Journal of Public Health Policy (2025) 46:326–341
https://doi.org/10.1057/s41271-025-00553-1

ORIGINAL ARTICLE

Perspectives of healthcare workers on drone-enabled healthcare delivery in challenging terrains of Manipur and Nagaland, India: a qualitative research

Sumit Aggarwal[1] · Nupur Mahajan[1] · Prakamya Gupta[1] · Sivaraman Balaji[1] · Simmy[1] · Naorem Shyamjai Singh[2] · Ayangla Saku[3] · Balram Bhargava[1] · Samiran Panda[1]

Accepted: 5 January 2025 / Published online: 27 January 2025

Abstract

Collaborative initiatives of the drone industry and healthcare sector are becoming a pivotal step in restructuring healthcare service delivery in India. This paper documents knowledge and perceptions of healthcare workers from various districts of Manipur and Nagaland towards the use of drones for medical supply in the region. The study utilized 27 in-depth interviews with healthcare workers to collect qualitative data, which was then analyzed using NVivo 14 for thematic and content analysis. The findings indicated that 57% of respondents are unaware of drones' applications, citing security and privacy concerns and a lack of understanding about their role in the program. This study demonstrates the optimistic perception among healthcare professionals regarding drone delivery of medical supplies to remote areas, highlighting its potential to enhance accessibility and overcome logistical challenges. It emphasizes the need for training, community engagement, and safety measures to ensure effective implementation of drone technology in healthcare delivery.

Keywords Drones · Healthcare service delivery · Vaccine procurement · Acceptability · Thematic analysis

Sumit Aggarwal and Nupur Mahajan wish to inform that the first two authors have contributed equally in conceptualization and preparation of this manuscript and may be regarded as joint first authors.

✉ Sumit Aggarwal
aggarwal.sumit@icmr.gov.in

[1] Indian Council of Medical Research, V. Ramalingaswami Bhawan, Ansari Nagar, New Delhi 110029, India

[2] State Health Society, Imphal, Manipur 795001, India

[3] Chief Medical Officer's Office, Mokokchung, Nagaland 798601, India

Key message

- The integration of drone technology in healthcare delivery presents a groundbreaking opportunity to overcome challenges in accessibility and infrastructure in remote regions of Manipur and Nagaland in India.
- While 57% of healthcare workers remain unaware of drone applications, there is a strong overall positive attitude towards their potential use, indicating an essential pathway for education and integration into existing healthcare systems.
- The findings highlight the need for collaborative initiatives between the drone industry and healthcare sector to enhance medical supply distribution, ultimately improving health outcomes in underserved communities.

Introduction

Unmanned automated vehicles (UAVs) or drones have gained widespread usage in the military and defense sectors globally [1]. The healthcare sector is also exploring the potential of using drones to improve access to medical supplies, vaccines, blood, and other necessities in remote and hard-to-reach areas [2, 3]. Countries such as the United States, Rwanda, Madagascar, and Senegal have already implemented drone-based delivery systems [4]. Various companies in the United States, such as Amazon, United Parcel Service (UPS), and Google, have been experimenting with drone delivery systems. Amazon, for instance, has been working on its Prime Air project, aiming to deliver packages to customers within 30 min radius using drones [5]. Rwanda has been at the forefront of drone delivery for medical supplies. Zipline, a California-based startup, has been operating drone delivery services in Rwanda since 2016. Their drones have been used to deliver blood products, vaccines, and other medical supplies to remote areas, significantly improving healthcare access [6]. Madagascar has also seen the implementation of drone delivery systems, primarily focused on medical supply delivery to remote areas [7]. Senegal has been exploring the use of drones for various purposes, including agriculture and healthcare. For example, the African Drone Forum held in Senegal in 2020 showcased innovative drone applications for agriculture, mapping, and delivery services [8].

In India, drone technology shows promise for expanding healthcare service delivery due to challenges associated with road transportation in difficult terrains, islands, extreme weather conditions, and inadequate infrastructure [9, 10]. Until now, conventional modes of transport have been used for delivering medical supplies to hard-to-reach areas in India. Drones can address challenges in connecting hub stations to primary care centers in difficult terrains [10]. Integrating this innovative technology into public healthcare transportation is crucial for efficient supply delivery. Studies show positive community backing for drones

when people are informed about their purpose, risks, and involved organizations [11–14]. Additionally, understanding the perceptions of stakeholders and healthcare workers is crucial for the development, adoption, integration, and implementation of drone programs in the public healthcare system [15, 16]. However, there is limited scientific literature assessing the perceptions of healthcare workers engaged in drone-based deliveries within the Indian context [10].

Typically, any feasibility studies explore eight components: acceptability, demand, implementation, practicality, adaptation, integration, expansion, and limited efficacy testing [17]. In this feasibility study "i-DRONE" (ICMR's Drone Response and Outreach for North East), we explored the acceptability and adaptability of state and district stakeholders, including healthcare workers, regarding the introduction of novel technologies alongside. The study is based on a Rogers' Diffusion of Innovations theory [18], which provides a framework to systematically assess the feasibility of using drones for medical supply in Manipur and Nagaland. We aimed to understand how awareness, acceptability (particularly in terms of relative advantage), and adaptability (in terms of compatibility) influence healthcare workers' readiness to adopt this technology. Feasibility studies guided by this framework can inform stakeholders on how to effectively introduce and integrate drones into healthcare systems, ensuring they meet the needs and concerns of healthcare workers and communities in challenging terrains.

Data and methods

Study design

This study aimed to assess the feasibility of using drones to deliver vaccines and medical supplies was carried out in difficult geographical terrains including land, island, foothills, and across the hills in collaborations with the State Health Mission of Manipur and Nagaland. The Nagaland–Manipur region faced critical challenges with limited COVID-19 vaccine supply amid health and operational issues exacerbated by extremist activities. Conducting studies in this area was crucial for addressing healthcare disparities due to the remoteness and implementing effective public health interventions. The study's methodology, documented in a published research paper, outlines operational challenges faced by the scientific team and drone operators [19]. For this qualitative descriptive study, we collected data from September 2021 to December 2021 (4 months) from 27 participants, including 13 health administrators and 14 healthcare workers, selected using purposive sampling for in-depth interviews in five geographically challenging districts of the North-Eastern Region of India (see Supplementary Material Table S1 and Figure S1).

Participant recruitment

Study investigators employed purposive sampling to engage state- and district-level stakeholders and healthcare workers actively involved in COVID-19 vaccination and

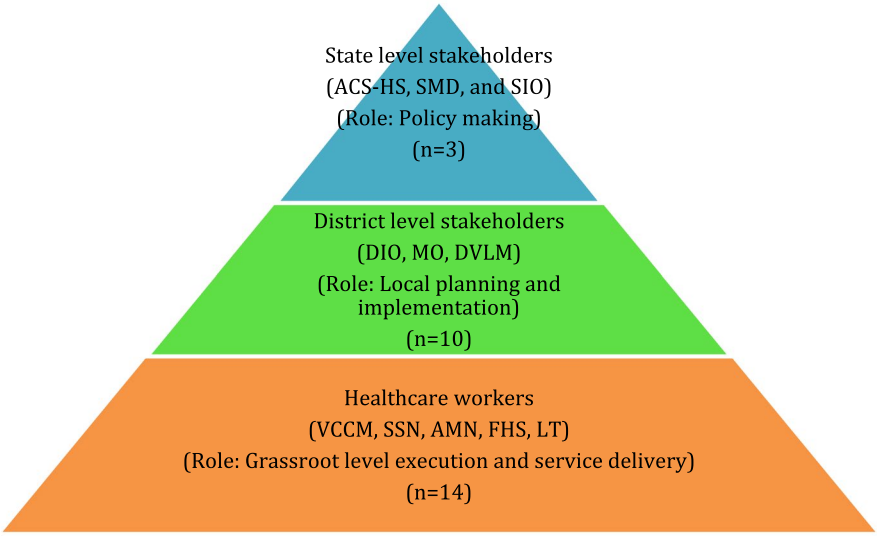

Fig. 1 Various levels of stakeholders and their roles in state healthcare program implementation and execution. (I-drone-ICMR project; India; 2021). *ACS-HS* Additional Chief Secretary and Health Secretary, *SMD* State Mission Director, *SIO* State Immunization Officer, *DIO* District Immunization Officer, *MO* Medical Officer, *DVLM* District Vaccine Logistics Manager, *VCCM* Vaccine Cold Chain Manager, *SSN* Senior Staff Nurse, *ANM* Auxiliary Midwifery Nurse, *FHS* Female Health Supervisor, *LT* Laboratory Technician

routine immunization (Fig. 1). Our inclusion criteria were (a) individuals who have not taken a long vacation break in the previous six months of employment; (b) individual who represent state-level stakeholders, district-level stakeholders, and healthcare workers; and (c) individuals who work on policy, maintenance, and ground-level execution (policy involves the development and implementation of guidelines and regulations governing healthcare practices, while maintenance refers to the ongoing support and upkeep of healthcare systems and resources to ensure their effective functioning, and ground-level execution refers to the practical implementation of healthcare policies and programs by frontline workers directly interacting with patients and communities).

Data collection

We adapted Troug et al.'s (2020) in-depth interview guide for our data collection on drone-based medical supply delivery in challenging terrains [15]. The data were collected by the first two authors with equal impact (SA: scientist, male, MD, epidemiologist, NM: research associate, female, PhD, anthropologist and SM: Scientist C, female, PhD, anthropologist); NM also completed translation and transcription; and SM (Simmy) did the coding. To ensure comfort and effective communication, we conducted in-person 20–60-min interviews in English, Hindi, Manipuri,

and Nagamese at a participant's workplace assisted by local field investigators who helped with translations.

We obtained their verbal informed consent prior to conducting the interviews using recorders. Rapport was established with the participants prior to the interviews with the help of local administration. While establishing rapport the participants were informed about investigators, the research, and the goals. All 27 interviews were digitally recorded for audio with participants' consent, aligning with ethical guidelines along with the field notes.

Training program

Concurrently, the researchers identified a need for short intervention training among healthcare personnel to effectively manage drone-related operations, prompted by emergent requirements observed during fieldwork. While the training was not initially delineated in the study protocol, its implementation became imperative in response to the practical demand encountered in the field. Thus, the study encompasses both an investigation of healthcare workers' attitudes towards drone usage and the subsequent provision of tailored training to address identified skill gaps and operational necessities. Around 76 participants, mainly male and female health workers at ground level were interviewed about how they felt towards the drone implementation in medical delivery in their area.

Data analysis

The study employed thematic analysis using NVivo 14, following Braun and Clarke's 2006 framework [20]. Initial codes were generated by two researchers; NM and SM, systematically identifying meaningful segments relevant to the research question. Themes were developed inductively, as codes were organized into potential themes based on observed relationships and patterns within the data. These themes were then rigorously reviewed against both the coded extracts and the entire dataset to ensure accurate representation. Each theme was clearly defined and given descriptive names that captured its essence. We also created a codebook to facilitate consistency and transparency throughout the analysis process. Finally, we presented the integrated themes in a coherent narrative, supported by illustrative quotes from the participants, addressing the core research question. The coding tree is provided in Supplementary Material Figure S2. To minimize bias and ensure reliability and validity, SM, anthropologist and SA, public health professional, contributed for the data analysis using a triangulation method. The analysis was divided into three sections highlighting findings with verbatim quotes, addressing stakeholder knowledge, perceptions, and concerns towards drone-based delivery of medical supply. To achieve this, specific domains and probe questions were identified, which are listed in Table 1.

Themes derived from interviews elucidate healthcare workers' perceptions of drone technology in terms of its benefits (improved emergency response, enhanced healthcare access), challenges (technological reliability, regulatory barriers), and

Table 1 Probe Questions for Assessing Knowledge and Perceptions of Stakeholders at Various Levels towards Drone-Based Delivery of Medical Supplies (I-drone-ICMR project; India; 2021)

Domain	Questions
Awareness, functionality, and benefits of drones	Have you seen a functioning drone in past?
	What do you know about the applications of drones?
	In which conditions, the drones cannot be used?
	According to you what are the benefits of using drones to carry and delivery medical supplies?
	In your opinion, the supplies delivered by drones have same quality and effectiveness as conventional methods?
Possible risks related to drones	Do you think there are any risk to using drones to carry medical supplies?
Perceptions and apprehensions related to drones	Will you highlight the apprehensions which the community may have regarding use of drones in such vicinity?
	What are your opinions on the security concerns?
	According to you what may be the challenges while being trained for this programme?
	Do you have any apprehensions in participating in this programme? Any concerns regarding drones?

implications for patient care and health outcomes. The interconnectedness of themes underscores the complexity of integrating drone-enabled healthcare delivery within the socio-cultural and infrastructural context of Manipur and Nagaland.

Ethical clearance and regulatory approvals

All necessary regulatory approvals from the Ministry of Civil Aviation (MoCA), Directorate General of Civil Aviation (DGCA), Airport Authority of India (AAI), and the State Health Authorities of Nagaland and Manipur are obtained prior to implementation of this initiative [21]. Ethical clearance was obtained from Indian Council of Medical Research, Central Ethic Committee on Human Research (CECHR) Bengaluru, India.

Results

The participants in this study represented a diverse range of stakeholders involved in the programmatic implementation and execution of medical deliveries in the states (Fig. 1). The study comprised 27 participants, including 17 males and 10 females, aged 24 to 58 years, with a mean age of 41 years (SD: ±9.4). In Manipur, mainly Meitei language is used by the local population, whereas there were language barriers in Nagaland due to diverse linguistic landscape, leading to isolation and restricted social cohesion. However, in Manipur in Karang island, a village amidst

security concerns, residents view new developments with skepticism, fearing connections to military operations or government interventions. This heightened sense of suspicion and caution exacerbates existing unease and uncertainty. A history of conflict and instability in the area, along with a deeply entrenched feeling of self-preservation, contributed to the predominant sense of dread about strangers, which complicated the research team's interactions with the locals at first.

Thematic analysis

Through qualitative analysis, significant themes emerged, capturing diverse perspectives and lived experiences that offer insights into participants' attitudes and beliefs towards drones, enhancing our understanding of this cutting-edge approach (themes are summarized in Table 2, Figure S3, and S4). Collected data show ***limited awareness regarding drones, regulations, and exposure***: 57% of respondents are unaware of use of drones. Many respondents expressed that they have a limited or no previous experience with this technology (#1). Some respondents associate drones primarily with photography, events, weddings, and use in security and military contexts. They recognize drone usage in capturing visuals and being utilized for surveillance and related purposes (#2). Participants from both Manipur and Nagaland expressed concerns about the drone regulations in their respective states (#3).

Despite limited exposure, there is generally a positive curiosity expressed by respondents.

We observed positive reception and excitement surrounding the use of drone technology in healthcare, particularly for the delivery of medicines and vaccines to remote or inaccessible areas. Participants expressed openness to understanding and adapting to the use of drones in healthcare (#4) and enthusiasm about the innovative initiative and highlighted its potential benefits in improving medical infrastructure, providing timely and efficient healthcare services, and overcoming geographical challenges in regions like Northeast India (#5). The positive community response and the recognition of the potential impact of drone technology contributed to this overarching theme.

We asked participants about their perceptions regarding drone-based deliveries and grouped their responses into identified themes based on their views on this technology and the community's reaction towards drone-based deliveries. Participants perceived the use of drones as they can improve healthcare accessibility to remote areas, overcome geographical challenges, and offer time efficiency and quick delivery. Healthcare workers highlighted it as a solution for delivering medical goods to remote and hard-to-reach areas (#6). They viewed drone technology as a solution for remote island villages and remote areas struggling to access medical facilities, thereby bridging the gap and providing essential healthcare services. The geographical challenges in hilly and remote regions, where traditional transportation methods are often impractical or time-consuming, drones were considered a solution to overcome the challenges such as bad roads, traffic jams, and inaccessible areas and ensure efficient delivery of vaccines and medical supplies as per the healthcare staff (#7). Many respondents highlighted the time-saving aspect of using drones. They emphasize that drones can transport vaccines

Table 2 Summaries of quotes

Quote ID	Content	Participant
Limited Awareness		
#1	*I have seen drone in marriage, but this one is very big*	*ANM 1*
#2	*I had only heard about its use in the defence context but did not know about any initiative in the medical or health space*	*ACS 1*
#3	*I was aware that drone-based delivery of goods is going on in various states… but I didn't know there were rules and approvals need to be taken from ministries*	*SMD 2*
#4	*I am very happy that our hospital will be participating in this unique initiative*	*ANM 1*
#5	*We see the use of drones as a very welcoming and appreciative move*	*ACS 1*
Perceptions of the acceptability of drones among stakeholders and community		
#6	*In areas like Karang, which is an isolated island village, this kind of technology will be a boon. Similarly,.. henglep, houchung, and many others which are inaccessible…Such initiatives will definitely be very beneficials*	*MO1*
#7	*It will be beneficial in hilly areas as there is no accessibility in remote locations, during heavy monsoons, the roads which exist are very bad*	*ANM 3*
#8	*…this project will be very effective; we can transport vaccines on the same day. As currently, we transport vaccines one day prior to vaccine day, and in case of shortage we have to send the beneficiaries back. Also, it will take less time in transportation*	*DCLM 1*
#9	*I have seen that drone based delivery of vaccines was very safe and quick. It did not cause any damage to the vials and the quality of the vaccines was also fine. There were no issues*	*MO 1*
#10	*It was packed properly, and also, the temperature was maintained inside the box when we opened it. The temperature logger indicated 6 degree, which is inside the permissible limit*	*DIO 3*
#11	*Drone technology will be very useful if collaborated with the ongoing procedures in UIP*	*DIO 1*
Concerns for Adaptability		
#12	*Main challenge will be in understanding the technicalities of the drones*	*ANM 3*
#13	*I don't understand English or Hindi, so, I am afraid that I won't be able to contribute much*	*CCM1*
#14	*I observed people were concerned regarding drone landing…*	*MO 3*

Table 2 (continued)

Quote ID	Content	Participant
#15	*… understanding the technical part of drone would be very challenging..if there can be coordination between us and the drone operators,..it would be more convenient*	*SN 1*
#16	*…this is additional work added for us… we have to take turns as all staff cannot be engaged in this throughout… the permission from authority for participation is sometimes problematic*	*ANM 5*
#17	*Manipur is an insurgency area, so, we might face challenges with the law and order in some sensitive areas. Also, there may be cases where people might feel that these drones are military drones or for suspicious activities and thus, might retaliate to its presence. But, we will have to set up proper awareness drives among tribal and people living in remote areas to make them aware of what this device is and what are its uses. This will help them in gaining confidence in the health system of the state*	*SMD 1*
#18	*People here in this island do not go out a lot, so, drones are very alien to them… but, you..explained its benefits and possible risks… will serve as connectivity to the city for them*	*CL1*
Interventional measures		
#19	*I think we can train the healthcare workers thoroughly to undertake the packaging, loading and unloading of material properly*	*DIO 1*
#20	*We are afraid right now, but once we see a demonstration and have practice and training, we will be fine. I hope there will be no major issue or challenge*	*ANM 2*
#21	*I have myself designed a small drone made out of electronic wastes which is used for photography*	*CCM 2*
#22	*They may be trained and capacity building should be prime focus. The drone operators may be in constant contact with the HCWs, so that they have a familiarity with the other person and their work as well*	*DIO 3*

on the same day, reducing the need to transport them one day prior (#8). Therefore, they expect drone-based delivery to enhance vaccination programs on designated days and handle leftover vaccines efficiently, especially in emergency situations and challenging weather conditions. Drones were praised for their reliability in delivering medical supplies and temperature loggers, ensuring timely and safe delivery, and for monitoring vaccine efficacy during transportation (#9). Respondents noted that drone deliveries are safe, quick, and do not cause damage to the vials (#10). Healthcare staff emphasized the idea of integrating drone technology with the ongoing conventional methods of Universal Immunization Programme (UIP) delivery (#11). This is particularly seen as beneficial for inaccessible areas like Karang Island in Manipur district. The suggestion was to gradually introduce drone technology alongside providing training to staff, creating a hybrid approach.

To assess the adaptability of healthcare workers using the probes, we identified the several themes regarding ***technical challenges***, ***weather considerations, and landing locations***. Several participants expressed concerns about understanding the technical aspects of drones. The primary hurdle lies in comprehending the intricacies of drone technology (#12). They perceived the technology as a potential challenge due to limited technical knowledge or language barriers. Without proficiency in English or Hindi, they were concerned about their limited contribution (#13). Many participants highlighted the need for awareness and support in comprehending the technicalities of drone operations (#14). Healthcare workers, including youth representatives, expressed valid concerns regarding potential safety issues associated with drone-based delivery, such as the risk of drones being attacked during deliveries and potential privacy issues. Healthcare staff emphasized that weather conditions, particularly heavy rain and high winds, pose potential obstacles to drone operations, including crashes, displacement, and faulty navigation, necessitating contingency plans for potential risks. Concerns were raised by healthcare staff about the distant location of drone take-off and landing sites, with suggestions to make them closer to health facilities. Logistics management, including time management and the coordination of supplies, is identified as a challenge.

Participants emphasized the importance of effective communication between healthcare personnel and drone operators for smooth operations, despite concerns about specialized manpower and experienced staff to handle technical challenges (#15). Participants expressed concerns about the additional workload associated with the drone-based delivery program (#16) and security concerns about drone use in remote areas, emphasizing the need to raise awareness and improve understanding of drone-based delivery systems (#17). Stakeholders identified confusion about COVID-19 infection, vaccination, and drone technology due to lack of awareness, rumors, and misinformation. However, community acceptance and understanding increased after investigators worked with them (#18).

Interventional measures

The study revealed that healthcare workers perceive participation in a drone-based healthcare program as an opportunity to improve accessibility, especially in remote areas. To address hesitancy due to lack of technical understanding, we developed a

comprehensive training module. The training was conducted in English and Hindi, with local language explanations provided when needed. This initiative empowered healthcare workers with the necessary knowledge and skills to contribute effectively to the program, bridging the technical understanding gap and enhancing its successful implementation and execution. We identified several themes regarding the training aspects.

Healthcare workers express their commitment to undergo training sessions to familiarize themselves with drone technology. This includes understanding the concept, practicing, and gaining the necessary skills for smooth operations (#19). Some healthcare workers initially expressed apprehensions or fears but express confidence that these concerns can be alleviated through proper training, demonstration, and practice (#20); and some expressed the technological savviness and ability to learn and adapt to new technologies (#21). There was a willingness to learn and overcome challenges, suggesting a positive attitude towards incorporating drone technology. Participants emphasized the need for coordination between healthcare workers, stakeholders, local administrators, community, and drone operators, including being available during operations and maintaining constant contact. Collaboration was seen as crucial for the successful integration of drone technology into healthcare practices (#22).

Discussion

The increasing use of drones in various applications has created a need for user-centric insights regarding the acceptance and adaptability of this technology, particularly in healthcare systems operating in remote and resource-deprived locations [14]. In line with this objective, the present study explored the acceptability and adaptability of introducing drone technology for the transportation of medical supplies among stakeholders and healthcare workers involved in the state healthcare systems of regions. Additionally, the study documented the challenges faced by healthcare workers in the existing service procurement and delivery mechanisms in these geographically difficult terrains. Health authorities reported that achieving last-mile deliveries of healthcare services in the challenging terrains of the regions, compounded by torrential monsoons, is a daunting task. A study conducted by Bajwa et al. (2018) highlighted the challenges faced in last-mile deliveries in Manipur, emphasizing the urgent need for interventions to strengthen the capacity of the state's transportation system [22].

Regarding the acceptance of drone technology, the present investigation found that while some respondents showed keenness, a few are not familiar with the related mechanisms. The proportion of respondents familiar with drones is observed to be lower compared to previous studies conducted among community dwellers in Malawi and Mozambique, Africa [15], and among healthcare workers in Germany [14]. As some respondents, reported a lack of understanding regarding drone functionality and operational mechanisms, it indicates perceived complexity. This aligns with Rogers' concept that easier-to-understand innovations tend to be adopted more readily. Refresher training proved effective in reducing this perceived complexity,

thereby increasing acceptance. However, the acceptance of healthcare workers towards using drones for healthcare service delivery, as observed in the present study, is consistent with the observations from Ghana and Germany [14, 16]. It has been documented that including technical knowledge about drones in training sessions significantly enhances acceptance [23, 24]. These sessions aimed at bridging knowledge gaps were essential, as they demonstrated how drones could integrate into current systems. This shows Roger's compatibility with established procedures is critical for enhancing readiness among healthcare workers. Similarly, in the present study, interventional training has been provided to address the knowledge gaps among healthcare workers and stakeholders.

The acceptability of such technologies is not only crucial among policymakers but also among community members and influencers. Despite some initial apprehensions, the stakeholders demonstrated positive attitudes towards accepting drone technology as a means for health service delivery. Operational barriers, such as identifying drone sites, establishing drone command and control centers, and building rapport with local partnering stakeholders, are observed in the early stages [23]. However, after informing them about the benefits and involving them in initial trial sorties, participants became more engaged in the study. For instance, the first sortie conducted between Bishnupur District Hospital and Karang Island in the Loktak Lake, covering an aerial distance of 12 km in 12 min (compared to a road distance of 35 km covered in 2 h), is perceived as a useful initiative by the local communities and authorities [25]. The study found that stakeholders recognized the time efficiency of drone delivery, illustrated by the successful 12-min flight from Bishnupur District Hospital to Karang Island compared to a 2-h road trip. This significant advantage over traditional methods positively influenced acceptance, aligning with Rogers' principle that perceived benefits are crucial for technology adoption. Similar experiences were reported in drone-based deliveries conducted in sub-Saharan Africa and America, where initial skepticism turned into acceptance as operations proved to be time-efficient [15, 26, 27].

The present study highlighted the concerns of the community regarding safety and privacy, particularly, in areas sharing international borders with Myanmar, which have witnessed events of insurgency and unrest. Awareness campaigns conducted during the fieldwork regarding drone-based deliveries, their benefits, and associated risks helped communities to appreciate the importance of drone technology in healthcare service delivery. The successful outcomes of initial drone deliveries, such as reduced delivery times, served as observable evidence of the technology's effectiveness. The visible benefits reinforced the positive attitudes towards drone technology, supporting the notion that innovations demonstrating clear results are more likely to be adopted. Similar results were observed in a perception study conducted in remote tribal areas in Mozambique, where drones were used to supply life-saving drugs [3, 15].

The present investigation revealed that prior to accepting the technology, healthcare workers are uncertain about the benefits due to a lack of knowledge regarding their roles in the program and the functionality of drones. This finding aligns with the most reported response by users in perception studies on novel technologies [28, 29]. Additionally, studies have observed mixed reactions, primarily related to trust

and safety concerns [30]. One study suggested that safety concerns among healthcare workers may stem from the use of personal log-in information, which is a common practice in many app-based technologies used for setting up preferences [31].

The study highlights the importance of drone technology in healthcare delivery, particularly in challenging environments. It highlights the need for innovative solutions to address last-mile delivery challenges, such as drones, and emphasizes the need for comprehensive training and technical knowledge among healthcare workers. The study also suggests that community engagement and awareness campaigns can help disseminate drone technology, addressing safety and privacy concerns. Operational barriers, such as establishing command centers and site selection, need to be addressed through strategic planning and collaboration with local partners. Safety and trust concerns should be addressed through clear policies and protocols. The findings contribute to the growing body of knowledge on drone applications in healthcare, particularly in challenging environments.

Strengths and limitations of the study

The strength of this study is that it gathered qualitative data from various stakeholders in state healthcare services, identifying challenges in remote and hard-to-reach areas. It captured stakeholders' apprehensions, satisfaction levels, and perceptions of integrating drone technology into healthcare programs. However, the study had limitations, such as testing in a limited number of locations and not incorporating quantitative measures or a larger sample size. Despite these, the findings offer valuable insights into challenges and perceptions in remote healthcare delivery, highlighting the potential role of drone technology in addressing these issues. Further research in diverse settings and larger sample sizes would be beneficial.

Conclusions

The i-DRONE project provides insights into the need for training healthcare workers regarding drones, active community engagement, and trained drone pilots about healthcare aspects. We explored the acceptance and adaptability of drone technology for healthcare service delivery in challenging terrains of Manipur and Nagaland. The findings highlighted the challenges faced in last-mile deliveries and demonstrated the positive attitudes of stakeholders and healthcare workers towards using drones. The study emphasized the importance of awareness campaigns, training programs, and addressing safety and privacy concerns to enhance the acceptance and successful implementation of drone-based healthcare delivery. These findings contribute to the growing body of knowledge on the application of drones in healthcare systems, particularly in remote and resource-deprived areas, and offer insights for policymakers and program implementers. By leveraging this innovative approach, the transportation of medical supplies can be significantly improved, enhancing accessibility to essential healthcare services for remote communities. The use of drones in healthcare delivery is a promising solution but concerns about privacy and safety must be

addressed. Comprehensive route plans and careful operation, avoiding densely populated areas, are crucial. Regular maintenance checks, pilot training, and adherence to airspace regulations are essential. By addressing these concerns, the potential of drone-based delivery in healthcare can be realized, providing efficient and timely medical supply services. Further exploration and evaluation of drone-based delivery systems are needed to ensure scalability, sustainability, and long-term impact.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1057/s41271-025-00553-1.

Acknowledgements The authors would like to thank Mr. Haggai Zatun, Ms. Pounga, Ms. Joypriya, Ms. Senvotila Aier, and Mr. I Temshier Longkumer for assistance in data collection and translations. Additionally, the authors are immensely grateful to all the participants for providing their time. The authors wish to thank all the staff from district and state medical health teams who facilitated smooth conduct of this study in their respective areas.

Author contributions SP and SA conceived and conceptualized the study. SA and PG prepared the study design and selected the study settings. Further, NM, SB, SA, and PG conducted fieldworks, and NSS and AS facilitated in identification and recruitment of participants for the study. Data were collected jointly by NM and SB. Further, the interviews were transcribed by NM, and then analyzed, and interpreted by Simmy. The manuscript was prepared by NM and SA equally, and reviewed by SB, PG, Simmy, BB, and SP. BB and SP administered the project and resources. All authors have read and approved the final manuscript.

Funding The funds for open access publication of the research findings of the study were provided by Indian Council of Medical research, New Delhi, India. This research project was also funded by the above-mentioned institution.

Data Availability The datasets used and analyzed for this study are available with the first two authors on reasonable request.

Declarations

Competing interests All authors declare that they have no conflict of interest.

Ethical approval Necessary clearance was obtained from the *Central Ethics Committee on Human Research (CECHR)*, Ref No. CECHR-001/2021 and regulatory approvals were obtained from the Ministry of Civil Aviation, Government of India.

Consent for publication Approvals for publications generated from this research project have been approved the competent authority of the authors' institution. Additionally, consent from all the participants was obtained, while explaining them that the data may be used for publication purpose.

References

1. Balasingam M. Drones in medicine—the rise of the machines. Int J Clin Pract. 2017;71(9):e12989.
2. Singireddy SRR, Daim TU. Technology Roadmap: Drone Delivery – Amazon Prime Air. In: Daim T, Chan L, Estep J, editors. Infrastructure and Technology Management. Innovation, Technology, and Knowledge Management. Cham: Springer; 2018. https://doi.org/10.1007/978-3-319-68987-6_13.
3. Graboyes RF, Bryan D, Coglianese J. Overcoming Technological and Policy Challenges to Medical Uses of Unmanned Aerial Vehicles. Mercatus Research Paper, Available at SSRN, 2020. https://ssrn.com/abstract=3561743 or https://doi.org/10.2139/ssrn.3561743
4. Nouvet E, Knoblauch AM, Passe I, et al. Perceptions of drones, digital adherence monitoring technologies and educational videos for tuberculosis control in remote Madagascar: a mixed-method study protocol. BMJ Open. 2019. https://doi.org/10.1136/bmjopen-2018-028073.
5. Kim J, Shah P, Gaskell JC, Prasann A. Scaling up disruptive agricultural technologies in Africa. Washington, D.C.: World Bank Publications; 2020.
6. De Leon R. Zipline takes flight in Ghana, making it the world's largest drone-delivery network. CNBC. 2019.
7. Knoblauch AM, de la Rosa S, Sherman J, Blauvelt C, Matemba C, Maxim L, Defawe OD, Gueye A, Robertson J, McKinney J, Brew J. Bi-directional drones to strengthen healthcare provision: experiences and lessons from Madagascar, Malawi and Senegal. BMJ Glob Health. 2019;4(4):e001541.
8. Knight R. Drones deliver healthcare. Inside Unmanned Systems, Autonomous Media. LLC, Report. 2016.
9. Suman A. Drone technology transforming healthcare in India. Biospectrum. 2022. https://www.biospectrumindia.com/views/17/22358/drone-technology-transforming-healthcare-in-india.html. Accessed 5 Jan 2023.
10. Jeyabalan V, Nouvet E, Meier P, Donelle L. Context-specific challenges, opportunities, and ethics of drones for healthcare delivery in the eyes of program managers and field staff: a multi-site qualitative study. Drones. 2020;4(3):44.
11. Fraser A. Withcraft and Explosions: Perceptions of Drones in Africa. WeRobotics Blog. 2017. http://werobotics.org/blog/2017/08/10/witchcraft-and-explosions-perceptions-to-drones-in-africa/
12. Thompson S, Bracken-Roche C. Understanding public opinion of UAVs in Canada: a 2014 analysis of survey data and its policy implications. J Unmanned Veh Syst. 2015;3:156–75.
13. Eichleay M, Mercer S, Murashani J, Evens E. Using Unmanned Aerial Vehicles for Development: Perspectives from Citizens and Government Officials in Tanzania. FHI360. 2016. https://www.ictworks.org/wp-content/uploads/2016/02/UAV-public-perceptions-tanzania.pdf. Accessed 25 Jun 2020.
14. Fink F, Paulicke D, Grünthal M, Jahn P. "Of course, drones delivering urgent medicines are necessary. But I would not use them until" Insights from a qualitative study on users…' needs and requirements regarding the use of medical drones. PLoS ONE. 2023;18(5):e0285393.
15. Truog S, Maxim L, Matemba C, Blauvelt C, Ngwira H, Makaya A, Moreira S, Lawrence E, Ailstock G, Weitz A, West M. Insights before flights: how community perceptions can make or break medical drone deliveries. Drones. 2020;4(3):51.
16. Sham R, Siau CS, Tan S, Kiu DC, Sabhi H, Thew HZ, Selvachandran G, Quek SG, Ahmad N, Ramli MH. Drone usage for medicine and vaccine delivery during the Covid-19 pandemic: attitude of health care workers in rural medical centres. Drones. 2022;6(5):109.
17. Bowen DJ, Kreuter M, Spring B, Cofta-Woerpel L, Linnan L, Weiner D, Bakken S, Kaplan CP, Squiers L, Fabrizio C, Fernandez M. How we design feasibility studies. Am J Prev Med. 2009;36(5):452–7.
18. Aggarwal S, Gupta P, Mahajan N, Balaji S, Singh KJ, Bhargava B, Panda S. Implementation of drone based delivery of medical supplies in North-East India: experiences, challenges and adopted strategies. Front Public Health. 2023;11:1128886.
19. Rogers EM, Singhal A, Quinlan MM. Diffusion of innovations. In: An integrated approach to communication theory and research. London: Routledge; 2014. p. 432–48.
20. Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol. 2006;3(2):77–101. https://doi.org/10.1191/1478088706qp063oa.
21. Data obtained from https://www.icmr.gov.in/idrone.html. Accessed 12 Jan 2024.
22. Bajwa S. Achieving Last Mile Delivery: Overcoming the Challenges in Manipur. Development and Disaster Management: A Study of the Northeastern States of India. 2018;229–37.

23. Eißfeldt H, Vogelpohl V, Stolz M, Papenfuß A, Biella M, Belz J, et al. The acceptance of civil drones in Germany. CEAS Aeronaut J. 2020;11:665–76. https://doi.org/10.1007/s13272-020-00447-w.
24. Demuyakor J. Ghana go digital Agenda: the impact of zipline drone technology on digital emergency health delivery in Ghana. Humanities. 2020;8(1):242–53.
25. Press Information Bureau. Shri Mansukh Mandaviya, Union Minister for Health and Family Welfare launches i-Drone, ICMR's drone-based vaccine delivery model. 2021. https://pib.gov.in/PressReleasePage.aspx?PRID=1760806. Accessed 20 Jan 2023.
26. Goodchild A, Toy J. Delivery by drone: an evaluation of unmanned aerial vehicle technology in reducing CO2 emissions in the delivery service industry. Transp Res Part D Transp Environ. 2018;1(61):58–67.
27. Mathew AO, Jha AN, Lingappa AK, Sinha P. Attitude towards drone food delivery services—role of innovativeness, perceived risk, and green image. J Open Innov Technol Market Complex. 2021;7(2):144.
28. Stephan F, Reinsperger N, Grunthal M, Paulicke D, Jahn P. Human drone interaction in delivery of medical supplies: a scoping review of experimental studies. PLoS ONE. 2022;17:e0267664. https://doi.org/10.1371/journal.pone.0267664.
29. Rosamond WD, Johnson AM, Bogle BM, Arnold E, Cunningham CJ, Picinich M, et al. Drone delivery of an automated external defibrillator. N Engl J Med. 2020;383:1186–8. https://doi.org/10.1056/NEJMc1915956.
30. Okolo CT, Kamath S, Dell N, Vashistha A. "It cannot do all of my work": community health worker perceptions of AI-enabled mobile health applications in rural India. In: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. 2021. pp. 1–20.
31. Dhagarra D, Goswami M, Kumar G. Impact of trust and privacy concerns on technology acceptance in healthcare: an Indian perspective. Int J Med Informatics. 2020;1(141):104164.

Sumit Aggarwal MD, is a Scientist and Program Officer at the ICMR-Headquarters, Delhi, New Delhi, India.

Nupur Mahajan PhD, was a Research Associate at the ICMR-Headquarters, Delhi, New Delhi, India.

Prakamya Gupta PhD, was a Scientist C at the ICMR-Headquarters, Delhi, New Delhi, India.

Sivaraman Balaji PhD, was a Scientist C at the ICMR-Headquarters, Delhi, New Delhi, India.

Simmy PhD, is a Scientist C at the ICMR-Headquarters, Delhi, New Delhi, India.

Naorem Shyamjai Singh MD, was a Mission Director at the National Health Mission, State Health Society, Babupura, Imphal, Manipur, India.

Ayangla Saku MD, is a DIO at the Chief Medical Officer's Office, Mokokchung, Nagaland, India.

Balram Bhargava MD & DM, is a Former Director General at the ICMR-Headquarters, Delhi, New Delhi, India.

Samiran Panda MD, is a Additional Director General at the ICMR-Headquarters, Delhi, New Delhi, India.