PERIODICAL

Drones in medicine—The rise of the machines

This is a medical kitty hawk moment.

Drones are pilotless aircrafts that were initially used exclusively by the military but are now also used for various scientific purposes, public safety, and in commercial industries. The healthcare industry in particular can benefit from their technical capabilities and ease of use. Common drone applications in medicine include the provision disaster assessments when other means of access are severely restricted; delivering aid packages, medicines, vaccines, blood and other medical supplies to remote areas; providing safe transport of disease test samples and test kits in areas with high contagion; and potential for providing rapid access to automated external defibrillators for patients in cardiac arrest. Drones are also showing early potential to benefit geriatric medicine by providing mobility assistance to elderly populations using robot-like technology. Looking further to the future, drones with diagnostic imaging capabilities may have a role in assessing health in remote communities using telemedicine technology.

The Federal Aviation Administration (FAA) in the United States and the European Aviation Safety Agency (EASA) in the European Union are some examples of legislative bodies with regulatory authority over drone usage. These agencies oversee all technical, safety, security and administrative issues related to drones. It is important that drones continue to meet or exceed the requirements specified in each of these regulatory areas. The FAA is challenged with keeping pace legislatively with the rapid advances in drone technology. This relative lag has been perceived as slowing the proliferation of drone use.

Despite these regulatory limitations, drones are showing significant potential for transforming healthcare and medicine in the 21st century. Unmanned aerial vehicles or drones are aircrafts without on-board human pilots or passengers.

Drones were first used in the late 1800s and early 1900s for various military operations.

They are manufactured in various shapes and sizes, both small and big. Small drones can even be miniaturised to insect-sized devices. Larger drones possess long endurance at high altitudes and are capable of carrying large payloads.

Aerial drones of today can be remotely controlled and launched in air using various methods depending on their type. They can be hand thrown, catapulted, launched from a pneumatic or rocket launcher, or even by conventional wheeled take-off from a prepared runway.

Drones can land over rugged terrains without risk to flight crews made them ideal for such deployments.

Apart from aerial drones, ground-based drones have also been recently developed and tested. These robot-like drones are embedded with artificial intelligence technology to aid human activities.

Recently, their use has expanded to include various scientific, public safety and commercial tasks such as acquiring disaster area data and images, building maps, relaying communications, supporting search and rescue operations, surveillance of traffic, in the agricultural sector for farming, delivering goods (international retail companies including Amazon, Google and Walmart have been quick to embrace drone technology), and yes, saving lives in medicine.

With respect to this latter task, this paper identifies a myriad of potential drone applications in medicine as well as the current regulatory limitations affecting drone use. In addition, this paper identifies emerging developments in drone technology that may expand its current applications in medicine. The intent of this paper is to raise awareness of drones as a technological tool that can enable medical personnel to perform their jobs more effectively and ultimately save more lives.

1 | ROLE OF DRONES IN MEDICINE

1.1 | Current applications

The first non-military deployments of drones occurred following major disasters, where they supported damage assessments in the affected areas. Their ease of use and ability to bypass road closures and fly over rugged terrains without risk to flight crews made them ideal for such deployments.

Drones have subsequently been used to deliver small aid packages to communities affected by major disasters, including the 2010 earthquake in Haiti, the 2012 hurricane (Superstorm Sandy) that affected the north-eastern United States, Canada and the Caribbean, the 2015 category 5 cyclone (Pam) that struck the islands of Vanuatu, and the 2015 earthquake (Gorkha) in Nepal.

In Papua New Guinea, the organisation ‘Doctors Without Borders’ used drones to transport dummy tuberculosis (TB) test samples from a remote village to a large coastal city. This application of drones was significant because the country has a large TB burden with an increasing incidence of multidrug-resistant TB.

Similarly, drones have been used in the fight against the human immunodeficiency virus (HIV), which has long posed a challenge to third-world nations. In Malawi, Africa—a nation with one of the highest rates of HIV infections in the world—the United Nations Children’s
Fund (UNICEF) delivered HIV testing kits using drones, thereby dramatically reducing the time required to test infants living in rural areas. If drone use is acknowledged as more cost-effective and efficient than current delivery methods using diesel motorbikes, the delivery process for medical testing kits and supplies will be revolutionised in Africa.

In the first government-approved drone delivery in the United States, the National Aeronautics and Space Administration (NASA) recently tested a medical supply delivery to a small clinic in rural Virginia using a drone. Supplies included medications for asthma, high blood pressure and diabetes. The testing of the feasibility of this state-of-the-art technology for such a purpose was a tremendous success, as it proved to be safe and dramatically reduced the delivery time.

In Rwanda, Africa, drones were used to transport blood products and medicines to critical access hospitals and remote regions. The drones navigated using the Global Positioning System (GPS) and Rwanda’s cellular network. Hospitals ordered blood and medicines via text messages and received the supplies within 30 minutes. The ability to transport blood is important; a single patient with massive bleeding can easily deplete the blood supply in medium-sized hospitals, and larger hospitals can run low on certain blood types. Several prior studies have demonstrated that drones are a safe method for transporting blood products, donated blood and vaccines using samples containing microbes.

1.2 | Potential applications

In medical centres that are large or undergoing renovation, drones can be used to transport blood samples and medications within the facility (ie, intrahospital delivery). Expansion of conventional pneumatic transport system can be costly; perhaps, drones may provide more cost-effective floor-to-floor transport capabilities for specimens and medications. Intrahospital drone use faces unique challenges related to potential GPS or radiofrequency communication interference, an increased need for proper and safe navigational programming, and equipment size and cost constraints. Ultimately, however, drones have the potential to improve overall patient care in hospitals.

Considering the unique mobility needs of the elderly people and senior populations, the use of small, robot-like drones with manipulator arms that can aid in bringing medication and water or performing household chores is currently being investigated. In addition to demonstrating effectiveness and reliability, these drones must account for patient psychology and be accepted as part of a patient’s daily life. Exposing patients to an environment where drones are flying about can compromise their safety and security. Mishaps can lead to falls, severe injuries or even death. Current research aims to design a drone that studies people’s reactions to it, including their heart rates and head tilts. The objective is to create a drone that is both human and environment friendly. If successful, this application will represent an important breakthrough in the field of geriatric medicine.

In emergency medicine, studies have shown that the use of drones may prove to be safe and feasible for delivering an automated external defibrillator (AED) for out-of-hospital cardiac arrests (OHCA) in areas identified using GIS (Geographic Information System) models. The various methods of delivering an AED after arrival on-site while keeping the drones within the line of sight were further studied. This study showed that the use of an AED-equipped drone might have the potential to reduce the time to defibrillation for OHCA. A similar study conducted in the Netherlands considered the use of an ambulance drone designed to deliver an AED directly to heart attack victims. In this application, emergency services personnel provided instructions regarding AED use and cardiopulmonary resuscitation procedures to persons assisting on-site via livestream video and audio connections. The use of drones in this application has the potential to decrease response times and increase survival rates, especially for patients in cardiac arrest.

In a concurrent development, medical and aviation experts in the United States teamed up to develop a medical drone fitted with special sensors, infrared devices and telemedicine capabilities as part of the Health Integrated Rescue Operations (HIRO) project. A drone equipped with video-conferencing capabilities via Google Glass was designed to deliver a medical kit containing emergency supplies. This combination of technologies allowed first-responder healthcare workers to guide bystanders in assisting those in need via telemedicine.

These specialised drones may have the potential to help ensure the delivery of life-saving treatment directly to disaster sites or to other victims before emergency personnel arrive at the scene.

Expanding their involvement in the development of potentially life-saving equipment, the technology giant Google was recently granted a patent to develop a system capable of deploying drones carrying specialised medical equipment in response to medical emergencies. Users of the system simply need to press a button to call for help. Such innovations in drone technology are expected to continue.

1.3 | Regulatory limitations

In the United States, the Federal Aviation Administration (FAA) exercises regulatory authority over drone use and has established a set of rules for all affected stakeholders. These stakeholders include large corporations such as Amazon and Google as well as small remote emergency care facilities. The FAA has been regarded by many as too limiting and bureaucratic regarding the use of drones; lack of timely legislations relative to the rapid advances in technology has had the effect of discouraging or creating a barrier for drone use. In lieu of postponing drone use until new legislation takes effect, the stakeholders have the option of applying for an exemption from the current legislation. Many healthcare organisations have applied for such exemptions.

Likewise, the European Aviation Safety Agency (EASA) recently drafted the first European Union regulations for civil drones to fly safely in European airspace. This provides the basic guidelines for ensuring safety, security and privacy of people. These regulations include the extent to which other traffic or people on the ground could be endangered, drone certification, insurance measures and protection of the environment with regard to noise as well as the excess emission of carbon dioxide. Issues such as threats to security because of drones and flights over conflict zones were also addressed. The EASA will develop detailed regulations on drone flights in the future.
Advantages and disadvantages of drone technology in medicine

| Pros                                                                 | Cons                                                                 |
|----------------------------------------------------------------------|----------------------------------------------------------------------|
| 1. Saving human lives—drones can provide humanitarian aid and       | 1. Regulatory limitations need to be addressed and updated before    |
| potentially life-saving treatments to areas affected by natural     | drones can be used in the medical field. These include legislations   |
| disasters and emergencies, leading to a quicker, more efficient      | pertaining to predetermined flight corridors where drones need to fly |
| response time. The provisions include medical supplies, antivenom   | ‘in the line of sight’. In medical emergencies, the fastest route    |
| and blood products                                                  | needs to be employed for ensuring life-saving therapy, including ‘flying out of sight’. As such, any deviation from this might adversely impact the health and survival rate of a patient |
| 2. Delivering laboratory samples or blood, as well as unique         | 2. The effectiveness of drones will depend on the individual aiming   |
| products brought to remote clinics or hospitals                      | to deliver help to the emergency victim. This could be a layperson   |
|                                                                     | and not someone who can necessarily administer medical treatment.   |
|                                                                     | Such an arrangement might be a setback when compared with the more  |
|                                                                     | traditional medical transport methods and delivery of medical aid   |
| 3. Delivery of prescriptions and other supplies to hard-to-reach     | 3. Storage and transportation of all drugs and specimens via drones  |
| people including those at sea or at home                            | needs to be carefully implemented and monitored. This includes      |
|                                                                     | temperature of storage and duration of transportation as these can   |
|                                                                     | affect drug efficacy and specimen data results. Any compromise on   |
|                                                                     | these parameters could lead to serious consequences to the health   |
|                                                                     | and well-being of a patient                                        |
| 4. Transportation of organs for transplantation                     |                                                                      |
| 5. Potential to transport defibrillators to patients in cardiac     |                                                                      |
| arrest                                                              |                                                                      |
| 6. Potential to deliver telemedicine and medical support including   |                                                                      |
| diagnostics, or even tools such as portable ultrasound to remote    |                                                                      |
| areas                                                               |                                                                      |

In brief, the FAA’s and EASA’s regulatory purview includes all technical, safety and security, and administrative issues in aviation. For drones, technical issues relate to battery life, payload capacity, and the ability to detect and avoid any problems from the home base. Safety and security issues include the drone’s ability to avoid near misses, collisions and accidents as well as hijacking and espionage. Administrative issues relate to drone operator training and licensing and the service provider’s legal compliance, fiscal health and compliance, and service costs. To achieve continued growth in drone applications, drones must meet or exceed the requirements specified in each of these regulatory areas.

1.4 | Future innovations

With many new advancements in drone technology, it is postulated that drones may expand further to include diagnostic capabilities, namely in the imaging field. Diagnostic ultrasound imaging can provide much needed help and care to communities living in remote areas. This can be achieved using telemedicine, ie, the ‘delivery of healthcare and sharing of medical knowledge over a distance using a telecommunications system’. For instance, the evolving telemedicine technology has boosted access to cardiac ultrasound, ie, echocardiography, thereby proving the value of long-distance consultations, guidance and even remote-controlled examinations of patients in rural, hard to reach areas.23

As demonstrated by these perspectives, the potential drone applications in medicine are extensive and may be transferrable worldwide. These applications face challenges such as national legislations, climate zones and topography, medicolegal and licensure issues, finance and reimbursement, as well as community attitudes and acceptance in different nations. These problems need to be addressed by people involved in the medical and drone industry as well as by manufacturers, insurance companies, legislative authorities and government bodies.

Without doubt, there are many advantages in using drone technology in our daily lives; however, an equal number of disadvantages are encountered too. Table 1 presents the advantages and disadvantages of the drone technology in medicine.24,25 Ultimately, for this technology to succeed globally, the stakeholders mentioned above need to work together to integrate it seamlessly into our communities.

In summary, drones are a rapidly developing technology with increasing worldwide applications. They have developed into a valuable tool in medicine by demonstrating their ability to address issues faced by both medical personnel and patients. Common drone applications in medicine include providing disaster assessments when other means of access are severely restricted; delivering aid packages, medicines, vaccines, blood and other medical supplies to remote areas; providing safe transport of disease test samples and test kits in areas with high contagion; and providing rapid access to AEDs for patients in cardiac arrest. Drones are showing significant potential for transforming healthcare and medicine in the 21st century.

ACKNOWLEDGEMENTS
None.

DISCLOSURE
None.

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