The Potential of Multi-rotor Drone to Strengthen Emergency Medical Service System: a preliminary study in a Chinese county

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Abstract

Objective: To explore the feasibility and advantage of using multi-rotor drones in a county emergency medical service system.

Methods: This study was conducted in Changxing County, Zhejiang Province from January to September 2018. We applied drones to simulate the transfer of first aid materials from health centers to the Changxing County People's Hospital. A total of 3 indicators were obtained: (1) The flight time of the drone; (2) The estimated time of ambulance dispatched from the county hospital was measured by Baidu map, Amap and Tencent map software; (3) The road transportation time measured by Amap software at 0: 00, 8: 00, 10:00, 12:00, 14:00, 16:00, 18:00, 20:00.

Results: A total of 10 health centers were included in this study. Linear distance from county people's hospital to these centers was (10.97±3.59) km, and the road distance was (13.61±4.95) km. (2) The flight time of drones were (16.35±5.15) min, less than road transportation time measured by Amap, Baidu, and Tencent map software, which was (21.40±5.15) min, (22.50±6.11) min, (22.00±5.23) min, respectively (P 0.01). The road transportation time measured using Amap software was longer than that of drones from 0:00 to 20:00 (P 0.01), with the maximum time of (27.80±6.12) min at 18:00, and the minimum time of (21.40±5.15) min at midnight. Drones could save up to 14.07 min at most and 2.8min at least, with an average save of (7.98±1.32) min.

Conclusions: Drone was faster than road transportation to transfer first aid medical supplies within a county. Further researches are needed to integrate drone into emergency medical service system.

Introduction

Conventional emergency medical service(EMS) system strengthening approaches to enhance coverage of quality healthcare, such as personnel training and capacity building, improved infra-structure and adequate health financing, develop gradually all over world. Recently, the National Health Commission of China has specifically emphasized the continuous advancement of emergency and critical care medical service in a county [1, 2]. Numerous counties in China are characterized by an underdeveloped economy, inconvenient transport system, insufficient medical resources, low first-aid level, and efficiency [3, 4]. Consequently, timely delivery of emergency medical resources to patients is a major challenge in a county.

Unmanned aerial vehicles (UAVs) technology has improved vastly over the past decade. It has strong flight maneuverability, which is not affected by ground traffic conditions, and can fly to the destination in an approximated straight line [5]. UAVs are classified based on criteria such as flight range, power source, size, operating altitude, and flight mechanism [6], and be regarded as a new strategy to address the public health needs of victims in disasters. Multi-rotor drones can be feasible in a variety of situations, including the delivery of merchandise [7], take-out food [8], and highway patrol [9]. Drones have further been proposed to deliver Automated External Defibrillators (AEDs) to the scene of a cardiac arrest [10], and the

rapid transfer of blood samples and drugs [11]. These studies were mainly in economically prosperous developed areas such as Canada or Sweden. However, there have been no reports on drone used in medical emergency system from rural areas of developing countries. The purpose of this study was to explore the feasibility and advantages of the application of drones in the county medical emergency system.

Materials And Methods

Study Design

We designed this simulation study to evaluate the efficiency of a multi-rotor drone in transporting first aid medical supplies within a county. The study was executed in Changxing County, from January to September in 2018. Participants were the Second Affiliated Hospital of Zhejiang University Medical College, Changxing County Health Bureau, Changxing County People's Hospital,10 health centers, and the Ant Network Company. the design and implementation of the overall research scheme were provided by the second affiliated Hospital of Zhejiang Medical University; The Changxing County Health and Health Bureau was responsible for the coordination of various medical institutions; The Changxing County people's Hospital and the health centers facilitated the preparation of drone take-off and landing sites. Antwork was responsible for the safety of the drone take-off and landing, the provided drones and the flight control, conducted flight route survey, and submitted approval to the air traffic control department.

Geography

The Changxing County is located in Zhejiang province, China: Huzhou, which on the north of Zhejiang low hills to the West Bank of Taihu plain transition area. The terrain is west high and east low, between latitude 30 °43'N and 31 °11'N, and longitude 119 °33'E to 120 °06'E. The total population is 0.64 million in a 1430 km^2 area. Changxing County is subdivided into 4 streets subdistrict, 9 towns, and 2 townships, each with a county health center. Each community is covered by a single municipally run ambulance service that is managed by the city or the municipal government.

Flight route selection

The network points of the drone flight were determined based on the geographical distribution of the hospitals in Changxing County and the maximum range of the drone (30km). In total, 10 health centers with a radius of 25 km, centered on Changxing County People's Hospital, were selected. Notably, n = 10 flights simulated first aid material transfer was presented for each flight. Specific geographic information and drone flight routes were obtained using Google Earth software (Google company, USA, see Fig. 1). The Drone took off and landed in an open space of 4 × 4m, there were no obstacles and shielding objects in vertical airspace (see Fig. 2). The Antwork company developed a preliminary flight route which avoided high population density areas and important buildings, then, they optimized routes after field surveys.

Flight plan

Jieyan TR7 multi-rotor drones were adopted (provided by the Hangzhou Antwork Co., Ltd., China), with the following specifications: the size of 1110 × 1272 × 501 mm; Warehouse volume of 25 L; Effective load of 7 kg; The power supply of 12s polymer lithium battery; The maximum flight speed of 16 m/s; the maximum range of 30 km; The maximum elevation limit of 2000 m. Each flight was made on sunny or cloudy days, with no strong wind, rainfall, snow, and haze, and an application was made to the air traffic control department in advance for approval. The drone has machine intelligence and cloud intelligence. Ordinary personnel can also achieve one-click control take-off, whereas a management background can monitor the whole flight in real-time, as well as technical personnel to provide on-site emergency support. We purchased third party liability insurance for UAVs. The flight using “beyond visual line of sight” technology [12], landing the drone at the scene, and bystander retrieval of the first aid medical supplies from the drone. The systems of the drones used global positioning system tracking as well as multiple communication techniques to locate the position of the drone at all times. The drone was set to 12.5 m/s, we recorded the flight time from the health centers to the county people's hospital. Time records were accurate to seconds.

We defined our feasibility outcomes as any barriers encountered that did not enable us to locate the drones, including, legislative barriers that would not allow us to fly the drones, issues that occurred during ascent, flight, or descent that prohibited the drone from landing on scene.

Data collection and analyses

Excluding the holidays, special events, and abnormal weather, the Baidu map(Beijing Baidu Netcom Science and Technology Co., Ltd, China) ,Tencent map (Tencent Technology Co., Ltd., China) and Amap(Autonavi Holdings Co., Ltd ,China) were used to determine the road traffic time from 10 health centers to Changxing County people's Hospital at midnight on the same day. Then, we used Amap to obtain the road traffic time of the above route at 0: 00, 8: 00, 10:00, 12:00, 14:00, 16:00, 20: 00. Each software consumed the shortest time scheme.

For descriptive statistics, we adopted SPSS version 20.0(IBM, Armonk, NY) Wilcoxon signed-rank test was used for comparative analysis between the Software group and the UAV group. A p-value of < 0.05 was considered statistically significant.

Results

The basic information for each hospital, the straight line distance, and the road traffic distance are shown in Table 1. The air distance for the 10 lines was less than the road traffic distance, (10.97 ± 3.59) km and (13.61 ± 4.95) km (P 0.05) respectively. The maximum difference was 6.2 km, the minimum difference was 1.02 km, with an average of (2.64 ± 1.71) km. No challenges were encountered during drone activation through dispatch, ascent, landing from the drone.

Table 1
Characteristics of Drone (Unmanned Aerial System) Flights vs Road Traffic

Health Center	Air Line Distance(km)	Road Traffic Distance (km)	Drone Flight Time (min)	Road Traffic Time (min)		
				Baidu Map	Tencent Map	Amap
Shuikou	10.1	14.1	15.33	24	23	22
Xiaopu	8.3	9.9	12.67	17	18	18
Meishan	19	23.6	28.2	33	33	31
Lincheng	15.2	21.4	21.93	32	28	29
Hongxingqiao	11.5	12.9	17.5	25	23	23
Lvshan	11.2	12.7	16.52	23	23	22
Lijiaxiang	10	11.7	14.9	19	20	19
Hongqiao	8	9.9	12.12	19	18	17
Huaxi	7.8	10.3	11.77	17	17	17
Jiapu	8.58	9.6	13.03	16	17	16
Mean	10.97 ± 3.59	13.61 ± 4.95*	16.35 ± 5.15#	22.50 ± 6.11	22.00 ± 5.23	21.40 ± 5.15
* Comparison of airline distance with road traffic distance, P 0.05;						
# Comparison of drone flight time with road traffic time measured by Baidu map, Tencent map, and Amap, P 0.05						

Comparing UAV Flight time with road travel time measured using the three Software at midnight: The drone flight time for 10 lines was (16.35 ± 5.15) min, all of which were less than the road travel time measured by Amap, Baidu map and Tencent map software, including (21.40 ± 5.15) min, (22.50 ± 6.11) min, (22.00 ± 5.23) min (All P 0.01,see Table 1).

Comparing flight time of UAV with road travel time measured by Amap at different time points in a single day. The average flight time of UAV was remarkably smaller than the road traffic time measured using Amap at different time points in a day, particularly at 18:00 (see Fig. 3).

Discussion

This study examines the effect of multi-rotor drone on rapid transport of medical supplies in Changxing County, China. We demonstrated it was feasible to establish a drone based medical supplies transfer system in a county, and the drone flights spent less time compared to road transportation. To our

knowledge, no investigation has reported the multi-rotor drone to transport first aid supplies in a county emergency medical service system.

In this study, we analyzed the results from 10 drone flights and the data form three map software at midnight, and then we compared flight time of UAV with the road travel time measured by Amap at different time points in one day. These three electronic maps were the mainstream products in China, and the travel time data from them were accord with the real traffic conditions. The road travel distance provided by map software from 10 health centers to county people's hospitals were 23.6km at maximum and 9.6km at mimimum, with an average distance of (13.61 ± 4.95) km. In one day, the best traffic condition was at midnight and it took (21.40 ± 5.15) min, whereby it increased to (27.80 ± 6.12) min at 6pm. The flight time of the UAVs were (16.35 ± 5.15) min, whereby 14.07 min was saved at most, 2.8min at least, and (7.98 ± 1.32) min on average compared to road traffic. It was evident that the use of drones for transporting first-aid materials in Changxing County had a better time advantage over road transport. We were able to perform all 10 test flights without any notable issues in terms of drone ascent, drone flight. Moreover, the flight speed of the drone in this study was set at 75% of the maximum value. Notably, if a faster speed was accepted, or the traffic conditions could get worse, or even the road was interrupted, consequently, the use of the drone was advantageous.

Remarkably, the findings presented in our work are consistent with reports from previous research. For instance, time saved by drones was of great significance for the rescue of patients with cardiac arrest outside the hospital [13, 14]. Claesson *et al.* used drones to transfer the AED to the scene, which they showed to be faster than ambulances. They integrated drones with geographic information systems to deliver AEDs in rural and urban areas, which saved 19 min and 1.5min, respectively [15, 16]. Besides, the use of drones may contribute to a rapid search for drowning victims as well as snow disaster victims [17, 18].

Currently, the distribution of emergency medical resources in the world is unbalanced [19, 20]. The equitable allocation of health resources helps to deliver effective resources to those most in need and to ensure accessibility to basic health services and fairness for vulnerable populations [21]. Some studies showed that one of the effective measures to improve survival in patients with cardiac arrest was to optimize response time [22, 23], another research suggest that drone-delivered AEDs can improve outcomes for out-of-hospital cardiac arrest victims. Therefore, drones can be an important component of EMS in these remote regions and communities. For example, during the outbreak of the new corona virus disease [24], the public transport operations were stopped and the community were quarantined, which result in the health service stations were short of medical support. Therefore, there is an urgent need to establish an air transport network for the timely and rapid distribution of medical inspection goods and materials.

With the focus of the world health organization on primary health care, we can fully utilize the advantages of drones to establish a UAV emergency logistics network. As a result, this will improve the

EMS system in rural and remote areas, optimization of emergency medical resource allocation, and advance the level of EMS system.

Study Limitation

This feasibility study has a few limitations. First, we used a flight to simulate the transit of first-aid supplies, which was not an actual clinical emergency. However, this was the first time that drones were used in the pioneering research of county EMS system in China with great scientific significance. Second, our flights occurred during optimal weather conditions (sunny with little wind) and may not be replicated in windy or colder environments. Thirdly, the road traffic time in this study was obtained using three map software, which may not be accurately consistent with the actual transport or ambulance. Thus, we got data from three kinds of independent mainstream electronic map software, to better reflect the actual traffic situation.

Conclusion

This study demonstrates that drones are faster and reliable when transporting first-aid medical supplies between health centers within a county when compared to road transport. However, further research is required to optimize the integration of drones into the emergency medical response system.

Declarations

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Authors' contributions

Minhai Zhang, Qiang Li, Mao Zhang, Fangmin Ge conceived the study.Minhai Zhang, and Zafar Ullah Khan drafted the manuscript, did the literature search and the statistical analysis. Mao Zhang, and Lin Shi critically revised the manuscript.All authors shared trial data, gave crucial feedback on the protocol, and provided critical revision for and approved the final version of the manuscript.

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Availability of data and materials

The datasets of the study are available from the corresponding author on request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Abbreviations

EMS: Emergency Medical Service; UAVs: Unmanned Aerial Vehicles; AED: Automated External Defibrillator.

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Figures

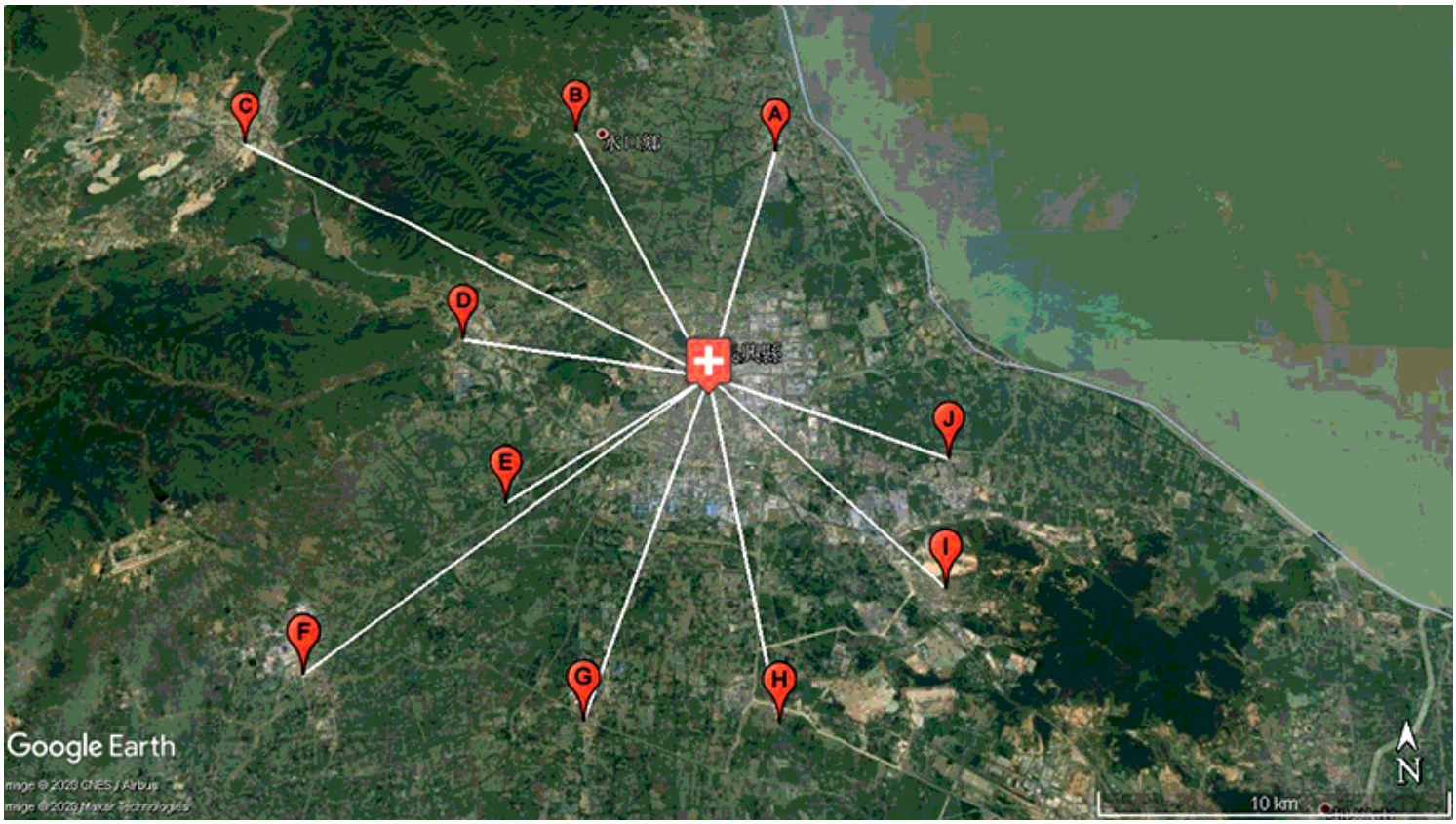

Figure 1

The geographical location of health centers in Changxing County and the drone flight routes. Note. A Jiapu Health Center, B Shuikou Health Center, C Meishan health center, D Xiaopu Health Center, E Huaxi Street health center, F Lincheng Health Center,G Hongxingqiao Health Center, H Lvshanxiang Health Center, I Lijiaxiang Health Center,J Hongqiaozhen health center.)

Figure 2

Drone landing at health center.

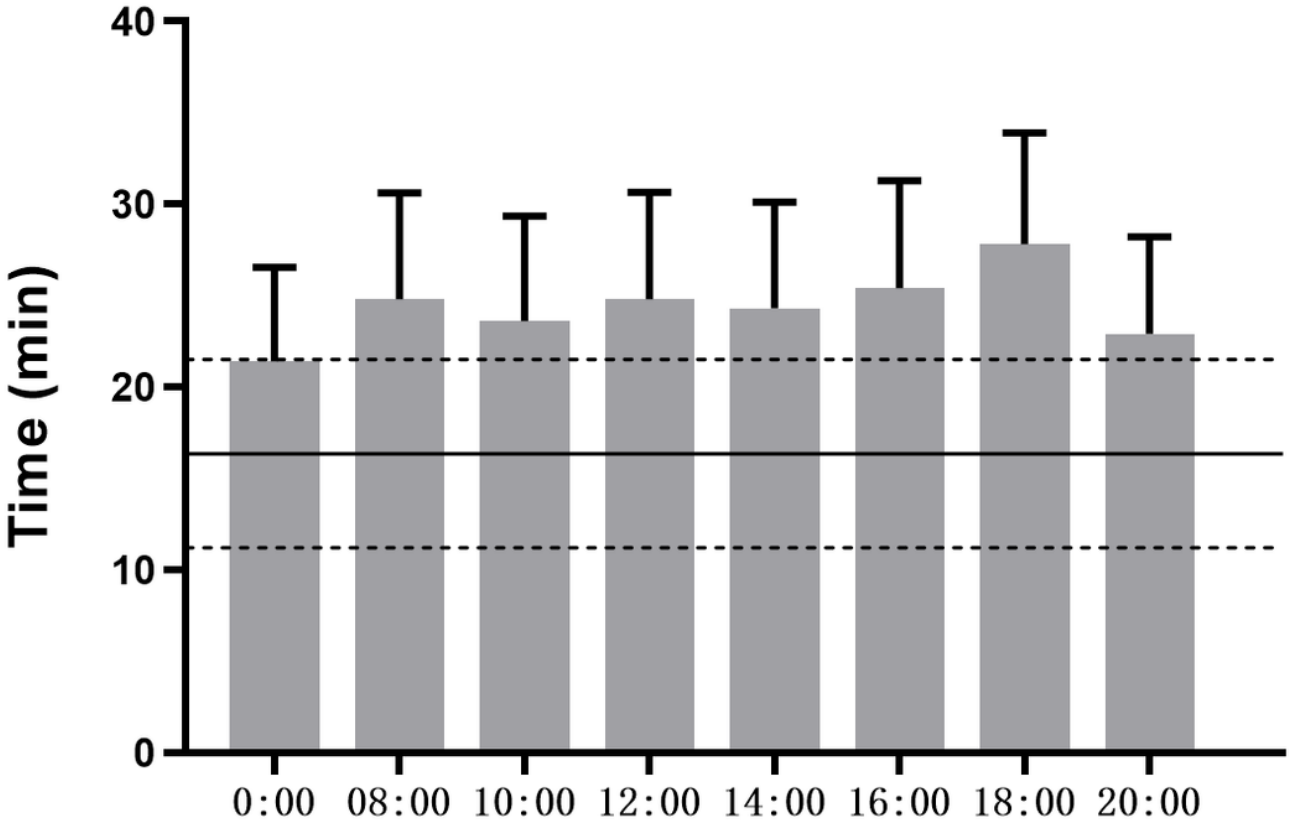

Figure 3

Comparison of drone flight time with road travel time measured using Amap. Note. The solid line was the mean time of UAV, while the dotted line was the standard deviation