i-DRONE (ICMR's Drone Response and Outreach for North East)

INDIAN COUNCIL OF MEDICAL RESEARCH
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Training Module on

Drone Based Delivery of Medical Supplies

Indian Council of Medical Research
New Delhi – 110029

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ICMR, New Delhi

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1. Background

Immunization programs implemented in developing and low-middle income countries often faces numerous challenges in the delivery of vaccines to the target population.

The interruptions and ineptitudes in the supply chain affect the timely delivery of medical supplies as well as their quality.

In most of the countries, road transportation is the ideal choice for the Medical Supply from one point to another.

Although this is effective in regions with established transportation network, it is still challenging in the hard-to-reach terrains such as remote villages, hills and islands.

In addition, irrespective of the geography, the Medical supply may be interrupted by extreme weather conditions and natural disaster.

Furthermore, considering the present Coronavirus Disease 2019 (COVID-19) pandemic, the efficient delivery options need to be explored immediately.

Unmanned Aerial Vehicle (UAV), commonly called as drones, originally developed for defence purpose, may be the promising alternate for the effective delivery of vaccines.

Drones are familiar for their rapid, cost-effective and safe delivery of medical supplies even to hard-to-reach and tuff terrains compared to other air transportation systems.

Various countries have tested the competence of drones to transfer medical supplies such as diagnostic samples (tissues, urine and blood), medicines, blood packages, vaccines etc.

In most of the feasibility studies, the quality of transferred materials and required parameters for the clinical viability were not affected by the drone transportation.

This training module has been developed to assist the steps to be carried out for the effective delivery of medical supplies through drone.

2. Introduction

In the most populated country like India, the delivery of medical supplies through drone would be one of the ways to overcome the challenges of the vaccine supply chain.

However, determining whether a drone would be beneficial to an immunization program in India is difficult without a proper feasibility study to forecast supply chain performance and costs.

In this regard, ICMR initiated the feasibility study to test the prospect of drone based vaccine delivery in India, in a phase wise manner.

The Phase I study conducted in collaboration with IIT-Kanpur, showed that drones could be an effective and reliable mode of vaccine transportation for a predefined objectives and path.

After the successful completion of this Phase I study, ICMR conducted a Phase II study in the real-life settings for future integration of this technology into the existing Universal Immunization Program (UIP).

The Phase II study has been successfully conducted in the States of Manipur and Nagaland. The feasibility of flying drones in tuff terrains with medical supplies have been successfully tested in these States.

Based on the experience gained in the Phase I and Phase II study conducted, the ICMR has developed this training module to assist the people who involved in delivering medical supplies through drone.

3. Purpose of this Document

This document has been developed based on the literature review and challenges experienced during *i*-DRONE Study.

This document summarizes the list of things to be executed by the healthcare and drone operators while implementing the drone based delivery vaccine delivery model.

This document would assist healthcare workers and the drone operators to work independently form others to perform the drone based vaccine delivery.

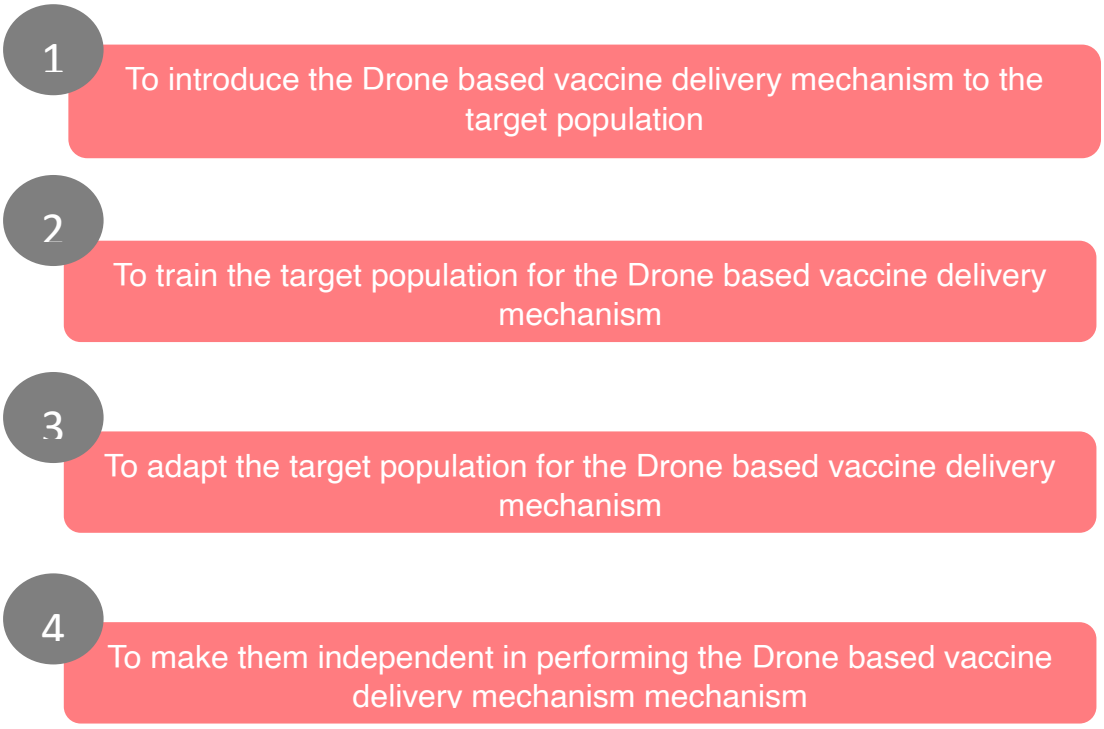

Figure 1. Purpose of the training module.

4. Current vaccine delivery system in India

Level of health system in India is from States to the Sub-centre. The vaccines will be transported from the National Centres or Manufacture to the end-users, which is given in Figure 1.

The typical route of transportation is via road. The present study develops the drone based transportation mode for the supply of vaccines from district to various CHCs, PHCs and SCs.

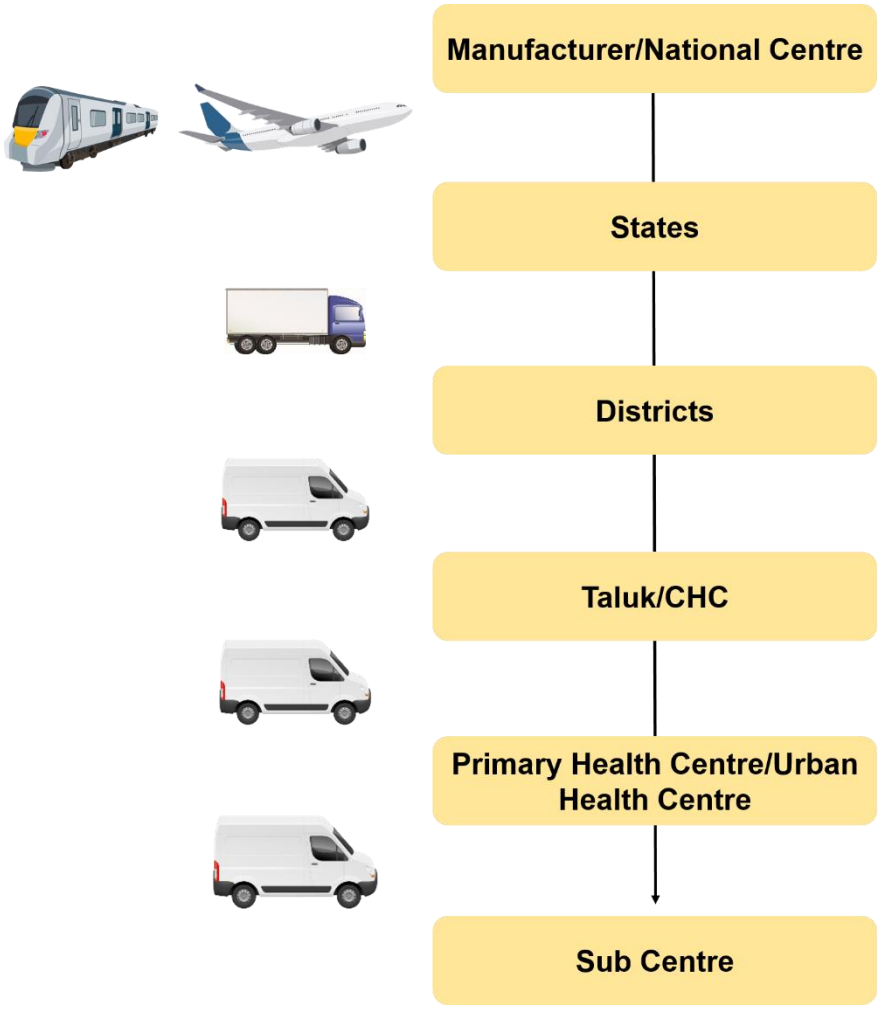

Figure 2. Overview of the present vaccine delivery mechanism in India.

5. Cold chain system for vaccine transportation

Cold chain system is a system of storing and transporting vaccines at recommended temperatures from the point of manufacturer to the point of usage.

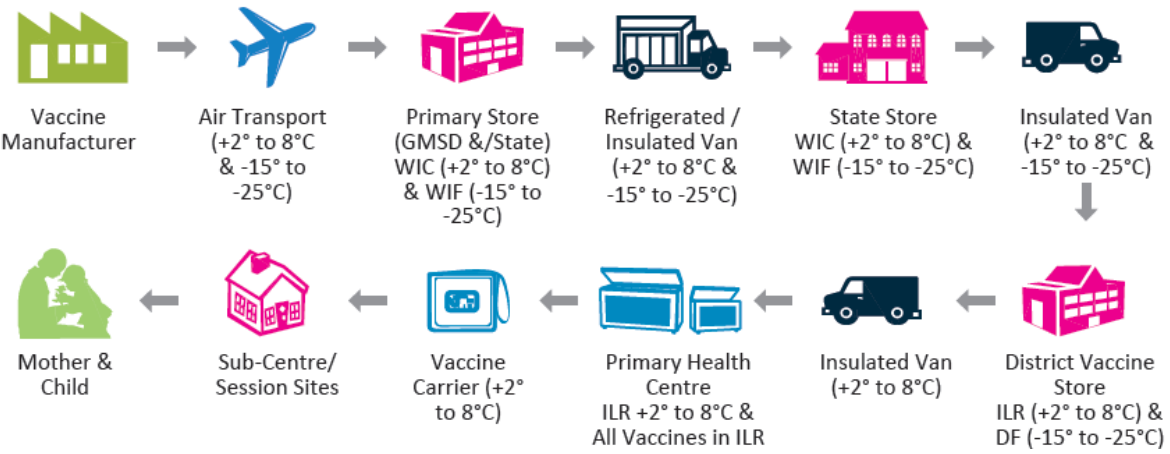

Figure 3. Overview of cold chain and logistics management in India.

The key elements of the cold chain are:

Personnel: to manage vaccine storage and distribution (vaccine and cold-chain handler at each cold-chain point)

Equipment: to store and transport vaccine and monitor temperature

Procedures: to ensure correct utilization of equipment and ensure vaccines are stored and transported safely.

Apart from these conventional land route for the transportation of the vaccine delivery, the drone based delivery is found to be effective in delivering vaccine under the required temperature maintenance.

6. Unmanned Aerial Vehicle (UAV) or Drone

Unmanned aircraft systems were historically used exclusively by the military.

The use of remotely piloted aircraft systems (RPAS) and small drones has expanded to perform civilian tasks such as, supporting search and rescue operations; monitoring weather and traffic flows, delivering goods, and of course as a platform for aerial photography.

Drones are being employed to effect change in the environment; a good example is in agriculture, where efficiencies may be made by employing drones to spray fields and track crop growth patterns.

However, one of the most exciting areas of drone development is within the healthcare industries. Such applications include delivering medicines, vaccines, blood and other medical supplies that are urgently needed in inaccessible areas.

Drone aircraft currently are sorted into four categories:

Fixed wing aircraft, single rotor aircraft, multi-rotor aircraft (single and multi- are combined from here forward) and compound wing, which combines rotors and fixed wings.

Figure 4. Drone used in the i-DRONE study to deliver medical supplies.

7. Applications of drone in healthcare

In most of the countries, road transportation is the ideal choice for the vaccine supply from one point to another.

Although this is effective in regions with established transportation network, it is still challenging in the hard-to-reach terrains such as remote villages, hills and islands.

In addition, irrespective of the geography, the vaccine delivery may be interrupted by extreme weather conditions and natural disaster.

Furthermore, considering the present Coronavirus Disease 2019 (COVID-19) pandemic, the efficient delivery options need to be explored immediately.

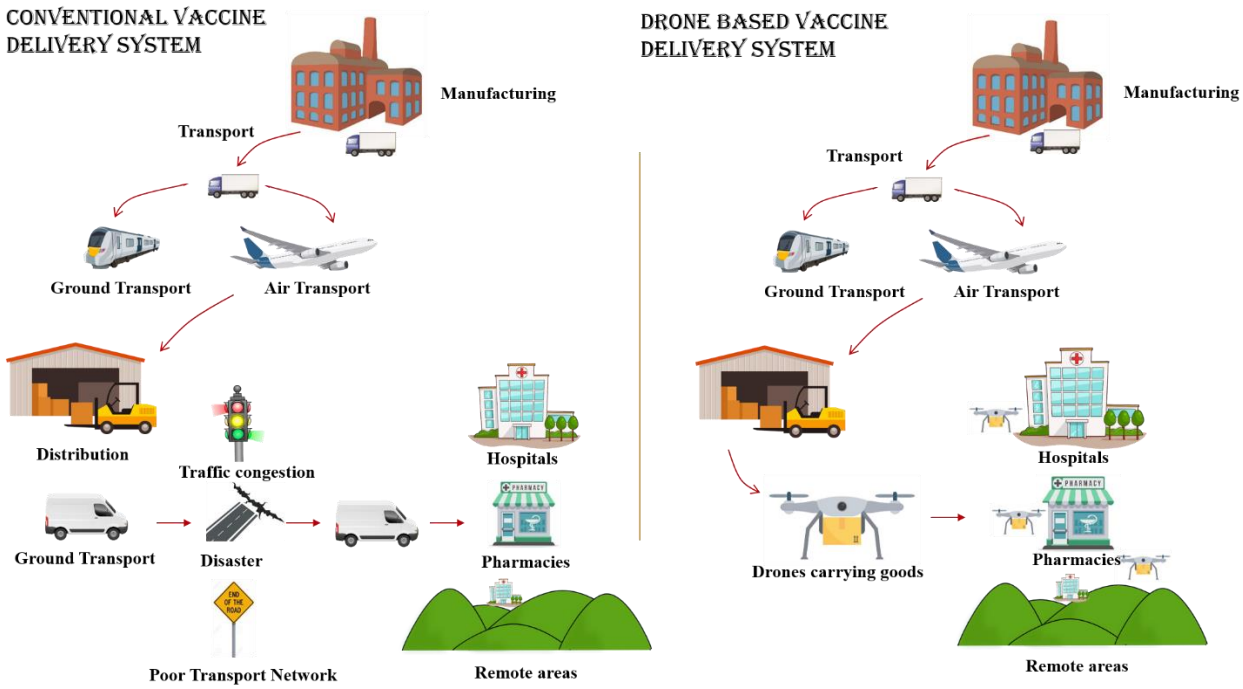

Figure 5. Advantage of drone based delivery during the abnormal condition compared to the conventional way of transportation.

8. Over view of drone based medical supply delivery system

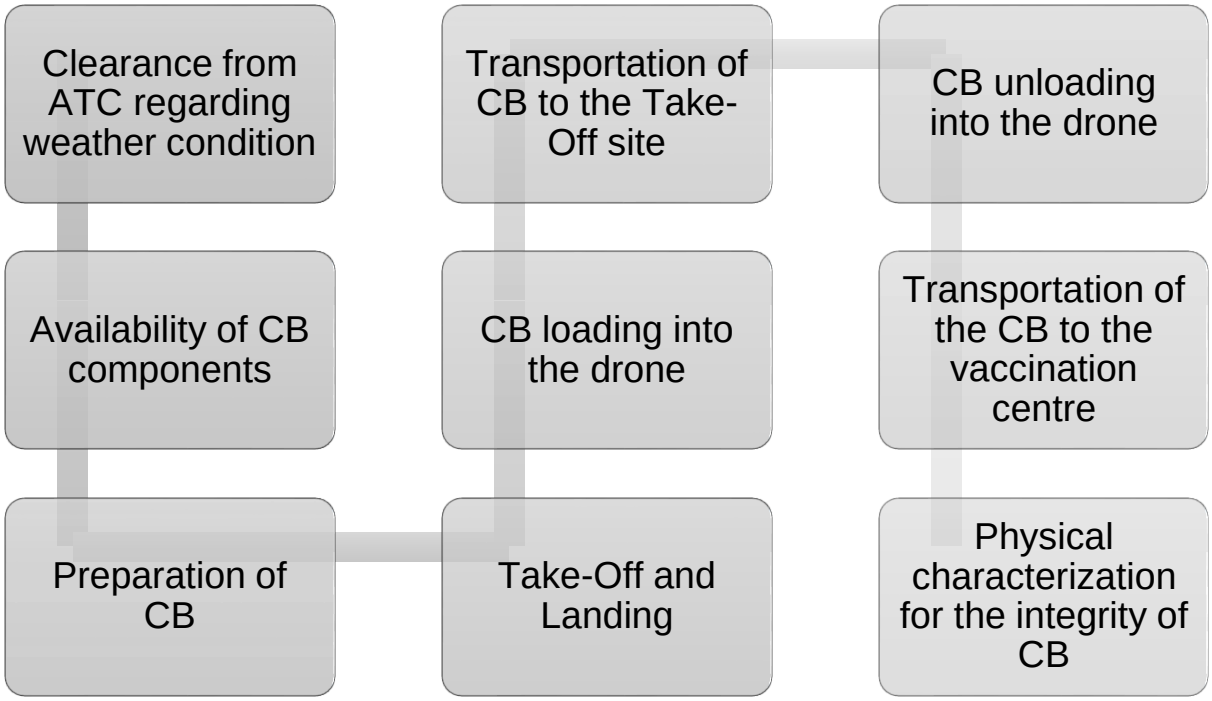

Figure 6. Major steps involved in the drone based vaccine delivery from one site to another.

9. Detailed training procedure

- ✓ Identification of routes, Take-off and Landing Sites.
- ✓ Development of KML file and obtaining clearance from ATC.
- ✓ Identification of healthcare workers at take-off and landing sites for training.
- ✓ Details of Carrier Box Components.
- ✓ Examination of Carrier Box Components before packing.
- ✓ Preparation of Carrier Box for the drone flight.
- ✓ Transportation of the Carrier Box to the Take-Off site
- ✓ Loading of the Carrier Box into the Drone.
- ✓ Take-off from the identified site
- ✓ Drone Flight
- ✓ Landing at the identified site.
- ✓ Transportation of the Carrier Box to the Health Centre.
- ✓ Physical Characterization of the Carrier Box components for the quality assurance.

a). Identification of routes, Take-off and Landing Sites.

It is important to identify the Point A (Take-Off site) and Point B (Landing site) between which the medicine are being transported.

The coordination of both the sites should be identified with the help of Drone operator/pilot for making the virtual plan to conduct the sortie.

The distance between the sites should be able to cover the drone with the necessary payload.

The Take-Off and Landing sites should be near to the District Hospital (DH), District storage centre, Community Health Centre (CHCs) and Primary Health Centre (PHC) for the effective delivery of the medicines.

The Take-Off and Landing sites should be clear ground and should not be covered by the electric wire, tall trees, tall buildings and other obstacles that affects the drone flight.

The Take-Off and Landing sites should be free of humans or animals during the entire time of sortie for the safety purpose.

The Take-Off and Landing sites should be free of any vehicles, tall graces which may interrupt the taking off and landing of drones.

At both the Take-Off and Landing sites provisions for electricity should be provided for the Drone Operator/Pilot to conduct the sortie.

Prior information should be given to the local police and military regarding the drone activity for the safety purpose.

b). Development of KML file and obtaining clearance from ATC.

Keyhole Markup Language (KML) is an XML notation for expressing geographic annotation and visualization within two-dimensional maps and three-dimensional Earth browsers.

KML file should be developed for each route that connects the take-off and landing sites using Google Earth.

This KML file for each location should be shared with the Air Traffic Control (Near to the operation sites) for their approval.

The Clarence should be obtained from ATC before conducting each sortie. The timing of take-off and landing should be planned according to the ATC.

Upon receiving the approval from the Air Traffic Control (ATC) for the particular sortie, the drone operator/pilot team will inform the Health-Care worker to prepare the Carrier Box.

Parallely, the Drone Operator/pilot should initiate the necessary action for the take-off for flying drones.

Drones cannot fly in all-weather condition, which might impact their reliability for time-sensitive operations.

Air temperature, wind speed, precipitation, and other atmospheric phenomena have been shown to adversely affect drone endurance, control, aerodynamics, airframe integrity, line-of-sight visibility, airspace monitoring, and sensors for navigation and collision avoidance.

According to DGCA, MoCA, Weather and meteorology: The standard atmosphere, Measuring, air pressure, Heat and temperature, Wind Moisture, cloud formation, Met Terminal Aviation Routine, Weather Report (METAR).

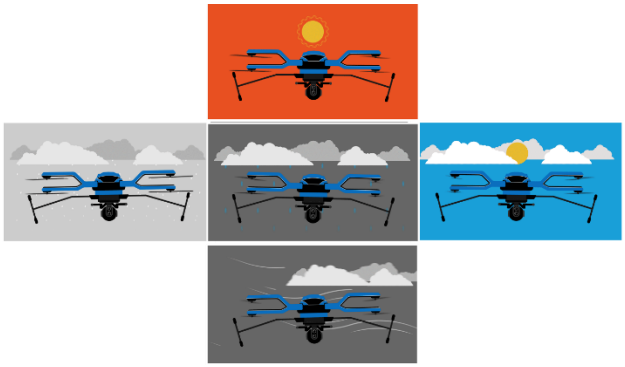

Figure 7. Various weather conditions faced by the drone.

c) Identification of healthcare workers at take-off and landing sites for training.

The healthcare workers should be independent of drone operator for loading and unloading the medical supplies from drone.

For this, the health care workers from both take-off and landing sites will be identified and trained accordingly.

The health care worker including ANM, staff nurse, technical assistance, store keeper should be trained for the delivery of medical supplies through drone.

- These trained staffs will have the following responsibilities
- Providing and receiving the ident form the DH/DSS/CHC/PHC.
- Checking the availability of the items listed in the indent form
- Preparing the carrier box for transporting the medical supply.
- Carrying the carrier box to the take-off site.
- Loading the carrier box into the drone chamber
- Carrying the carrier box to the Health Centre after landing at the landing site.
- Examining the quality of medical supplies delivered through drones.

d). Carrier Box Components

The typical carrier box (CB) contains the following essential components. The vaccines and other temperature sensitive items should be transported through insulation box with the temperature control.

Thermocol/ Conventional Vaccine Carrier Box

This outer cover box will serve as an insulation to protect the temperature of the inner chamber the CB as per the manufacturer requirement i.e. + 2°C to + 8°C.

Ice/ Gel Packs

Ice packs are plastic containers filled with water (0.4 litter). These are hard frozen in the deep freezer to maintain the inner chamber of the CB.

Temperature Logger

This is the battery supported handy equipment which will be placed inside of the CB for the automatic real time monitoring of the cabinet temperature of the CB at the set time interval.

Medicines/ Vaccines/ Surgical

This is the important component of the CB. The vaccine vials should be placed as such packed by the manufacturer into the CB.

e). Examination of Carrier Box Components

The following things should be ensured before the preparation of the CB

Thermocol/Conventional Vaccine Carrier Box

- ✓ The availability of the Thermocol/Conventional Vaccine Carrier Box.
- ✓ The box should be in good condition.
- ✓ There should not be any breakage/damage either inside or outside.
- ✓ The box should be clean and free from dust/water or any other things.

Ice/Gel Packs

- ✓ The availability of the required number of ice/gel pack for the sortie.
- ✓ 4-10 ice packs should in the required condition for the preparation of the VCB depending upon the size i.e. Small or Large.
- ✓ Ice packs should have kept in Deep Freezer that maintain the temperature between -15°C and -25°C.
- ✓ Ice-packs should be kept out of the Deep Freezer for one just before the VCB preparation. This is necessary to bring the temperature of ice packs from -20°C to -0°C. This conditioning will avoid the freezing of the vaccine.

Temperature Logger

- ✓ The availability of the temperature logger should be ensured well before the scheduled time of the sortie.
- ✓ The placement of the battery must be ensured in the temperature logger.
- ✓ The working condition of the temperature logger must be ensured by at least two individuals.

Vaccines/Medicines/Surgical

The availability of the Vaccines/Medicines/Surgical must be ensured before the preparation of the CB.

- ✓ The name, type and manufacturer of the Vaccines/Medicines/Surgical should be verified before the CB preparation.
- ✓ The labelling of the Vaccines/Medicines/Surgical should be intact. The items with partial or damaged labels should not be used.
- ✓ The number of Vaccines/Medicines/Surgical as per the manufacture should be verified in the package.
- ✓ The expiry date of the Vaccines/Medicines/Surgical as per the manufacturer should be checked.
- ✓ The in charge should ensure that the vaccines were stored in the temperature not more than 8°C, beyond which may affect the quality of the vaccines.
- ✓ The integrity of the Vaccines/Medicines/Surgical must be ensured before the CB preparation.

f). Preparation of Carrier Box

The following steps should be followed in the given order for the preparation of the CB.

Preliminary steps

- ✓ The CB preparation should only be initiated upon the confirmation received from the Drone/Health authorities.
- ✓ At least one medical staff should be involved in the preparation of the CB.
- ✓ Staffs involved in the CB preparation must wear the lab coat, gloves and masks.
- ✓ Staffs involved in the CB preparation should have gone through the 'Examination of Carrier Box Components' chapter.
- ✓ The table used for CB preparation should be well sanitized before the initiation of the process.
- ✓ The table should be free of other things apart from the CB components.

Preparation

- ✓ Thermocol/Conventional Vaccine Carrier Box should be first placed on the top of the strong table.
- ✓ The medical supplies that do not require any temperature control can be packed directly into the carrier box. The following steps should be carried to transfer the temperature sensitive items.
- ✓ Ice/gel packs should completely cover the item box to maintain the necessary temperature.
- ✓ At least 4 gel packs should be placed in the CB that carries the temperature sensitive items.
- ✓ Then, the carton box should be taken out from the ILR/DF and should be placed on those gel packs.
- ✓ The temperature logger in a sealed plastic bag must be placed inside the gel packs.
- ✓ Finally, two gel packs should be place on the top of the carton box.

- ✓ The conditioned ice-packs alone should be used for this packaging.
- ✓ After all of these steps, the lid of the vaccine carrier box should be closed properly.
- ✓ To make sure this, two layers of the cello taping should be done.
- ✓ The timing of starting of the CB preparation and end of the CB preparation should be noted.

Figure 8. Vaccine Carrier Box preparation.

g). Carrying Vaccine Carrier Box to the Take-Off site

After the completion of the CB preparation, the drone operator should be intimated to be ready for the take-off.

The CB should be taken to the take-off site either by walk or by vehicles by the health care worker.

The transportation time also should be noted.

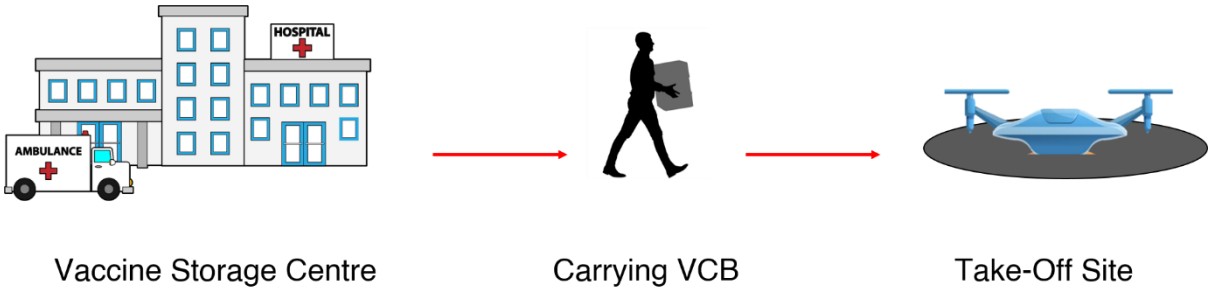

Figure 9. Carrying Carrier Box to the Take-Off site.

h). Loading of the Vaccine Carrier Box into the Drone

The drone operator should confirm the sortie details and type of medicines being transported before loading it into the drone.

After the confirmation, the drone operator should open the drone chamber and make it arrange for the CB placement.

The CB should be placed appropriately by which the transported medical supplies are not affected.

The CB should be properly placed inside of the drone chamber and tightened through belt to stabilize the CB.

Before closing the drone chamber door, the drone operator must ensure that all the necessary items are inside of the chamber.

Then, the drone chamber door should be closed and locked it properly. This should be ensured by one more person.

After the completion of all these procedures, the command centre should be informed for the take-off.

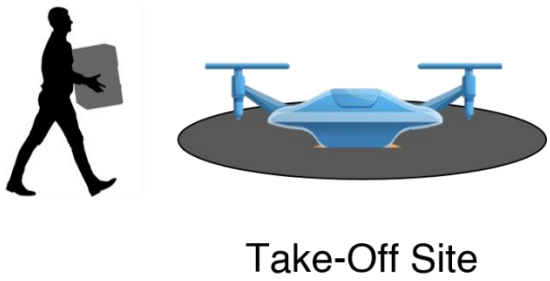

Figure 10. Loading of the Carrier Box into the Drone.

i). Take-off from the take-off site

After receiving the confirmation from the take-off site, the drone operator should initiate the take-off as per the standard procedure.

The drone operator should ensure that there are no technical issues in flying drones and should complete all the necessary procedures/documentations.

The drone operator should complete the check list before starting the flight.

Then, the drone operator should initiate the take-off and should be ready for the control of the entire flight.

After the take-off the drone operator should inform the representative of the landing site regarding the take-off time and the approximate time of the delivery.

The intimation also should be passed to the Health care team at the landing site.

Figure 11. Take-off.

j). Drone Flight

The entire drone flight should be monitored by the drone operator and record the following details, GNSS data, flying dynamics, vibration and other environmental parameters.

The drone operator should ensure that the drone is flaying in the pre-defined path and not deviating from its original route.

The drone should be examined by the drone operator for any external damage or change that had happed during the flight.

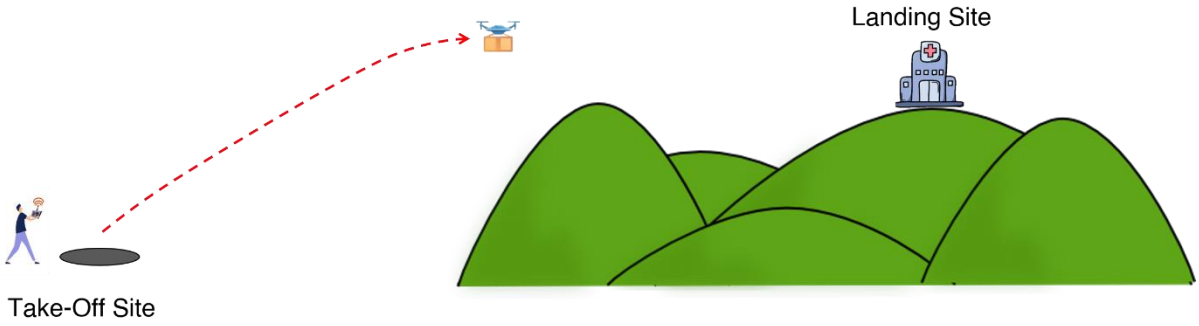

Figure 12. Drone flight.

k). Landing at the landing site

After successful completion of the sortie, the drone will land at the landing site.

The healthcare team should reach the landing site at least 5 minutes before the expected time of the drone arrival.

The drone operator should ensure that the drone is landed at the pre-identified area for the landing of the drone.

Then the drone cover should be unlocked and the inner chamber temperature of the drone should be measured and recorded by the drone operator.

If it is an automated landing, the Health Care Worker should do the unloading from the chamber.

Then, the VCB will be handover to the healthcare team and they should ensure the integrity of the CB box before taking it into the health care centre.

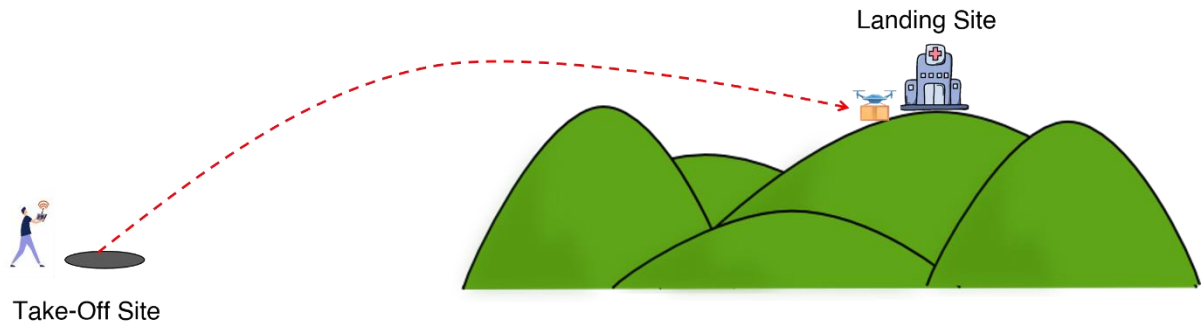

Figure 13. Landing.

l). Carrying Carrier Box to the Vaccination Centre

The healthcare team is responsible for the transportation of the CB into the health care centre.

The team should inspect for damage to the CB, if any.

The CB should be safely transported to the health care centre and store appropriately.

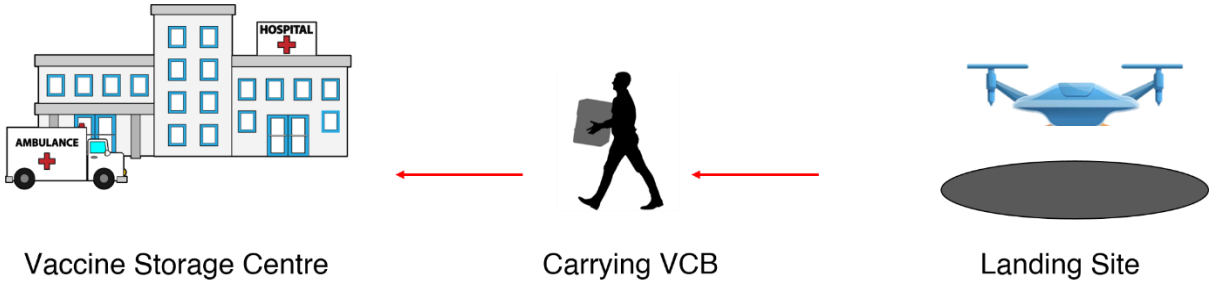

Figure 14. Carrying Carrier Box to the Vaccination Centre.

m). Physical Characterization of the Vaccine Carrier Box components

After reaching the health care centre, the seal of CB should be removed and the inner temperature of the CB should be measured (if the medical supply is temperature sensitive).

Then, the temperature logger should be taken-out and the temperature log should be fetched.

The medical supply received should be stored properly in the health care centre and quality checked.

The vaccine/medicines should be removed take and kept in the refrigerator/deep freezer. Before that the damage/turbidity in the vaccine vials should be recorded.

Then, ice packs should be removed and stored in the deep freezer. Also, the damage/leakage in the ice packs should be tested.

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