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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

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Abstract: Unmanned aerial vehicles (UAVs), also known as drones, have significant potential in the healthcare field. Ethical and practical concerns, challenges, and complexities of using drones for specific and diverse healthcare purposes have been minimally explored to date. This paper aims to document and advance awareness of diverse context-specific concerns, challenges, and complexities encountered by individuals working on the front lines of drones for health. It draws on original qualitative research and data from semi-structured interviews (N = 16) with drones for health program managers and field staff in nine countries. Directed thematic analysis was used to analyze interviews and identify key ethical and practical concerns, challenges, and complexities experienced by participants in their work with drones for health projects. While some concerns, challenges, and complexities described by study participants were more technical in nature, for example, those related to drone technology and approval processes, the majority were not. The bulk of context-specific concerns and challenges identified by participants, we propose, could be mitigated through community engagement initiatives.

Keywords: drones; unmanned aerial vehicle; health; healthcare; delivery of health; care; drones for health; ethics; practical challenges; community engagement; stakeholder participation

1. Introduction

The integration of unmanned aerial vehicles (UAVs), also known as drones, into health systems represents an area of massive potential [1–18]. Half the world population lives in rural areas, defined in diverse ways across countries, but characterized by non-urban density population [19,20]. Many of these areas are underserved when it comes to healthcare. The health worker shortage is twice as high in rural areas compared to urban areas based on the International Labor Office, Social Protection Department statistics of 174 countries [21]. Additionally, 56% of the rural population do not have access to rights-based health coverage; as compared to the average of 38% without legal health coverage worldwide [22].

Until now, the delivery of medical supplies and blood to rural, underserved communities has relied on traditional transportation methods, such as by foot, aircraft, or automobiles [11,14]. These methods are limited, especially in settings located far from local hospitals, with poor or non-existent ground transport infrastructures, or presenting other challenges to rapid transport, such as mountains [6,11,14]. Drones have the potential to circumvent such limitations. Drones have been used to deliver medications to mobile clinics in the rural and underserved and mountainous Appalachian region of southwest Virginia [6]. Drones are delivering blood from Rwanda's capital city to local hospitals, cutting down delivery time from four hours to merely 15 min [14]. In Canada, Drone Delivery Canada has partnered with Moose Cree First Nation communities living in remote areas of Northern Ontario to deliver goods, such as medical supplies [4]. Studies have shown that automatic external defibrillator (AED) delivered by drones can reach individuals in cardiac arrest approximately 19 min faster than the emergency medical services (EMS), improving patient survival and recovery rates [2,3,10,12,18]. Drones are being used to expedite the process of getting biological samples for diagnostic purposes to laboratories, reducing risks of biological samples becoming non-viable in the process of transportation [8,11,14,23,24], and there are many potential uses of for drones for telemedicine are in expansion [1,25].

The potential for drones to support health systems extends beyond rural areas. Drones hold significant promise to support infectious disease control and public health emergency response. Drone use has further expanded in the course of the COVID-19 pandemic, which is ongoing as we write. Supporting infection control and response initiatives in several jurisdictions, drones have been used during the pandemic to: spray disinfecting chemical in public spaces; issue public health announcements reminding individuals to maintain the recommended six feet distance from their fellow citizens; to transport medical supplies, such as PPE, vaccines, samples and blood to hospitals in need of these supplies; and to deliver medications, masks, and sanitizers to elders living in remote communities [26–29].

The use of drones is relatively new in the healthcare context, with the result that there has been little exploration and documentation of challenges or concerns for drone usage in healthcare settings[45]. The study on which the present article is based had as its objective: to understand the concerns, challenges and complexities of implementing drones for health projects as perceived by individuals involved in introducing and implementing these projects. In doing so, this study responds to calls for the development of a "drone theory in global health", which calls a need for critical engagement with the social, political, and ethical meanings and implications of the biomedical drone in global health supposed problem-solving [30]. Ultimately, our hope is that findings from this study can serve to advance awareness of diverse context-specific concerns, challenges, and complexities that can be anticipated, and potentially, mitigated by parties involved with implementing and using drones for health delivery.

2. Methods

This article draws on results from a qualitative perceptions study involving semi-structured in-depth interviews with individuals (N = 16) from nine countries working on the front lines of drones for health programs. Qualitative research is well suited to gaining detailed insight on experiences, relationships within, and the functioning of healthcare initiatives [31,32]. This multi-sited comparative perception of healthcare study replicates an approach commonly used in program design and quality improvement in the healthcare and humanitarian aid sector [13,33–35]. Perception studies are often used in healthcare to understand how frontline health staff, patients, policy-makers and communities view healthcare initiatives, providing insight about the satisfaction, perceived advantages and disadvantages, and perceived importance of health programs [36–38].

2.1. Recruitment and Sampling

Recruitment involved purposive and snowball methods. Eligibility criteria for participation required that potential participants: (1) work in a role that involved responsibility for introducing and implementing drones for health programs; (2) be willing and able to participate in a one-hour individual virtual interview. Uncertain about the demographic of individuals in these roles around the world, we were committed to seeking a balance of men and women in our sample, but also aware, through our contacts to the sector, that more men than women may be involved with the field implementation side of drones for health projects at this juncture. Initially, recruitment focused on individuals involved with drones for health programs in association with Flying Labs, a global network that supports context-appropriate application and expansion of drones around the world [39]. Country coordinators for Flying Labs with active or recently active health-related programs were contacted through their publicly available contact information, with an invitation to identify program managers, technical support, community engagement agents, or any other pertinent individuals with drones of health experience in the past year, whom we could invite to participate in the study. With limited responses to our requests, three months into recruitment, we expanded the strategy to include individuals working with drones for health programs outside the Flying Lab network. This second phase of recruitment relied on the dissemination of a recruitment poster through a monthly newsletter that was circulated by the Unmanned Aerial Vehicles (UAV) network. Snowball sampling was also used, as participants were asked if they had colleagues working in similar capacities either in that country or in another country context that might be receptive to an invitation to participate.

2.2. Data Collection

Interviews were conducted between June 2019 and February 2020 by conventional phone or Skype by two members of the study team (VJ and EN) in English, Spanish or Nepali. A translator was present to assist in interviews conducted in Nepali, as neither interviewer is fluent in Nepali. Interviews lasted between 20 and 140 min, and an average of 78 min. Interviews were digitally recorded with participants' consent.

2.3. Data Analysis

Interviews were transcribed verbatim, and where necessary, translated into English before being uploaded to NVivo 12 (QSR). NVivo software supports accuracy, transparency, and the opportunity for auditing qualitative data analysis [40]. In this case, we used NVivo for thematic analysis, "a form of pattern recognition used in content analysis whereby themes (or codes) that emerge from the data become the categories for analysis", further tailored to our research objectives through a combination of directed and interpretive approaches [13,41–43]. The first author established an initial set of codes based on the research questions (directed thematic analysis approach). Towards ensuring a codebook suited to the content of the interviews, as well as the goals of the study, two members of the study team then independently coded four interviews to identify additional themes, introducing the interpretive description approach [42]. Interpretive description seeks to advance understanding of a phenomenon by illuminating its "characteristics, patterns and structure" while being attentive to nuances and differences [42]. Resulting codes identified by VJ and EN were compared [44]. Discrepancies were discussed and resolved in dialogue with a third member of the study team (LD). The coding framework derived from this process formed the basis for subsequent analysis in NVivo led by VJ. Minor changes (i.e., changes in theme names or addition of emerging themes) were made to the codebook in an iterative process. EN performed an audit of the final codebook, to ensure coding completeness and accuracy.

2.4. Ethics

This study received approval from the Western University's Research Ethics Board (protocol approval #113823).

3. Results

3.1. Overview of Participants and Project Details

Sixteen participants (N = 16), including 11 men and 5 women, volunteered and were included in the study. Most participants were in leadership positions (n = 11), others were advisors (n = 2), technical staff (n = 1), or researchers (n = 2). Participants were involved in drone projects in 9 different countries and projects that can be categorized into five different sub-regions defined by the United Nations (UN). The number of countries that fall under each sub-region and the number of individuals interviewed are summarized in Table 1.

Table 1. Description of United Nation sub-regions and a number of countries where participants implemented drones for health projects.

United Nation Region	Number of Countries	Number of Individuals
Latin America and the Caribbean	2	2
Melanesia	1	2
Northern America	1	2
Southern Asia	1	4
Sub-Saharan Africa	4	6

Drones for health projects is a broad umbrella term we are using here to refer to the use of drones for health-related purposes. In those projects discussed by participants, these purposes included: delivery of biological samples (n = 8), live mosquito vectors (n = 2), and medical supplies (n = 10); geographic mapping (n = 2); and environmental and disaster monitoring (n = 3). Biological sample delivery involved the transport of blood and sputum samples from community health centers to laboratories or district hospitals for laboratory diagnostic testing in order to identify, diagnose, and treat patients for diseases, such as tuberculosis and HIV. Drones were used to deliver medications and vaccines to local pharmacies and automatic external defibrillators to help patients in cardiac arrest. Drones delivered live vector, such as genetically modified mosquitos to reduce dengue burden. Furthermore, drones were used to map certain locations in order to better understand the hazards caused by flooding. Table 2 includes a summary of the different uses and need cases for drones discussed by study participants.

Table 2. Participant-identified drone needs and actual use.

UN Region	Drone Need	Drone Use
Latin America and the Caribbean (n = 2)	• Improve access to healthcare services and medical supplies in remote communities • Reduce the disease burden	• Biological Sample Delivery • Medical Supply Delivery
Melanesia * (n = 2)	• Understand the health risks, hazards, and safety concerns related to flooding • Reduce the disease burden	• Mapping • Live vector delivery
Northern America (n = 2)	• Improve access to healthcare services in remote communities	• Medical Supply Delivery
Southern Asia (n = 4)	• Improve access to healthcare services in remote communities • Reduce the disease burden	• Biological sample and medical supply delivery
Sub-Saharan Africa (n = 6)	• Improve access to healthcare services and medical supplies in remote communities	• Biological sample and medical supply delivery

* Delivery occurred within the same island.

At the time of interview, most participants were involved in projects conducting pilot flights to test the feasibility of implementing drones for health projects (n = 15). One participant was involved in a project that already integrated drones into the country's regular supply chain for healthcare delivery. When the interviews took place, the projects have been executed between seven months and three years.

3.2. Benefits of Drones for Health Projects

Participants' accounts of the drones for health projects revealed various benefits to these projects in participants' eyes; some of these were explicit, and others emerged implicitly. These included direct benefits, such as better access to healthcare, enhanced health services, reduced costs to patients, reduced waiting times—all improving healthcare outcomes. Additionally, drones for health projects have indirect benefits that were not the primary objective of the project. This included building local capacity, potentially solving other issues, providing infrastructure to support and continue similar drone projects, mitigating existing risks, and motivating individuals.

3.2.1. Direct Benefits

Direct benefits of drones for health projects described by participants included maps for communities (n = 2), reduced delivery times (n = 10), and reduced healthcare-associated costs to patients (n = 2). Most of the projects aim to improve access to healthcare (n = 14). Drones for health projects have provided maps to communities in order to understand environmental hazards and fill in gaps within existing geographical data, allowing governments and organizations to more efficiently help communities prepare for and prevent such hazards (n = 2). Participants reported that drone delivery is more efficient compared to traditional healthcare delivery methods (i.e., automobile, by foot, and boat) (n = 9), especially in communities with either limited or no road infrastructure (n = 10). Transportation time was also enhanced with drone use in communities that experience severe weather, such as thunderstorms and strong winds (n = 7). In some instances, the difference between drone delivery and traditional delivery could be up to six hours (n = 1). Medication, and medical supplies were delivered in a timely manner (n = 5), with one participant noting this being important to protecting the integrity of the products. Consequently, individuals were able to be efficiently diagnosed and treated, which improved their health outcomes. For example, automatic external defibrillator delivered by drones could reach cardiac arrest patients 9 to 10 min faster than emergency medical services—this is crucial as cardiac arrest survival rate decreases 7 to 10 percent per delayed minute (n = 1). One participant said that in remote communities, individuals seeking diagnostic testing may need to travel upwards of 10 h to do so. Such travel time and accompanying costs (e.g., lost work time, transportation costs) could be a barrier for accessing healthcare for some. The use of drones to collect and deliver biological samples for diagnosis was cited as a benefit for patients in particular (n = 3). In fact, one study participant mentioned that a full house of people arrived at the local health center once they found out they could have their samples tested locally instead of having to go to the main village. Drones are able to "solve the gap, solve the problem of remoteness" (Participant 06). Additionally, drones enable health teams to test samples in hospitals with more sophisticated technology (n = 4) than what is available at local community health centers, supporting quicker and also potentially more accurate turnaround of results (n = 8). These drones for health projects were described by participants as aiming to reduce the disease burden of prevalent diseases, such as tuberculosis, dengue, and HIV (n = 7). A participant described that their team completed 200 hundred drone flights and delivered 2000 patient samples, helping them identify and treat dozens of tuberculosis cases that might otherwise have gone undetected and untreated (n = 2). Many participants felt strongly that drones for health projects represent efficient strategies to strengthen disease identification, treatment, and diagnosis (n = 8). Ultimately, the message from participants was that drones for health projects have the potential to improve healthcare outcomes by improving accessibility, reducing delivery times, and reducing costs to patients.

3.2.2. Indirect Benefits

Participant accounts included a description of several indirect benefits deriving from these drones for health projects. These included mitigating existing risks associated to travelling on unsafe roads; building local capacity; providing demographic information to improve other non-health-related services; introducing infrastructure, such as drone guidelines to support and continue similar health-related drone projects; and motivating individuals. These indirect benefits can potentially have long-term effects, such as providing individuals with skills, improve well-being, and creating legal documents, such as guidelines for future drone use—this results in sustainable positive changes in these communities.

Participants mentioned that drones for health projects minimized the need to travel dangerous roads (n = 4). Many of the drones for health projects described by participants involved local community members, university students, or health workers (n = 8). This involvement allowed these individuals to learn new skills (n = 8) and in some cases, earn additional income if their involvement was remunerated (n = 2). Some of the work completed through drones for health projects, such as creating geographical maps, was described as bringing benefits to communities beyond the projects, allowing governments to better serve their communities (n = 2). For example, in one country, the government used the information provided by drone teams to implement sewing programs for women.

Drones for health projects have resulted in countries modifying or developing drone guidelines that are now being adopted for purposes beyond health (n = 4). Participants are hoping to use drone technology to motivate youth to go to university and explore how they can solve their country's problems using innovative solutions (n = 2). Drones for health projects teams have developed committees positioned to involve various stakeholders in future drones for health projects (n = 3). In one instance, such a committee emerged to help convince the government to approve the first drones for health projects. In another country, a team funded a national drone steering committee to mobilize stakeholders (governments and organizations) that have interest in drone projects with the goal of drawing on this structure and its members for future drone projects, health-related or otherwise. Finally, participants said that the drones for health projects piqued interest in neighboring communities and even other countries (n = 4).

3.3. Concerns Surrounding the Implementation of Drones for Health Projects

The use of drones for healthcare gives rise to various concerns. These concerns have either been raised by participants themselves, or brought to their attention by community members, elected officials, healthcare staff, security personnel, or civil aviation organizations during community engagement initiatives. The primary concerns that were raised included issues of privacy, security, safety, and the long-term sustainability of the drones for health projects. Project-specific concerns were also identified by several participants; these concerns are specific to the implementation of drones for health in particular communities. The parameters of these concerns are described in greater detail below, along with participants' attempts to mitigate these for the projects they led or supported. See Table S1 in the supplementary file for exemplary quotes corresponding to key concerns, practical challenges, and ethical complexities identified by participants can be found in a table.

3.3.1. Privacy and Security Concerns

Participants reported privacy concerns expressed by community members arising from real or rumored capacities of drones capturing pictures or videos of private and public spaces and/or individuals in these communities (n = 11). Related to such worries in some cases were concerns that drones would be used for spying and policing people, their land, or resources, such as for gold mining (n = 5), as well as concerns related to the ownership and protection of drone-generated visual data (n = 5). Several participants had heard concerns that drones could lead to pictures and videos being taken for sale to people outside the country, for example, for tourism profit purposes, or exploited for mining purposes (n = 5).

A few participants said that during community sensitization where the project was being introduced, the army and police raised security concerns related to drone use and were opposed to having cameras attached to the drones (n = 3). These concerns resulted in the army and police restricting where teams could fly the drones (i.e., not over army camps) (n = 3). However, most drone projects participants were involved in did not have cameras attached to their drones (n = 9).

In those projects where the above concerns were raised (n = 11), participants eased individuals' privacy and security concerns by explaining and assuring them during community sensitization that the drones did not have cameras attached to them (n = 8). If they did use a camera, the participant explained how the data would be utilized (n = 3). To mitigate these concerns, participants and their teams also followed instructions provided by police and security, or guidelines and regulations the country has implemented for drone use (n = 4).

3.3.2. Safety Concerns

Concern for the physical safety of individuals, properties, and animals was brought up in several drones for health project settings (n = 12). Worry that the drone would crash into people and things during takeoff, landing, flight, or during unloading of deliveries was a common concern heard by participants (n = 10). Four participants described that there were concerns about individuals damaging the drone by throwing rocks at it (n = 4). There was also worry that in the future, drones could be used locally for purposes beyond health, such as biological warfare or war, putting community safety at risk (n = 3).

Several participants stated that they managed safety concerns by taking safety precautions, such as asking individuals to keep their distance from the drone and having discussions about safety and answering questions about safety during community sensitizations (n = 10).

3.3.3. The Importance of Context

Three participants underlined that some concerns were context-specific. For example, one participant described a community's initial distrust of the drone project in which they were involved and connected this distrust to past and ongoing examples of outsiders coming into the region only when wanting to exploit natural resources, and in the eyes of the community, act with disregard for the local populations. Another participant mentioned that one community was particularly concerned about where the drone was flying, as they did not want it to fly over a nearby refugee camp (n = 1). The leadership team in this community had pointed out to the drone team that the people at the refugee camp may be traumatized already, and that flying drones over the camp may further negatively affect the individuals.

In another setting, a participant was struck by associations in some community members' minds between drones and beliefs about magic and Satanism. In this case, the participant was unclear what histories or contextual factors might have been at the root of these associations. Regardless, this was unique to a single setting in their experience and serves to reinforce that concerns and community responses to drones for health programs are far from universal: these vary within, but also across different communities. Participants reported being sensitive to the ways concerns connect to local communities' economic activities, cultural beliefs, experiences with outsiders, histories of exploitation in some cases, and adapting project plans or communications where necessary (e.g., not flying near the refugee camp; clarifying the project was not connected to mining interests) in response to such context-specific concerns.

3.4. Practical Challenges of Implementing Drones for Health Projects

Participants identified the practical challenges they faced during the implementation and introduction of drones for health projects. These challenges were reported as limitations to the successful execution of these projects and were perceived by participants as impacting the ability to integrate these drones for healthcare delivery in the future. Key challenges identified include skepticism of drone technology, lack of resources, inability to access appropriate stakeholders, technical challenges, and lack of guidelines and regulations.

3.4.1. Skepticism of Drone Technology

Half the participants identified that community members, and elected officials were initially uninterested or skeptical about their drones for health projects and were hesitant to support it.

Different participants provided different interpretations of why community members and elected officials were hesitant. These included not understanding the drone technology; thinking that drones were replacing other health-related services in their community; and skepticism of whether the project was going to be unsuccessful (n = 6). The elected officials were not keen on changing policies and guidelines to accelerate the implementation of the projects (n = 1). Additionally, a few participants speculated that some community members did not participate in community engagement activities that introduced the drone projects to communities because the community members were not generally interested in this project or felt that the drone use case did not pertain to their medical needs (n = 2).

However, after successfully demonstrating and generating evidence that their pilot project worked, some participants reported observing a shift in attitudes (n = 3). Observing the drones at work, and perhaps also observing and growing to trust the team, typically in these participants' experience skeptical stakeholders grew to support the projects they initially doubted (n = 3). Preparedness for such skepticism is important, given skepticism of drones for health projects can act as a barrier to implementation, for example, by translating into difficulties obtaining official approvals, or diminishing engaged communities' acceptance to a project.

3.4.2. Lack of Resources

Several study participants reported a lack of resources as a barrier to implementing drones for health projects (n = 9). Resources identified as lacking for optimal operations of particular projects included time, staff, and overall funding. In some regions, the lack of electricity or material resources, such as a refrigerator to store biosamples or medical supplies, represented important barriers to implementing the drones for health projects in a particular area. A number of participants pointed out that many different stakeholders, including themselves, were impacted by time constraints. In the assessment of these participants, time constraints for the execution of a drone project impacted community engagement in particular, and opportunities to optimize drone testing. For example, some participants described having limited or no opportunity to fly drones, due to technical issues, weather conditions, or needing to spend a majority of their time gaining approvals to conduct the project instead of actually executing the project (n = 6).

Two participants described time as a limitation faced by health workers and lab technicians. Such specialists, integral to the integration of certain projects within existing testing or diagnostic infrastructure, already faced heavy workloads. It was clear to at least two participants that enthusiasm and engagement with new drones for health initiatives was tempered amongst such specialists by an understanding that these projects implied additional responsibilities being added onto their existing heavy workloads. Time constraints on limited yet essential human resources available to move projects forward and ensure their smooth operation could and did in some cases, impact achievement of project objectives. Additionally, seven participants mentioned a lack of individuals with appropriate expertise to quickly come onto projects as supervisors, technicians, and pilots (n = 7). However, this was not a major barrier in participants' eyes. Participants reported being able to train and rely on community members and community health workers to support projects. Little to no incentives were provided to community members working with drones for health projects. This lack of remuneration was not flagged as a concern by any of the participants. In a minority of projects, drone teams recruited individuals with the appropriate skills or expertise to support field implementation from outside the project's context (n = 4).

A handful of participants mentioned the high costs associated with drone technology and the human resources required to execute drone for health projects (n = 3). Many more participants mentioned that the scope of their project was constrained by the limited budget, and worried about the future of these projects once funding of the pilot project ended (n = 10). Some participants (n = 4) explained that this worry was not only theirs: communities involved in pilots wanted to see these projects expand to all health facilities and other communities. No solutions were identified by participants to address these various resource limitations, which posed practical challenges to implementing, sustaining, and scaling drones for health projects to other communities.

3.4.3. Technical Challenges

Almost all participants faced technical challenges during the implementation of their drones for health projects. These related primarily to drone technology (n = 14), weather conditions (n = 7), and geography/topography (n = 3). Drone technology challenges included network issues (n = 4), GPS problems (n = 3), flying drones autonomously (n = 3), and precision landing (n = 4). Some participants (n = 3) pointed out that drones' short battery life limits flight distances, a problem exacerbated at higher altitudes. It was also brought to attention that drones need to be controlled for temperature and humidity when transporting samples (n = 3). Some technical issues resulted in drone crashes (n = 8).

Three participants described how the topography of flight paths could make it challenging to fly and operate the drone (n = 3). Additionally, the large size of some villages created challenges to the collection of GPS coordinates to fly the drone in and out of the village for one drone team. Weather conditions could and did pose a major challenge in participants' experience. Current drones in use cannot operate in certain weather conditions like severe wind and thunderstorms (n = 7).

Three participants mentioned that technical challenges have either caused a loss of drones and samples or raised concerns of loss of drones and samples. Almost a third of the participants (n = 5) admitted that the pilot project with which they had worked had not successfully completed its objectives, due to technical challenges.

A minority of participants reported being able to successfully overcome technical challenges by taking a back-up drone with them (n = 1), or having technicians and engineers troubleshoot the problem (n = 2). Study participants acknowledged that drone technology is new and evolving (n = 3), and more work needs to be done to expand their effective and reliable use for health projects. Several participants called for further fine-tuning and testing of the technology outside the context of projects, in order to resolve any technical issues (n = 7).

3.4.4. Lack of Guidelines and Regulations

Several participants mentioned limited or non-existent guidelines and regulations for drone use in the countries where they worked as a challenge (N = 6). In the absence of these reference points, some participants reported that they and their teams were unsure how to appropriately execute their drones for health projects (n = 3). Some countries had guidelines and regulations for drone use, but these were not specific to drones employed for health purposes, limiting their utility as frameworks for drones for health projects (n = 2). Participants noted that these general drone guidelines did not address health-related safety and privacy issues and standard operation procedures for transporting medical supplies and biological samples (n = 2). Additionally, general drone guidelines in some national settings defined limitations on the radiofrequency employed by drones, their altitude and distance, and their cargo weight in ways participants saw as incompatible with the mission of drones for health projects (n = 4).

Some participants found that the lack of appropriate healthcare-related guidelines made it time-consuming for them to adapt existing guidelines and get approvals to conduct the project (n = 2). On the other hand, a participant described that a country with no drone regulations made it easy for them to implement the drones for health projects as they had the flexibility to develop principles of operations that could facilitate the project execution (n = 1).

To overcome these challenges, participants adapted the general drone guidelines to better accommodate the drones for health projects (n = 2). Two participants explicitly called for healthcare-specific drone guidelines (n = 2). As a matter of fact, countries have further developed their drone regulations after the introduction of drones for health projects (n = 4). Participants recognized that governments are learning during this process as guidelines are evolving (n = 2).

Many participants reported that collaboration with stakeholders such as, for example, national and local government, the ministry of health, telecommunication regulatory agency, and civil aviation is required to develop drone regulations to conduct these drones for health projects (n = 4). Guidelines can also be developed by learning from other countries which successfully implemented these drones for health projects (n = 1). Not only is it challenging to execute these projects without the appropriate guidelines, but it also makes it difficult to sustain the project as there are no regulations governing the management and execution of drones for health projects (n = 2).

3.4.5. Inability to Access Appropriate Stakeholders

Several participants pointed out that they faced challenges contacting appropriate community stakeholders at the outset of projects (n = 11). Two participants said they were able to communicate with local community members only after arriving at the local community (n = 2). The lack of phone lines or cellular networks in some areas made it difficult to inform community leaders of a project prior to their physical arrival (n = 2). One participant reported that a lack of clear social hierarchy and leadership in one community made it particularly difficult to know how to initiate engagement with the community, as they typically approached elected or traditional leaders for permission to speak to the broader community. Some participants noted low attendance at some of their project's community information sessions, attributing this low turnout to their failure to figure out how to properly communicate to communities, organizations, and leaders about the community sensitization (n = 3). It was observed by many participants that local community members were usually at school, away from the community, busy with household chores, or at work when community engagement activities, such as information sessions or flight demonstrations took place (n = 6). Several participants noted it was especially hard to engage male community members because they were the ones usually away for work (n = 5).

The large population size of some of the communities positioned to host drone for health projects made it hard for participants and their teams to know to what extent invitations and attendance of community engagement activities were effective and inclusive (n = 3). This was further exacerbated if information sessions were held in more central villages, but aimed to include populations from surrounding villages (n = 1). To mitigate limitation to formal community engagement, a significant number of study participants reported that their teams relied on children, women, elected officials, or traditional leaders to relay the information about the project.

This shows how teams conduct engagement initiatives expecting individuals who attend these initiatives to further spread awareness about these projects within the community. Aside from community engagement activities, a participant identified that they faced difficulty hiring local youth to join the project as most of them moved from the remote village for work (n = 1). Additionally, two participants mentioned that it was hard to coordinate meetings with non-governmental and governmental organizations to execute this project because they are busy (n = 3). One participant recommended overcoming these challenges by being flexible to change the meeting date to best-fit everyone's schedule (n = 1), having used this strategy themselves successfully.

3.5. Ethical Complexities in Implementing Drones for Health Projects

Participants' accounts brought to light several ethical complexities that merit consideration when initiating drone for health projects. These include complexities of consent, host communities' perceived limited understanding of drones for health project, the fit of project goals with community priorities, and the need for transparency and honesty in project management.

3.5.1. Complexities of Informed Consent

Providing individuals residing in remote communities with the opportunity to provide their informed consent to the introduction of drones for health projects in their midst is important, as it promotes individual autonomy, and prevents individuals from feeling a project is being imposed without respect for their preference. Obtaining consent from communities and residents in communities, especially when working in remote areas where drone teams will be perceived without a doubt as outsiders, supports good or ethical practices of community engagement and implementation. However, participants' reports of consent practices underlined these as clear sites for potential ethical complexity. For example, one participant mentioned that they were unsure whether executing the drones for health projects without community sensitization and with just the consent from the traditional leader was appropriate (n = 1). Different approaches were taken in different contexts: Collective consent was sought in some locations and cases (n = 7), while individual consent from community members was sought in others (n = 6).

There were inconsistent consent practices within and between drones for health projects (n = 5). For example, consent practices were different in rural and urban settings within the same country, in one participant's account. Some participants mentioned that in rural settings, their normal practice was to ask community representatives if it was acceptable to make use of private lands (n = 3); while other participants described their normal practice as involving obtaining consent from the landowner instead (n = 3). The impacts of these different practices, in terms of community perceptions of the drone projects, was unclear to participants. Inconsistent consent practices could undermine individuals' autonomy or respect for local culture.

Many projects relied on obtaining collective consents from representatives in the village to conduct and present these drones for health projects in the communities (n = 7). This harbored its own ethical complexities. Participants described sometimes getting help from community representative to convince community members who were hesitant in providing informed consent (n = 3). In one scenario described by Participant 08, the team was unable to obtain permission from community members to land the drones on private properties. The public health officials suggested the team get help from the ward councilors to convince the community members to cooperate with the team. Participant 08 proceeded with this plan, but felt uncomfortable given they suspected community members felt unable to refuse a recommendation from their ward councilor. A few other participants explicitly stated that individuals usually do not disagree with the elected or traditional representatives (n = 3).

3.5.2. Individuals' Perceived Limited Understanding of Drones for Health Projects

A facet of obtaining informed consent is ensuring that local community members, government, and non-government organizations fully understand the nature of the drones for health projects.

In fact, many of the above-mentioned concerns stem, according to many of this study's participants, from limited awareness and understanding of drones for health projects. Such limited awareness has, in several instances, according to participants, led to rumors and miscommunication, causing individuals to fear drones or resist the implementation of drones (n = 9). These included rumors and misunderstandings that drones would be used for mining (n = 3), surveillance (n = 5), policing (n = 2), or military reconnaissance (n = 2). Some participants explained that such rumors and misunderstanding stemmed from individuals' real and perceived experiences of drone use. For example, in some settings, community members were aware of their government's plan to use drones to police the border, or seen drones dropping missiles in movies. In one instance, there was a misunderstanding that drones were being introduced with a plan to replace existing health services (n = 1). Such concerns, participants reported, could be further amplified when these drones for healthcare projects were implemented by foreigners. In at least one case, this distrust was based on a community's past experience of hosting a project whose team had never followed up to share the results of the project. More often, distrust was connected to a colonial history that involved foreigners stealing their lands or otherwise harming them (n = 3). Another rumor participants had heard was that foreigners were sucking the blood out of community members with witchcraft-like (drone) technology (n = 2).

In addition to these misunderstandings, participants worried that community members and elected officials may not actually understand the "spectrum of harms and benefits the drones might cause" (Participant 08) (n = 4). Participants hypothesized that limited understanding originated in either the fact that stakeholders were unfamiliar with drones being used for healthcare (n = 4), or had heard rumors spreading about the project (n = 9), or did not have the literacy skills to fully grasp the idea of using drones for healthcare (n = 1). Several participants mentioned that they were quite certain community members might not fully understand the complexities of the drone technology and the implications drones may potentially have on their safety and privacy (n = 5). Some study participants asserted that any limited understanding they observed did not surprise them, as it was difficult for them to fully understand the consequences of their own drones for health projects before actually executing the project (n = 3).

A majority of participants emphasized the need and importance for community sensitization to help individuals better understand these drones for health projects (n = 9).

Participants indicated that they were able to clarify any misunderstanding through community sensitization, where they explained the drone project, answered questions, and allowed community members to interact with the drone technology (n = 9).

3.5.3. Aligning with Community Priorities

It has been brought to light through several participants' description of the drones for health projects that these projects sometimes do not necessarily meet the needs of the local community (n = 7). Communities do not want studies and trials; they want solutions to their problems (n = 1). However, almost all drones for health projects in which our study participants were involved were generating evidence and testing the feasibility of drones for healthcare (n = 15), rather than transforming health realities in these communities. For example, a participant mentioned that though their project identified the cause of the flooding in the community, the drones were not actually fixing this problem (n = 1). A point made by a couple of participants was that drones are sophisticated technologies that do not, however, solve more basic problems impacting day to day life in communities (n = 2), such as access to food.

It is important to consider the ethical implications of allocating resources to implementing these expensive drone programs instead of allocating resources to other areas that might better address community health needs. Currently, drones for health projects are focusing on one use case or even one disease, and a participant reported that this worried some individuals in these communities as it does not address what they regarded as their most urgent health problems (n = 1).

Several participants reported being approached by individuals and organizations with requests to expand the drone use case (n = 5). A participant mentioned that they included additional use cases, such as sending medicines in addition to vaccines based on one community's needs and requests (n = 1). By consulting with local communities, participants were better able to tailor the drones for health projects to meet the needs of the in a more meaningful and impactful way (n = 2).

3.5.4. Transparency and Honesty in Project Management

Study participants insisted it was important for them to be honest with local communities about what to expect from the drones for health projects (n = 5). In some settings, participants had been unable to successfully conduct promised pilot flights, due to technical issues (n = 3). Participants involved in these projects recognized that, by not fulfilling their plans, communities were left feeling disappointed and were not given the opportunity to better understand the drone project.

Participants acknowledged the importance of being honest with community members about what the drone technology could and could not achieve (n = 5). Clear upfront communication about the parameters of drones for health projects was recommended as the key to managing expectations about project outcomes, especially where projects are feasibility tests and project timelines are short. As one participant noted, if they overpromised and underdelivered, then it would make it harder for them to operate again in that community (n = 1).

4. Discussion

Drones have the potential to transform healthcare landscapes. They are being used for a wide and expanding range of purposes, from biological sample delivery, live vector delivery, and medical supplies delivery, to mapping, disaster monitoring, and environmental monitoring. This study provides a unique snapshot into the perceived benefits, challenges, and complexities of using drones for health, in the eyes of those on the front lines of this rapidly evolving technology.

Participants highlighted both direct and indirect benefits of using drones for healthcare purposes, especially within rural settings with limited road infrastructure and access to healthcare. Direct benefits described included: better access to healthcare; enhanced health services; reduced costs to patients; and reduced waiting times. All of these were framed by participants as ultimately improving healthcare outcomes. Indirect benefits cited included: building local capacity; potentially solving other issues; providing infrastructure to support and continue similar drone projects; mitigating existing risks, such as the need to travel dangerous roads; and motivating individuals (and in particular youth) to think of innovative ways to use drone technology to solve local issues.

In terms of challenges experienced in the process of introducing drones for healthcare purposes in a range of settings, these were both practical and ethical. Participants described having to navigate skepticism of the project amongst community members and government officials. What emerges from accounts of this challenge is a reminder that introducing changes in health systems requires much conversation, explanation, and collaboration with the populations who supposedly stand to benefit from these interventions. Community engagement is viewed as an ethical and practical imperative when implementing any new information and communication technology [45–47]. Many drone companies and organizations have recognized the need to engage with local community members whether it is through hosting community engagement initiatives about drones or developing drone software that enables local community members to fly drones [30]. However, there are current gaps in the literature describing community engagement practices for the use of drones in the healthcare context [48,49]. Good community engagement takes time, and will be uniquely articulated to local population needs, concerns, and preferences. If community engagement processes are to be authentically integrated within the use of drones for healthcare programs, timelines for these programs may need to be more flexible, in accordance with never wholly predictable processes, norms, and ideals of community engagement in specific contexts.

Several participants experienced practical challenges of limited time, money, or human resources to implement the drones for health projects in a manner that was fully satisfactory to them. Where experienced, these limitations on resources impacted time allocated for drone demonstrations, community engagement more generally, and the ability to resolve technological issues. Regulations and negotiating rights to fly is a common barrier to initiating and accelerating healthcare-related drone projects [30]. Likewise, many participants also noted that the drone projects with which they were involved experienced slowdowns linked to a lack of healthcare-specific drone guidelines in the jurisdiction where they were operating. This lack of regulatory framework made it harder to gain approvals from governments and civil aviation to execute these drones for health projects. Beyond these contextual challenges, participants described many technical challenges associated with the technology. These impacted their ability to complete pilot flights and projects in a timely manner.

It is important to note that like most new technologies, drones may lend themselves to function creep [50]. The term "function creep" refers to when technology is used in ways other than what it was originally intended to be used for [50,51]. These changes usually result in increased surveillance and control, which are unacceptable [50,51]. This is especially concerning since there is a history of using drones for policing, surveillance, and military purposes [52,53]. Many concerns surrounding these projects were brought to attention through participants' account of their experiences. These included privacy, security, safety, sustainability, and context-specific concerns. These real and perceived concerns may be because drones are being tested in areas that have long histories of colonial surveillance where unmanned and manned vehicles have been used for reconnaissance, war, and scientific research [30]. These collective colonial and postcolonial memories inform citizens' response to contemporary health campaigns [30]. This needs to be taken into consideration, since biomedical drones are being deployed in parallel with the deployment of military drones [30]. These medical drones can be mistaken for military drones by civilians causing them to have anxiety and post-traumatic stress, especially if deployed in countries that have a history of being attacked by military drones [54]. This exacerbates the mistrust citizens have of these humanitarian interventions [30].

By looking closely at the concerns raised by community members and stakeholders, it can be seen that the majority of these concerns stem from community members' limited understanding of projects. These misunderstandings need to be understood and corrected in order to facilitate individuals' understanding of the benefits and consequences of projects. It is ethically and practically crucial that individuals on the "host" end of drones for health projects be given the opportunity to voice their (mis)understandings, often sources of concerns, prior to the roll-out of projects. If individuals do not understand drones for health project, they cannot critically evaluate the project and assess for themselves its benefits and risks.

Likewise, it is important for individuals in communities hosting these projects to understand and help define projects' potential benefits. Understanding these benefits can help garner their interest, collaboration with, and confidence in these projects. It would be unethical to implement these drones for health projects based on the consent provided by individuals who have not considered the risks and fully understand the nature of these drones for health projects. There is no doubt that it may be challenging for drone teams to correctly identify and disclose these risks and benefits of drones, due to the novelty of this technology [55]. Still, it is important that project coordinators and field staff make efforts to identify and address any misconceptions related to drones for health projects. In addition to clearly explaining what projects and the drones involved will and will not be doing, project coordinators and field staff should be prepared to provide communities hosting these new projects with the opportunity to identify how drone teams can operate in ways to mitigate community rumors and concerns. Drones for health program teams cannot be confident they are serving the interests of their target populations if they do so in the absence of clear, context-appropriate sharing of information and dialogue about the project with community members.

Current practices reported by participants in this study indicate there remains room for improvement in this area. Processes for seeking informed consent for new drones for health programs are not consistent between and within projects. Inconsistent consent processes have the potential to undermine respect for individuals' autonomy and culture. Drone teams need to consider the power imbalances between community leaders and those they represent, and try to understand what norms of decision-making are in specific settings, They must seek to understand what such norms and dynamics mean for consent processes. Community leaders may hold more power than community members allowing them to influence and even make decisions on behalf of the rest of the community [56–58]. This unequal symbolic power relations may cause ethical tensions between community-level consent and individual-level consent impacting an individual's ability to make decisions for themselves [59]. In order to do this kind of work, it is ethical to ensure that drone projects meet the needs of the communities by consulting with community members. This could also provide an opportunity for participants and their teams to be transparent about what drones could achieve and manage stakeholder expectation.

Practical challenges, ethical complexities, and contextual particularities overlap and need to be considered in tandem. Participants reported they and their teams were able to resolve or address many of these ethical complexities and practical challenges by collaborating and involving stakeholders, such as community members, elected officials, healthcare staff, security personnel, or civil aviation organizations.

For future drone projects, it is recommended to use evidence generated from this project to draft a global guidance document on key practical, ethical and legal considerations for the implementation of drone for health projects. Such a document should be developed in collaboration with key stakeholders, such as drone teams, private sector, and governments. We also suggest that drone teams collaborate with involved communities' elected and traditional leaders to identify local needs and create context-specific guidelines based on the global guidance drafted based on the findings from this study. Guidelines and the global guidance will then have to be re-evaluated and adapted based on needs and gaps identified by stakeholders that emerge after the implementation of these guidelines in these local contexts (Figure 1).

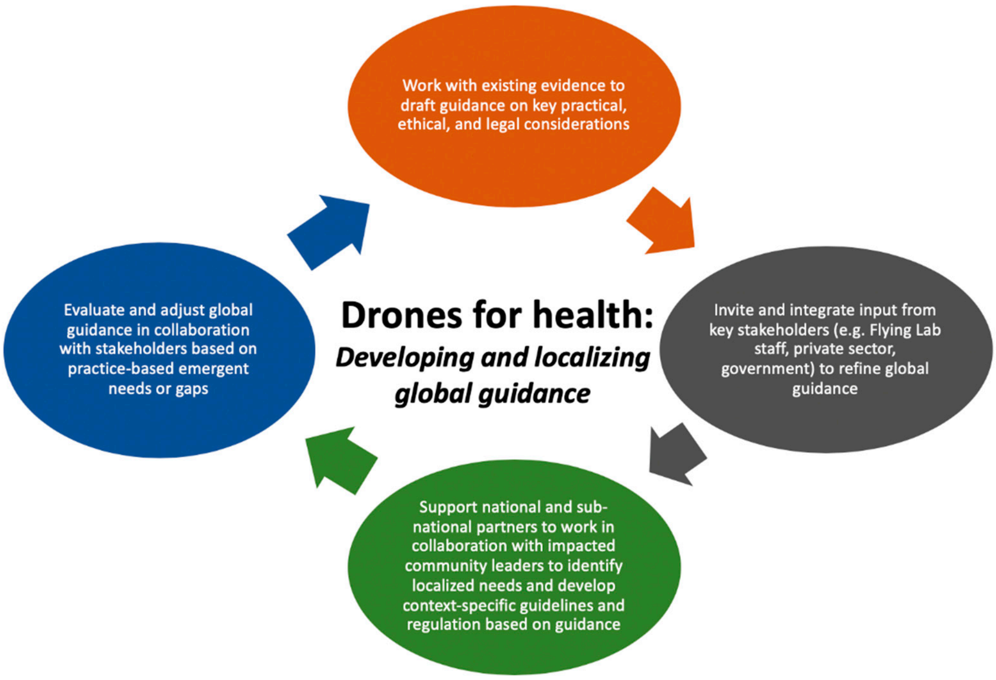

Figure 1. Developing and localizing global guidance.

Global guidance should include guidance on developing consistent context-appropriate consent processes. This will ensure that informed consent processes are consistent within and between projects. Drone teams need to identify how to obtain consent while respecting local customs and values, recognizing that collective consent is preferred and ethically acceptable in some sub-national settings and countries [60,61]. However, obtaining informed consent for drones for health projects may be onerous and even impossible, due to the indefinite number of people affected by such programs[75]. Alternatively, individual consent can be replaced by consent-by-proxy from governments and drone technology developers if these drones for health projects are categorized as public health initiatives instead of research projects [55,62,63].

Global guidance can underline the core importance of community engagement. Such engagement is key, as participants asserted, to identifying, understanding, but also importantly learning how to mitigate any context-specific concerns in ways that are satisfactory ideally to engaged community members. Community engagement is also important in terms of laying the groundwork for drones for health projects to be truly localized eventually: maybe eventually funded, but certainly developed and staffed at the local level. Guidance could outline a framework for organizing community engagement initiatives that are context-appropriate, and cautious to respect local cultural and social norms.

It is evident from participants' accounts that there is a need for healthcare-specific drone regulations that include health-specific cargo weight and flight distance allowances, in addition to other jurisdiction-specific rules pertaining to the delivery of health materials. Global guidance may also underline the importance of such regulatory supports and their development at the local level.

5. Conclusions

In conclusion, this study aims to bridge this gap in the literature by providing a summary of the ethical and practical challenges faced by front line staff who introduce drones for healthcare projects to communities. By presenting the ethical and practical challenges of these drones for health projects and how participants and their drone teams overcame these challenges, this paper provides an initial framework that could guide the introduction and implementation of future drones for health projects. In doing so, this paper contributes to the "drone theory in global health", which calls a need for more critical engagement with the social, political, and ethical meanings and implications of the biomedical drone in global health supposed problem-solving [30]. Developing drone theory requires advancing evidence of the implications and complexities of drone use in practice and in specific contexts. This study's findings can inform emergent evidence-based elaboration of why and how drones represent meaningful new technologies on the landscape within the global health landscape.

Beyond what drones mean in specific settings, we hope and intend this study's findings to be of use in the short term. Practically speaking, it is our hope recommendations for addressing various challenges identified by participants in this paper will be of use to another drone for health teams, as they undertake other drones for health projects. There exists no global guidance to orient drones for health projects. The ethical and social implications of those drones for health projects described in this article could be used as a starting point to develop such guidance, which may serve as an important tool to facilitate the execution of future drones for health projects.

6. Study limitations

It is important to note that almost all the drones for health projects discussed by participants were short-term proof of concept projects. Hopefully, practical and ethical challenges outlined by participants, and implementers' abilities to respond to population concerns, can be mitigated in future through more experience-based preparedness and resourcing for diverse community engagement and trust-building processes in diverse settings. Further research is needed to determine whether the ethical and practical concerns, challenges, and complexities identified in these pilot projects persist once projects become more permanent programs within health systems.

This study did not include drones for health projects from Europe. This is the result of our recruitment and sampling strategy, which took as its point of departure Flying Labs that are located in low- and middle-income country contexts. Towards developing global guidance and drone theory, further research is needed to ensure greater cross-country and region representation.

Finally, this study did not explore differences in concerns, including perceived potential risks to privacy and safety, for example, associated with rural versus urban missions. The majority of projects described by participants, in accordance with operations of Flying Labs and the participants recruited through the UAV Network, were working in a rural and remote setting. Further research would be merited to explore such potential differences.

Supplementary Materials: The following are available online at http://www.mdpi.com/2504-446X/4/3/44/s1. Table S1. Exemplary quotes corresponding to key concerns, practical challenges, and ethical complexities.

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