T-CPR, which makes good sense to continue studies on this topic in the future [21]. Using UAV technology was also proved as promising by studies piloted in the community of Caledon, Ontario. Drone-delivered AEDs may be feasible and effective, but successful uptake in smaller communities will require work on education about cardiac arrest literacy levels [22].

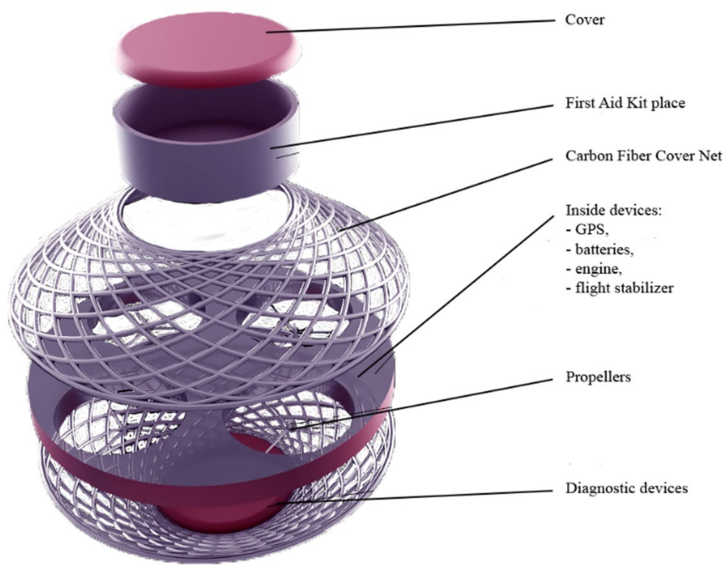

Fig.1. *Conceptual design of diagnostic-rescuing drone [23]*

Drones During COVID-19 Era

The pandemic period offered a real opportunity to use UAVs for providing healthcare support to the COVID-19 victims. Quick, effective, and contactless transport of vaccination and medication can help in reducing the number of infections. In case of a strict lockdown, drones can also be utilized for providing food and other supplies in areas the most affected by COVID-19 [24, 25]. Mini-drone systems can also provide real-time activities that can be used to pose a severe outbreak to community security [26]. Additionally, by using a thermal camera and high precision infrared, drone systems are capable of detecting victims of SARS-COV-2, squaring their temperature, or conducting the test, which also helps in detecting infected patients on a street. During the pick of the pandemic, China used drones to disinfect streets and distribute medications [27].

In September 2019 researchers conducted the first successful BVLOS mission to deliver diabetes medication. That showed the drone's capability to carry medical supplies reliably. In this state of crisis, this function could be used for the rapid delivery of medical supplies, as well as groceries, as witnessed in some parts of China, the USA, and Australia [23]

Conclusions
Until nowadays, drones were considered more as an essential component of militaries. This perception has changed what led to the explosion of the drone industry. As shown in this review, the potential for drone use in clinical microbiology, epidemiology, transportation of medical supplies and even mapping the virus spread is enormous.

UAVs may significantly increase access to health care for the communities lacking good infrastructure. However, challenges like legal medical issues or national airspace legalization need to be taken into consideration, which could also help in developing new transportation in healthcare and life-saving technology ideas.

Further work on the development of service flying drones will be an impulse for development both for works related to the construction of light internal combustion engines [28] and methods for the analysis of experimental data [29, 30] and scenarios of possible failures [31].

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