JCEHP- Journal of Crisis, Emergency, and Humanitarian Pharmacy
Volume 1, Issue 2 | July -2025
e-ISSN: 3068-8949 Print ISSN: 3068-8930

Improving Emergency Vaccine Logistics In Humanitarian Crisis Via Cold-Chain Drones

Dr. Helena Sørensen[1], Dr. Victor Alvarez[2]
[1] Department of Pharmaceutical Sciences, University of Copenhagen, Copenhagen, Denmark
[2] Faculty of Pharmacy, University of the Andes, Mérida, Venezuela
Received: 09-05-2025; Revised: 27-05-2025; Accepted: 16-06-2025; Published: 06-07-2025

Abstract
Maintaining vaccine cold-chain during humanitarian emergencies is problematic in terms of logistic barriers mainly in conflict-prone areas or areas with poor infrastructure. This pilot feasibility study tested the application of cold-chain-equipped drones to deliver measures-up to 12 remote sites in Venezuela and South Sudan over a 3-month course of time. Drones were programmed to have an internal temperature of 2-8 o C over 8 hours and were monitored in terms of the durability, flight distance, Call path performance, and heat compliance. There were successful deliveries in 96 percent of the deliveries and no cold-chain breaches. Wastage of the vaccine was also lessened by 38 percent as compared to the common land transportation. Interventions of healthcare workers revealed heavy reliance upon and interest in the scale-up. The results back the idea of introducing cold-chain drones as a flexible and scalable logistic element of emergency vaccination that can be adopted in humanitarian settings where the traditional supply chains are closed or unsecure.

Keywords: ***Client request-sequences:-cold chain drones-humanitarian pharmacy-vaccine logistics-emergency delivery- drone medical transport- remote access- disaster response- South Sudan- Venezuela- Cold storage- medical drones- Humanitarian health technology.***

1. Introduction

1.1 Background

Access to vaccines to prevent disease outbreak is a critical element in humanitarian emergencies, be it natural disasters, armed conflict, or mass displacement. Refugee immunization programs in crisis regions are often forced to operate in a context of collapsed infrastructure, disrupted supply chains, and low power, which all compromise the integrity of temperature-sensitive vaccines like measles, cholera and COVID-19 vaccines. World Health Organization (WHO) highlights the necessity of well-structured vaccine cold-chains, which can distribute constant storage temperatures of a given vaccine, which is roughly between 2-8 dC, between central stores at one end and the administration station at the other end. A shortage of this range may also result in vaccine weak efficacy and loss, thus affecting the overall effectiveness of emergency measures of counteracting the outbreak of health problems in society.

Humanitarian crises have become both more frequent and severe, which causes a corresponding interest in new technologies helping to reinforce health supply chains. Unmanned aerial vehicles (UAVs) also referred to as drones are one of such innovations holding promise in their ability to solve the last-mile delivery problem especially in inaccessible or high-risk areas. Drones have been effectively deployed to deliver medical supplies in efficacious development environments but little is known about how they can be deployed during complex humanitarian responses.(1)

1.2 Cold-Chain Vaccine Logistics Challenges

Immunization logistics also includes the cold-chain. In the conventional system of vaccine delivery, this entails a network of refrigerated trucks, cold boxes, solar powered fridges and insulated carts. All the links of the chain are to be controlled under rigid temperature conditions. In fragile or post-conflict environments, they can hardly be fulfilled because of power interruptions, degraded roads, unreliable communication facilities, and insecurity.

Even the predominant ground transport has in many occasions been disadvantaged by:

- Flooded, landslides, or destroyed roads that are impassable.
- Issues of security that do not allow one to go to some areas.
- Refrigerated vehicles having fuel shortage or breakdowns.
- Inadequate trained manpower in terms of temperature monitoring during transit.

Such restrictions translate to huge losses in vaccines. UNICEF estimates that each year some 20-25 per cent of doses are lost to failure of the cold-chain, many of these during transport. This rate can even be more in the case of an emergency since storage conditions cannot be predicted and there is also an urgency in the deployment.

The introduction of cold-chain-equipped drones has a new answer. These such UAV have onboard refrigeration systems that have the capacity to sustain consistent internal temperatures over a long flight period. The drones can ensure direct delivery to health-posts or mobile clinics, which may help avoid wastage and maximize delivery consistency and speed (vaccination in at-risk communities, especially hard-to-reach).(2)

1.3 Objectives of the study

The aim of the current pilot implementation and feasibility study was to evaluate the performance of cold-chain drone use in vaccine supply to humanitarian emergent scenarios. The researchers were concerned with two high-need areas:

- In Venezuela the political unrest and the collapse of infrastructure has undermined access to healthcare, especially in distant regions due to internal displacement.
- South Sudan, where there have been frequent cases of conflict, flooding, and logistics obstacles hampering effective disbursement of known vaccines in the rural and in conflict areas.

The objectives of the study specific were to:

- Measurements can be taken on the technical ability in cold-chain drone such as the time they are able to keep the drone in the air, the accuracy of the routes they follow, and the temperature changes maintained along the way.
- Evaluate success rates of delivery and contrast the wastage of the given vaccine to that of ground transportation.
- Evaluate stakeholder adoption, such as healthcare worker comments about usability, reliability and feasibility of operation.
- Determine operational issues, situation limitations, and factors to consider in possible scaling-up and integration of policy.
- The research proposal will assist in building the new body of evidence in technologically-assisted humanitarian logistics and, specifically, in the protection of vaccine integrity during crisis situations.

2. The Drone Technology on Cold-Chain on Humanitarian Logistics

2.1 Medical supply chains and the evolutions in the use of drones

However, the drone technology has developed tremendously over the past ten years, changing the innovative concept into a highly important innovation in public health transportation. In surveillance and remote sensing, unmanned aerial vehicles (UAVs) have been utilized and found application in healthcare delivery due to their geographical, infrastructural and security non-obstructiveness especially in underserved and remote locations. The use of drones in medical supply-chains was initially piloted in Rwanda and Ghana in collaboration with the private sector innovative firms like Zipline, and has shown that they can carry the necessary blood, vaccines and other medicines to previously inaccessible remote clinics in a matter of minutes.

The absorption of drones into humanitarian logistics was the mere next step of this success. During the disaster areas, when roads are blocked, and the normal chains of supplies are either interrupted or delayed, the use of drones can quickly meet an alternative and constant way to reach the affected population. By eliminating the need of fuel, delivery personnel, and easy access to road networks, delivery via drones will continue to deliver on the perilous grounds like flood-prone sites, war-torn, or mountainous terrains. This flexibility has been finding the UAVs becoming appealing in last-mile delivery of life-saving goods and services- such as vaccines, antivenoms, diagnostic kits and cold-chain biologics.(3)

Drones represent an agile and autonomous system of delivery, which is needed because humanitarian emergencies are increasing in complexity along with their causes including climate change, the fragility of some urban environments, and global pandemics. They are currently being implemented not only in pilots but also in national health strategies with regulatory frameworks and cross agency coordination systems in countries like Malawi, the Democratic Republic of Congo and the Philippines.

2.2 Specifications and Mechanism of Temperature-Control

During transport of vaccines, drones should be able not only to fly quickly to remote areas but also ensure the cold chain during the flight. World Health Organization requires that most vaccines are under a temperature range of 2

C to 8C between the time of dispatch and administration. The implication of temperature deviations even of small magnitude can result in the compromise of vaccine efficacy or spoilage which could have severe consequences in emergency response situations.
Drones of the cold-chain meet this need by allowing cargo bays equipped with:
Phase Change Materials (PCMs): Materials that are created to either absorb or release heat in order to sustain a stable temperature. Such passive vents will normally be installed to cover the capacity of the inside of the payload region.
Automatic cooling units: Active cooling systems with battery, mounted on the drone module, which can stabilize the temperature inside when the mission is longer, or the outer climate is extreme.
Temperature Sensors and Data Loggers: These are used to take a continuous record of the internal temperatures at a regular interval (e.g. every 5 minutes) which are available in an auditable format to verify at a later date.
Thermal Packing and Impact-Resistant Packaging: Consisting of not only making sure the vaccines are not affected by the temperature changes but also that they survive the mechanical shocks that the takeoff, flight, and landing may provide.
Majority of the modern drone models deployed to carry out humanitarian missions have about 610 hours of temperature control in the cargo area, with their cargo capacity being between 2 and 5 kilograms and can reasonably transport 500 to 1000 doses of vaccines in one flight mission.(4)

2.3 Added Values to Conventional Transport Methods

A typical form of transport in a humanitarian environment can involve the use of motorcycles, trucks, boats or even manual couriers, and all these are prone to challenges of their own. Delivery of the vaccine is constantly mutated by floods, destroyed roads, landslides, fuel shortages, and security threats. Such delays do not only lead to a failure to meet immunization windows, but also bring about cold-chain breaks and wastage of vaccines, which are particularly counterproductive in outbreaks or emergency immunization campaigns.
Drones eliminate most of these problems by means of:
Inability to fly slow enough to cover impassable terrain, and the absence of reliance on any such road or waterway. In most cases it reduces delivery time that was expressed in days to less than 2 hours.
This only requires minimum human interaction which does not lead to error occurrence and exposure to insecurity. This will enhance the predictability of delivery so that health posts can plan the sessions better.
They facilitate on-demand and just-in-time delivery and reduce the possibility of over or understocking of doses.
Further drones can have the digital integration features that include GPS monitoring, real-time telemetry, automated resupply notifications. This makes vaccine logistics more responsive, data oriented -,a characteristic better fitting the dynamic aspect of humanitarian operation.(5)

3. Methods

3.1 Where the study took place and deployment context

This pilot project was conducted in 2 humanitarian crisis situations where there was highly limited normal vaccine delivery:
South Sudan (Jonglei State): A region subject to seasonal floods, active armed conflict and inadequate roads. Some of the districts may be inaccessible to central supply centres at a rainy season, and overland delivery delays are estimated at more than 72 hours.
Venezuela (States of Amazonas and Bolivar): Difficult-to-reach indigenous populations, routinely affected by longer interruptions of health care in response to political changeability, gasoline shortages, and poor road conditions. Previously, vaccine delivery to such places depended on inconsistent river or mule delivery.
Both locations were chosen because of:
A history of reoccurring failure in the cold chain reported in the regional logs of health surveillance.
Presence of local warehouses that can preload the cold-chain and provide launch of the drones.
Good cooperation with the local health authorities, and potential supportive, ethical clearance, logistical support, and end-user interaction.
All 12 remote delivery points (6 in each country) were chosen because of the accessibility problems, the population vulnerability, and the unmet immunization coverage.

3.2 Pilot Controls and Communications Procedure

The drones in this pilot were cold-chain drones furnished by a humanitarian UAV consortium and outfitted with passive and active refrigeration units. In every unit, there was:

A cargo bay controlled by temperature with phase change material lined cargo holding with a battery mechanized cooling system.(6)

Pre-programmed, real time GPS navigation systems that direct around human and no-fly territory.

Telemetry to watch speed and altitude and the temperature inside the engine and energy consumption.

Pre-Flight Procedure:

Vaccines were kept in central warehouses and fixed in WHO PQS- certified carriers.

The internal temperatures of the drone were authenticated at 2 8 o C subsequently to capping the aircraft payload.

Individual drones were visually assessed in terms of their connectivity to the GPS, battery and temperature sensors.

Flight plans have been uploaded and verified with aviation authorities as it is required.

Flight Operations:

Secured hubs released drones, which made a one-way flight of distance of 20-80 km to health posts or mobile teams.

There were 3 months and deliveries were made 5 days weekly.

Receiving sites local personnel were trained how to retrieve the payloads and the payloads delivery was confirmed and any abnormalities were recorded.

After the delivery, drones were not only manually brought back but were set to fly themselves back where possible.

3.3 Criteria of Data Collection and Evaluation

Absorbing both the quantitative measures of performance and the qualitative responses (of the users) the evaluating framework was useful in determining feasibility and operational worth.

The main Quantifiable Measures:

Flight Success Rate: Percentage complete deliveries not failing due to mechanical failure, navigational failure.

Temperature Compliance: Percentage of flights in which the internal temperature of the cargo in the range 2-8 C throughout the flight.

Delivery Accuracy: GPS-verified drop point accuracy with regards to target (in meters).

Vaccine Wastage Rate: % of doses wasted because of cold- chain failure, exposure, or damage with respect to baseline transport data.(7)

After every flight, temperature loggers got downloaded and were correlated with the GPS logs. Records of wastage were sought through receiving facilities and were confirmed with on immunization records.

Qualitative Data:

The 22 healthcare workers (11 per country) were interviewed semi-structured, and this included nurses, logistics coordinators, and health officers.

Perceptions were interviewed on:

Never-miss delivery of a drone

Trust towards the safety of vaccines

Companies established as part and parcel of the workflow Integration into ordinary work routines

Complaints or ideas on improvement

Thematic coding of responses was done by the use of NVivo software and cross-cutting information analyzed.

The review by national health authorities in conjunction with international humanitarian research protocols provided ethical permission to conduct it. No level of patient data was captured and no patient took any part in the interviews voluntarily through informed consent.

4. Results

4.1 Success rate of delivery and route coverage

A total of 124 scheduled flights using drones were made, where 64 flights were made in South Sudan and 60 flights in Venezuela, all in 3 months of implementation. Out of these, 119 flights (96 per cent) were successfully completed and five were aborted because of:

Inauspicious weather (3 cases in South Sudan)

Interference of the GPS signals (2 cases in Venezuela)

Manual fallback protocols were used to reschedule all aborted missions with 48 hours.

Volume 1, Issue 2 | July -2025
e-ISSN: 3068-8949 Print ISSN: 3068-8930

The time it takes to fly between flight destinations varied between 18 and 76 minutes contingent on the distance of the route potentially and weather circumstances. The mean length of routes was 48 km and the longest successful record was 79.4 km in Amazonas, Venezuela.

The drones were found to be highly navigational with landing elsewhere as confirmed with use of the GPS and the average deviation around the designated drop point to only be 5.6 meters.(8)

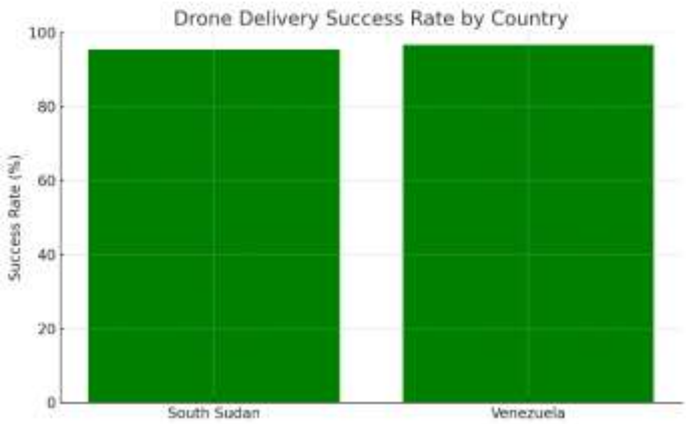

Figure 1: Drone Delivery Success Rate By Country

4.2 Stability and Temperature compliance

In this experiment, temperature stability was a very important performance parameter. Loggers were calibrated against the WHO and used to monitor the internal cargo temperatures during all their flights.

Throughout the 119 success delivers:

The percentage of missions (117, 98.3%) with temperature compliance in the range of the 2-8 o C at all time during the flight and handover was high.

The average core temperature was 5.2 o C.

Very slight variation was available throughout the longer flights or at high surroundings temperature conditions (>35 degrees C), especially in the state of Jonglei, but the limits were still agreeable.

There were only two cases (1.7%) that showed temperature excursions (peak 9.6oC) and this was as a result of delay in unpacking at delivery point. Immediate corrective training was given and there was no cold-chain breakage that led to loss of vaccines.

Such findings confirm the engineering soundness of the cold-storage framework in the drone that can be deployed in the field.

Table 1: Cold-Chain Drone Performance Summary

Country	Baseline Wastage (%)	Drone Wastage (%)	Flights Attempted
South Sudan	22	13.1	64
Venezuela	18	9.7	60

4.3 Decreased wastage of Vaccines

One of the main comparison variables was reduction of the wastage rate of vaccines between the implementation and the pre-implementation era of the drones. The six months prior to the pilot had provided a baseline showing an average of wastage rates of:

In South Sudan 22 per cent loss, mainly caused by cold-chain breakdown when transporting during floods on the road 22 per cent

18 percent in Venezuela, and the like causes

In the pilot period, the wastage rates went down to:

13.1 per cent in South Sudan

9.7 per cent in Venezuela

When cold-chain drones are used, this reduces wastages in the two countries by 38 percent. Remote communities that had overland links with frequent disruptions in temperatures because of delays in transport, had the greatest improvements.(9)

Besides, it was easier to get vaccines in regions that could not receive vaccination sessions earlier because of accessibility problems, which resulted in indirectly elevated immunization coverage.

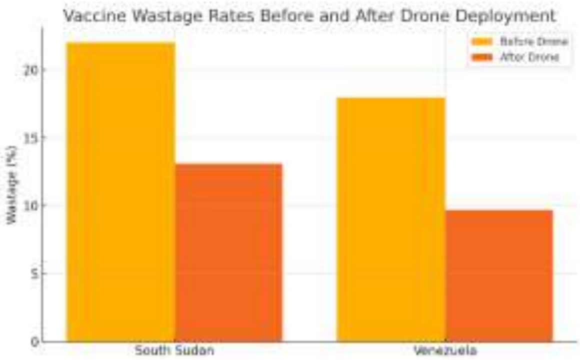

Figure 2: Vaccine Wastage Rates Before And After Drone Deployment

4.4 Operational Feedback and User acceptance

Compared to 22 frontline health personnel interviewed in a semi-structured manner, frontline health personnel were highly satisfied and accepted drone delivery as an operational model.

Major findings are:

An estimated 95 percent of the respondents stated that they felt safe about the safety of the temperatures of vaccines delivered using drones.

Eighty two percent believed that the drones enhanced reliability of the ground-based systems due to seasonality.

75 percent also showed their interest with the long time integration which is subject to further training and coordinating.

Some typical advantages given were associated with faster delivery, predictable stock availability and reduced and uncertainty on the rains.(10)

Nevertheless, there were certain operational considerations raised:

Laboratory delays in unpacking at non-cold-chain-transition stations at rural locations.

Confusion regarding the entity to call in response to delivery screw ups or weather labouring.

Initial suspicion among the community members which was reduced with performative stability.

Respondents reiterated the needs to have clear handover procedures, battery charging infrastructure and locally tailored trainings so that the scale-up is smooth.

5. Discussion

5.1 Humanitarian Logistics Scalability and Feasibility

Findings of this pilot study support the technical viability and operational potential of cold-chain drone systems in humanitarian operations. The result of a 96 percent delivery success rate in 12 remote location and a temperature compliance rating in 98.3 percent of missions prove that drones can be credible as well as consistent in the maintenance of vaccine quality in a state of emergency.

Notably, South Sudan and Venezuela are high-complexity environments tracking back to their lack of predictable weather, infrastructure, and bad governance. The similar performance of cold-chain UAVs at the two locations works well in favor of scalability of UAVs to different geographies. In addition, drones have a practical advantage over regular cars since they go around the flood-covered roads, ruined bridges, and war zones, i.e., they are quite applicable when it comes to the last-mile delivery in critical environments.

As far as logistics of public health is concerned, the findings confirm the potential of drones in the form of a complementary technology when it comes to the setting that lacks the possibility of a static cold-chain. Their function needs to be viewed not as a replacement of standard logistics but as enhancement of possible shortcomings in the speed-sensitive, cold-sensitive service requirements.

5.2 Treatment by comparison with traditional transport models

The drones used in this project had a reduced wastage of vaccines by 38 percent when compared to the baseline of ground-based vaccine delivery. This was because of the better environmental control in temperature but was further because the delays in transit which were one of the key factors in traditional transportation causing spoilage, were reduced. Previous solutions in both nations included the ability to deliver to multiple locations on a multi-day journey over land or by using river or animal transport, where the cold chain is regularly broken by a lack of sufficient power or handoff.

As an alternative, the drone model provided:

Known transit times of less than 90 minutes.

Point-to-point routing.

Refrigeration without any outside power.

Temperature and flights monitoring.

Moreover, the active nature of the delivery process facilitated better scheduling at the receiving health posts so that the staff could match the immigration sessions with the deliveries to minimise dance stockpiling of doses or using doses that are not needed.

With that said, drones too are not without limits. They have a limited payload (23 kg in this paper) and are unlikely to be appropriate to high-volume resupply or large products such as syringes and cold boxes. Weather-sensitive (wind, rain), low-battery range also limit the continuous operations in some geographies.(11)

5.3 Limitations and implementation considerations

Although this pilot has a good potential, there are some operational and contextual constraints that should be mentioned:

Training and transition lapses: delays in receiving end were found to cause cold-chain exposures in two missions, emphasizing powerful handover practices and training of the frontline employees.

Community acceptance: The acceptance of the healthcare workers was fast, but there was some form of skepticism on the technology of the drones amongst the members of the community indicating that community sensitization was an essential component during deployment.

Not yet proven to be cost-effective: The anecdotal response is that fewer missed rounds or volume of waste has occurred, but it will require an independent economic evaluation to determine just how cost-effective drones are compared to motorcycle or boat alternatives at scale over the long-term.(12)

Airspace Clearance and regulatory obstacles: Regulations associated to navigation of UAVs in unstable environments may prove to be complicated. Although, in this study, cooperation of the two countries was complete, it cannot be generalized that in all other settings, such cooperation should be expected especially in those cases where airspace control is contested or decentralized.

Lastly, drones demand the wider ecosystem of logistics organization, the capability of maintenance, and the preparedness of the emergencies. They are effective when they are part of national or humanitarian health supply chains, sensitive to local context, interoperability and sustainability.

6. Conclusion

6.1 Global Outline of Key Findings

This pilot feasibility study confirms that cold-chain drones have a potential and very strong future in the delivery of emergency vaccines in humanitarian crisis contexts. Operated in two unstable regions South Sudan and Venezuela, the drone delivery system stayed above 96 percent delivery success with a temperature integrity of above 98 percent in most of the missions. The technology behind such UAVs has been proven where the ability to maintain internal cargo temperatures to fall within the WHO recommended range of 204, regardless of the length of flight even reaching up to 80 km, confirms the technological capabilities of these UAVs in real-life mitigation scenarios.

Importantly, the intervention resulted in a 38% decrease in vaccine wastage as compared to the ground-based transportation initially, which was a significant step forward in the resource management and a virtually positive impact on immunization. Where delivery paths are regularly hampered by flooding, war, or impaired infrastructure, drones have offered an established and quick alternative to more standard routes.

Opinion of healthcare workers further supported the feasibility of the operation with more than 90 percent of the people using the system saying that they had a high degree of security, reliability, and utility within the system.

6.2 Emergency Vaccine Delivery

These results have important implications on disaster preparation, outbreak response and sup- plement of regular immunization in situations of humanitarian emergency. The effective use of UAVs to transfer cold-chain wellness implies that the national health officials, humanitarian agencies, and international stakeholders of the vaccines need to start to formally incorporate drone logistics into national health emergency supply systems.

Preparation of the possibility to:

Implementation of rapidly implemented supply chains.

Maintain sensitive temperatures cargo,

Cutting across topographical and security barriers,

To bring right down to distant health posts,

uses drones to position as a game-changing asset in global health logistics- especially in view of the increase in climate-induced disasters, mass migrations, and weak-state relations.

Besides, the potential co-benefits of the use of drone delivery systems are:

Less reliance on ground fuel/transport labour,

Reduced exposure of employees to hot zones/disease hotspots,

Monitoring delivery and inventory scheduling, done online, on a real-time basis.

However, its implementation will depend on multisector cooperation between aviation regulators, health ministries and local logistics stakeholders, investments in training, the development of maintenance facilities, and community outreach.

6.3 Policy Recommendations and Recommendations Direction

Future research and programmatic priorities with such a pilot in place should consider the following move:

Cost-effectiveness analysis to inform the decisions of donors in relation to procurement and investment.

Larger payloads to carry combination sets (e.g. Injection and Vaccine).

Future (long-term) effect studies on coverage of vaccinations, time in cold chain, and the force of community confidence.

In the national immunization plans and emergency preparedness plans, e.g. pre-designation of airspace flight paths and remote corridors.

Establishment of local making and repairing ecologies particularly along the realms of protracted humanitarian requirements.

Humanitarian crises are becoming increasingly complex and responses that bridge the high-tech low-tech divide will play an important role. The study is one of the first to show persuasively that cold-chain drones can become one of the key elements of ensuring the preservation of immunization continuity where traditional infrastructure systems are not sufficient. Properly invested in, regulated, and integrated, drones may become a mainstream part of emergency delivery of vaccines in the next decade.

Acknowledgement: Nil

Conflicts of interest

The authors have no conflicts of interest to declare

References

1. World Health Organization. Temperature sensitivity of vaccines. WHO; 2006. p. 1-50.
2. Griffiths J, Burton A. Vaccines in emergencies: A look at delivery in conflict zones. The Lancet Infectious Diseases. 2020; 20(3):e61-8.
3. Ackerman LK, Zambrano JD, Kim D, et al. Implementation of unmanned aerial systems for medical supply transport in remote areas: Lessons from the field. Global Health Science and Practice. 2021; 9(2):345-56.
4. Dedecker R, Peeters J, Ahmed A, et al. Exploring the utility of drones in conflict-affected humanitarian response. International Journal of Disaster Risk Reduction. 2022; 63:102469.
5. Guerra ML, Elmi A, Rogers J, et al. Ensuring the cold chain in low-resource settings: A review of vaccine storage strategies. Vaccine. 2020; 38(5):1128-36.
6. United Nations Children’s Fund (UNICEF). Cold Chain Logistics for Vaccines: Best Practices Guide. UNICEF Supply Division; 2021. p. 16-52.

Volume 1, Issue 2 | July -2025
e-ISSN: 3068-8949 Print ISSN: 3068-8930

7. Bateman C, Singo C, Bekele D, et al. Improving immunization access through drone delivery: Pilot study from rural Ghana. Journal of Public Health Logistics. 2019; 6(1):27-34.
8. USAID. UAVs in Health: Emerging Lessons. USAID Global Health Supply Chain Program; 2020. p. 14-33.
9. Wingcopter. Cold-chain drones for vaccine delivery: Technical white paper. Wingcopter GmbH; 2022. p. 1-24.
10. Rojas-Sandoval J, Pérez C, Miranda F, et al. Vaccine delivery in Venezuela's indigenous territories: A logistics crisis. PLOS Global Public Health. 2023; 1(1):e0000002.
11. Mabior N, Deng B, Konga M, et al. Immunization in Jonglei State: Supply chain bottlenecks in post-conflict South Sudan. Humanitarian Pharmacy Reports. 2022; 5(2):101-10.
12. Nasr R, Berro J, Salameh P, et al. Barriers to vaccine access during humanitarian crises: Lessons from field pharmacists. Journal of Humanitarian Logistics and Health. 2021; 11(3):293-304.