Fast Delivery of life saving medical supplies in rural areas of Ethiopia

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Abstract

Background: Ethiopia's maternal mortality rate is among the highest in the world with 470 deaths per 100,000 live births. Every year post-partum hemorrhage (PPH) remains the leading cause of maternal mortality in Ethiopia. The problem is worse in the rural setting where there are not proper facilities and trained health workers to administer injectable medicine. Currently, the methods used by health centers in rural areas include referring the patient to the nearest hospital within a short period of time even though most of patients die in the ambulances without reaching the hospitals in nearby.

Method: In this project, the design of rotary-wing unmanned aerial vehicle (UAV) with thermoelectric cold-box system is proposed. The temperature of blood bag is controlled by a thermoelectric cooler working based on the Pieter effect. The blood is transported to rural health centers through UAV, and the blood containing box will release it from higher altitudes using servo dropping mechanism.

Results: The prototype was built and undergone through different iteration process. The proposed device was tested for safety, delivery time, bioavailability, range of operation, weight of the package and durability. For this design, the drone was flown a distance of 10km with less than 15 minutes while 100 meters above the ground.

Conclusion: The proposed project has a clinical significance such as saving the lives of mothers and the child. Through the design of a UAV, the transportation of medical and biological component is feasible. The use of UAVs for medical supply delivery will considerably reduce the number of people admitting to the hospital and, therefore, minimizes the cost of medical services that comes with hospitalization.

Keywords: Maternal mortality UAV PPH Thermoelectric cooler Blood Vaccines

Background

In Sub-Saharan Africa, more than 250,000 women die each year due to complications related to pregnancy or child birth [1,2]. According to WHO (world health organization) report, Ethiopian's maternal mortality rate is recorded as one of the highest in the world with 470 deaths with 100,000 live births [3]. Direct and indirect causes can contribute to the maternal death. Hemorrhage, infection, hypertensive disorders and obstructed labour are considered as direct causes while the indirect one includes concurrent diseases that are complicated during pregnancy [1]. Postpartum hemorrhage (PPH) is defined as the loss of more than 500 ml blood after delivery [4,5,8]. However, for the clinical purpose any amount of blood loss that could potentially result in hemodynamic instability should be considered PPH [5]. It remains to be the leading cause of maternal mortality in developing countries like Ethiopia [3]. The problem is worse in resource poor setting where there are not proper facilities, such as refrigerator, and skilled healthcare givers to administer injectable uterotonics, which are the standard treatment for PPH [3,6,7]. Blood transfusion can be a life-saving medical intervention [10,11], and a vital reason for improving blood transfusion is to reduce maternal mortality rate. However, it is the least available service in district hospital, Ethiopia [3]. In African countries, one of the reasons identified is the challenge to provide access to blood due to infrastructure limitation [3.9]. Insufficient and unreliable cold storage capacity to accommodate the different types of blood and other medications required has been reported as a challenges [12].

To treat mother's suffered from postpartum hemorrhage and patient with a severe anemia, several techniques have been used. Of these oxytocin is a standard medical therapy that is routinely administered for prevention and treatment of PPH [3,6,7,13,14]. However, the cost and the need for a skilled person to inject could compromise its acceptability [3]. Misoprostol has also been

used as both prevention and treatment of PPH. Although the delivery of misoprostol reduces maternal mortality rate and could have advantages as it is easy to use and relatively cheap, it has been reported relatively less effective than oxytocin [3, 15-18]. The methods, currently, used by health centers in rural Ethiopia includes referring the patient to the nearest hospital within a short period of time [19,27]. However, these solutions create a problem most of the time because, the roads from rural areas to urban hospitals are not always as stable physically and provide a speedy transportation to patient as the result of this patient's die in the ambulances without reaching the hospitals in nearby. The other problem with the existing solution is mothers who delivered child safely by using medication have a high risk of developing severe anemia which requires immediate blood transfusion. Although the medications provide short-term solutions blood transfusion is must to solve the problem reliably. In Ethiopia, blood is not stored at rural health center because of inadequate blood, unavailability of material for the proper storage and unavailability of 24-hour electricity [3]. Also transporting blood and medical supplies by road is often a long and difficult process in Ethiopia because of limitation of infrastructure such as road, and number of ambulances [20]. These all limitation makes any health center in Ethiopia not to make any blood transfusion for birth giving mothers. In this project unmanned aerial vehicle with its own cooling system is proposed. Using a modified drone to implement a medical supply delivery system which carries blood first-aid equipment, medicine and other medical supplies, Ethiopian's health care system can eliminate the unnecessary burdens that families face and at the same time play a vital role in the development of technology in the medical arena.

Methods

Proposed Design

The design can be classified into two major parts based on the functions it provides. The first part is the unmanned aerial vehicle part which is designed to carry a payload to remote areas with automated navigation. The second design is the design of storage system called the cold-box for the safety of the blood transported the system contains a cooling unit and automatic temperature controlling system to carry bloods, vaccines and other medical supplies at the required temperature. The unmanned aerial vehicle consists of both software and hardware parts. The most common hardware components involved in prototyping include GPS (Global positioning system) and compass, flight control unit, data transmission module, data receiving module, remote controller, DC (direct current) motors and on screen display. Using these components, the UAV's body design was developed to allow for an appropriate implementation of each component while carefully considering the weight, the balance, and the drone's overall center of mass. The most important electrical component used for prototyping is flight controller. It is essentially the brains of UAV, which allows the drone to maintain balance, and it does this by gathering data through sensors and computing for the necessary changes for the motors. **Figure 1** show functional block diagram of the rotary-wing unmanned aerial vehicle and with thermoelectric cooler. The list of components used for designing cold box includes thermoelectric cooling system, LM35 temperature sensor, 12V battery and Arduino Uno microcontroller. **Figure 2** shows the flow chart of the cold-box design. The thermoelectric cooler designed operates with LM35 temperature sensor and DC fan to control the storage temperature of the cold-box. The blood during transportation needs to be maintained at standard temperature range to maintain at a normal condition. The LM35 senses the temperature of the cold box and compares with the standard temperature stored by the UAV. The thermoelectric cooler then reduces the temperature of the cold-box based on the temperature range measured by the LM35 temperature sensor.

Results

Final design

The design of the UAV and the cold box prototype has gone through different iteration processes to come up with the final working design of our project. In addition to this changes have been made to the design of our project. The design team modified the first proposed initial design until designing the final design. **Figure 3** shows parts of the final design (from left to right: from top to bottom). The following components has been used in the final design: S500 Multi-Rotor Air-Frame, Pixhawk Flight controller, X8R Receiver, GPS, Taranis transmitter, propeller, safety switch, Arduino UNO, Brushless DC motor, Lipo Battery, Lightweight material to make the package, servo motor, servo controller, DC fan, and LCD (liquid crystal display). **Figure 4** shows the final design of cold box and constitute in the quadcopter drone. Functional testing, electrical safety and performance testing have been done in order to verify whether the design criteria and specification were fulfilled. **Table 1** shows the test results (**see** at the end of the conclusion part)

Discussion

In Ethiopia, mothers who live in rural areas suffering from bleeding related complications even though the government has taken serious measurements. Medications, oxytocin and misoprostol, have been used for the management and prevention purpose [13-18]. However, they might bring severe anemia which requires immediate blood transfusion. This indicates that a fast and simple blood delivery mechanism is needed. In this study a device can deliver blood and other critical medical supplies to rural areas of Ethiopia is designed with appropriate controlling temperature mechanism. Drone technology is increasingly being used for medical purposes such as transporting blood, vaccines and organs in some countries [24]. In Rwanda, the collaboration of the government

with drone company (Zipline) makes it possible to deliver blood from the center to its rural areas. However, the designed device has no any cooling system which maintains the blood at optimum temperature, it has been used for a short trip [21, 22]. In the united states, manned aircraft was also proposed to reduce maternal mortality rate by delivering blood to critical access hospitals. However, risks to the flight crews travelling in remote areas was a great concern [23]. In 2016, pilot drone project was conducted and successfully delivered drugs and laboratory samples to rural places in Madagascar. Although it was a promising innovation, limited flight range, due to lack of cooling system placed inside the drone, was reported as a limitation [25]. The major challenges in the use of medical drone is the legal permission from Aviation Authorities in some countries like India [24]. Mostly bloods being delivered by the drone was jeopardize due to temperature difference during the flight [26]. So there must be appropriate temperature management in drone payload compartments. Our method provides reliable blood delivery mechanism with temperature controlled device. While the designed device meets desired objectives, it delivers medical supplies to a short distance. This is only due to low battery capacity which can be replaced by another powered battery that makes it possible to long distance travel with longer periods. On the other hand, unmanned aerial vehicle implemented in both Rwanda and Madagascar couldn't travel longer distance with keeping medical products at desired temperature for safety [21,22,25]. The proposed design provides high level of safety. It can also be used for transporting organs for transplantation.

Conclusion

In conclusion, this project provided insight on the feasibility of the objectives set out to be achieved. The design team successfully designed and built a drone with an arm attachment (for the cold box) to enhance the successful transportation of blood and other critical medical supplies.

Thus, the design and testing of the drone successfully demonstrated the concept feasibility of implementing blood and other critical medical supplies delivery drones in the health care system of Ethiopia.

Table 1: design objectives and their test results

No	Feature to be tested	Input	Method	Design specification	Result
1.	Delivery Time	Enumerating the time	Measuring the time using timer	Maximum of 10±5 delivery time	The time is in the range
2.	Safety	The storage temperature	Sensor, the LM35 temperature sensor	2°C-8 °C	The cooling of the thermoelectric cooler
3.	Weight of the package	The package loaded to the drone	Measuring the weight of the drone	The weight of the payload should be < 2.4Kg	The weight < 2.4Kg
4.	Range of operation	The distance traveled by the drone	Measuring the speed and time of flight	Up to 10Km	Operating range is below 10Km
5.	Bioavailability	The storage temperature of the UAV	The measurement of the temperature sensor	The material from which the cold box is manufactured	The reduced environmental effect on the cold box
6.	Durability	Physical analysis of the drone	Analyzing and calculating the service life of the drone	The strength of the different components	The components are good quality and light weight

Abbreviations

UAV: Unmanned aerial vehicle; GPS: Global positioning system; PPH: postpartum hemorrhage; WHO: World Health Organization; DC: Direct current; LCD: Liquid crystal display

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Authors' contribution

BF, AA, LG, ST, DO are investigators of this study and they conceptualized, designed, and implemented. All authors contributed to the preliminary study, the design, prototyping and testing. This study was initiated by LG. The article was drafted by BF, taking into account the comments and suggestions of the coauthors. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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