Chapter 5
Applications of Drones in the Health Industry

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Acronyms

AED	Automated external defibrillator
CPR	Cardio-pulmonary resuscitation
EMS	Emergency medical services
GNSS	Global navigation satellite system
OHCA	Out-of-hospital cardiac arrest
UAS	Unmanned aerial system
UAV	Unmanned aerial vehicle

5.1 Introduction

The definition of Unmanned aerial systems (UASs), Unmanned aerial vehicles (UAVs), or drones can be made as no passenger carries pilotless devices in the air (Gupta et al. 2013). Those airplanes have some types of equipment as a payload; those can be cameras such as high-resolution cameras, thermal cameras, laser

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scanners, location sensors for navigation, or other valuable payloads. In recent years, users have preferred to command UAVs with their autonomous functions instead of remote control. Furthermore, the use of UAVs is increasing worldwide for hobby and commercial purposes such as photography; military and scientific benefits are also preferred (ICAO 2011). This demand has created an industry that is altering the plans worldwide. The primary reason for choosing UAVs can be summarized as easily reachable worldwide.

There are many names for UAVs. “Drones” or “UAV/UAS” can be found in the international literature, and they mean the same thing. There is no distinct separation between those names, except for a particular technical feature. UAVs should not be understood only as an airplane flying in the air. In this context, UAVs consist of three components (Narayanan and Ibe 2015)

- The aircraft itself
- The payload on the plane
- The ground control station

Recently, significant innovations have been observed in hardware, software, and networks related to drones. The use of lighter composite materials in the structure of the drones and the integration of the Global Positioning System (GPS) enable the drones to perform more efficient flights. Depending on the technological developments in lithium batteries, drones can fly longer distances (Raffaello 2014). Moreover, with a webcam integrated into the drones, communication is provided by a control center (Prigg 2014).

The applications of drones in the healthcare field is a new but rapidly developing technology. With their valuable functions, drones successfully deliver drugs, blood (Amukele et al. 2015), vaccines (Haidari et al. 2016), and similar medical samples that are urgently needed to places where access is difficult. As far as we know, there is no comprehensive review presenting research on the health applications of drones. This review summarizes the current knowledge on the use of drones in healthcare and sheds light on future research.

5.1.1 Health Industry Needs for Transportation

AED Access to Cases

The defibrillator device is essential for recovering the heart rhythm in the prehospital event. The UAVs can provide 32% faster access rates to deliver defibrillator devices to patients in urban areas (Claesson et al. 2016). This figure becomes 93% in rural areas where helicopters and ambulances cannot reach most cases.

Drug/Tissue, Blood Product Transportation

Studies have shown that drone use can be strikingly detailed on organ transfers. The transferred tissue can be affected by vibration during flight. Also, other physical effects such as pressure and temperature may affect the transported tissue. Transportation must be planned in detail to overcome the abovementioned problems. Tissue transfers to complex regions can be effective compared to traditional logistic methods.

Telemedicine/Telesurgery

The resuscitation task could be harmful and complex for those who haven't learned this in medical school. It has become a simple task with the aid of peripherals equipped like a camera, microphone, speaker, and Automated External Defibrillators (AEDs) used over a patient who needs CPR.

5.1.2 Commercial Applications of Drones

Severe developments in information technologies, which started in the 1980s, made it necessary for companies to reorganize their activities and brought radical changes in the modern economy. Today, drone technology affects all sectors from infrastructure to agriculture on a large scale, creating effects similar to severe developments in information technologies (Mazur et al. 2016). In a short time, all customers will begin to see the impact of drones in all areas of the economy.

The fact that drones can travel their flight distances quickly and concisely has made their use very attractive in sectors requiring mobile and higher image quality. Using drones in daily activities in large-capital projects such as infrastructure and agriculture provides excellent benefits. The potential for drones to advance in the insurance and mining industries will drastically change the delivery process in the transportation industry. The increase in technological opportunities, legal regulations, and developments in investment support has enabled drones to be used in many new areas. Drone technology in these areas has led to new business and operation models. The Drones can be a helpful solution in some industries that require delivery constraints like time and capacity. Also, those industries may have gained some competitive advantage by using a low-cost solution.

Infrastructure

Drones have been used in various infrastructure management recently. Over time, this usage will become permanent and will develop further. While drones perform dangerous jobs successfully, they also serve different data efficiently, precisely, and at low cost. The contribution of drones in many infrastructure sectors is faster than in the energy, road, oil, and gas sectors. Small-sized drones are often used in civil infrastructure works. These drones are easy to use and have flexibility in infrastructure-related activities. The flight altitude is up to 10,000 feet (Nex and Remondino 2013). Current Federal Aviation Administration (FAA) regulations limit flight altitudes for civilian drones to 400 feet (FAA 2013). We can list drones in the infrastructure sector as investment monitoring, maintenance, and asset inventory.

Providing real-time awareness and accuracy during the construction process is complicated. It is accepted that drones will successfully deliver actual data to this challenging process. Drones can significantly increase the speed and quality of the design process by providing precise field data during the preconstruction process. It can also quickly observe construction sites during construction, collecting detailed data for progress reports. It supports investors in monitoring the construction sites, controlling the determination of the site boundaries, and storing the materials to be used. The information provided by the drones is automatically recorded, which allows the investor to access complex data more quickly. This rapid process shortens the response to problems and enables a more accurate analysis of results.

Maintenance is one of the essential parts of the infrastructure sector. Today, most maintenance work is done manually and is provided by personal inspections. On the other hand, this process leads to slow, costly, and low-quality results. With the use of drones in maintenance, acceleration of the process, reduction of costs, and significant quality improvement have been achieved.

Per developing technology, drones have also started to be used in inventory counting and inventory management in infrastructure companies. The use of drones allows the company to reduce costs, speed up the process, and, at the same time, provide detailed information about the assets. Since rotary-wing drones can easily reach hard-to-reach and dangerous areas, workplace safety is increased by preventing human life from being put at risk.

Insurance

Two negative trends affecting the insurance industry today are the increase in natural disaster damage and fraud. An insurance company can improve its procedures using drones, including risk monitoring, risk assessment, and claims method.

Insurance claims arising from natural disasters in the insurance sector have been on the rise recently. For this reason, it is of vital importance to respond quickly to the monitoring centers of the areas exposed to natural disasters by monitoring them with drones. To reduce this increase, monitoring activities to be carried out by drones and analysis of the collected data are required.

Using drones while making risk assessments in insurance transactions will be useful in solving many problems that may arise. Accurate risk management can be done, and insurance processes can be supported thanks to the data provided by drones.

Media and Entertainment

In parallel with the developing technology, one sector that uses drone-assisted solutions is the media and entertainment sector. Aerial photography is the area where drones are commonly used. Another application is to use drones as broadcast relays. In massive sporting events, such as bicycle races and motorcycles record competitions. The streams are sent to TV studios or stage management using helicopters. Because using drones to transmit video streams is cheaper than using a helicopter or setting up a road-wide infrastructure (Freitas et al. 2010). Shooting commercials and movies using drones is a frequently used method today. Drones are commonly used in wildlife documentaries. Using drones creates a lower cost for image capture than airplanes and helicopters. Drones were used in shooting movies, and outstanding results were obtained.

Telecommunication

Drones can take an active part in some of the most challenging tasks facing companies in the telecommunications industry. It can help this industry get rid of maintenance, system optimization, and cost problems. It also contributes to infrastructure services by using it in the broadcasting of telecommunication signals. Drones help with antenna control by taking video, measurement, pictures, and reading information. They help companies by using the advantages of security, low cost, and high speed.

Agriculture

Drones have a wide range of uses in the agricultural sector in the fields of irrigation, spraying, soil analysis, planting, and crop monitoring (Ahirwar et al. 2019) Drone technology attracts producers in the agricultural sector for low cost and takes necessary precautions by monitoring the crop. Drones are used at every stage of a crop's life cycle, from choosing the right time to harvest to analyzing the soil to planting the seed. Drones help to drastically reduce planting costs by creating excellent three-dimensional (3D) maps that allow soil analysis while planting seeds. Drones also successfully carry out crop spraying activities. As a result, drones will continue to provide important services to the agricultural sector in terms of crop growth and productivity with their ease of use and low cost.

Security

With their speed, size, and maneuverability, drones help to perform imaging tasks faster and more effectively in current technology. Drones can quickly reach hard-to-reach and large-scale areas, allowing operators to perform their traditional monitoring tasks more effectively. Drones can scan to a large extent by tracking objects safely by providing live streaming. Drones can remotely explore whether the area is safe for the response team to enter a location and perform an accident assessment.

Mining

Drones can do the activities of humans in the mining industry, where dangerous work is done intensively with the workforce. Its less costly and versatile use has accelerated the implementation of this preference. Drones cause less pollution than mining vehicles due to their ease of use.

Appropriately, drones can be beneficial in monitoring, surveying, and mapping of mines (Xiang et al. 2018). Drones can quickly map the open pit site, optimize mine transport routes, and securely provide control information. It can also reduce the cost of mining by supporting and automating the entire extraction process.

Transport

Depending on technological developments, it is seen that drones have outstanding potential in the transportation sector. Drones continue to be used in a wide area in this sector, especially in e-commerce package delivery, drug transportation, spare parts delivery, and intraday food delivery. It is indisputable that drones will be used more in the transportation sector than other methods based on human power, speed, accessibility, and low-cost advantages. We can classify the usage areas of drones in transportation as package delivery, spare parts delivery, medical logistics transportation, and food delivery.

Drones can make fast delivery to a predetermined point without much human activity. Other areas where drones are gaining popularity for delivery are spare parts and food delivery. Due to the fast delivery time and low cost of drones, many corporate companies are looking for the most economical way to make their deliveries. However, drones' most significant obstacles in their delivery business are limited flight endurance and payload capacities, which directly affect the costs. Improving the energy capacity using batteries does not mean improving the distance of the flight. The optimum number of batteries and energy capacity should be determined and engineered to achieve maximum flight endurance for electrically powered drones (Dorling et al. 2016).

Medical Logistics

The two most important areas where drones are used in medical logistics are drug and defibrillator transport. In delivering medical supplies to remote rural areas with drones, the high need in these regions and the low risk come to the fore. Since drones are not affected by traffic delays, they can deliver medical samples to healthcare workers faster under ideal storage conditions. Drones can provide defibrillators very quickly to patients who have had a heart attack, significantly increasing the survival rate.

5.1.3 Most Chosen Drone Types in Health Use

Multi-rotors Drones

Multi-rotor drones consist of two or more rotors and propellers, while the flight mechanism relies on the lift produced by the propeller. These drones are piloted by varying the speed of the rotor. The quad-rotor is the most used one among these types of drones. These drones can fly at high speeds and hover at any altitude or fly at low speeds. Also, these drones can take off and land vertically. Multi-rotor drones are used for short-range and short-term missions because of their low durability (Petricca et al. 2011).

Multi-rotors are suitable for specific missions, and their configuration depends on the requirements of those missions. However, rotary-wing drones have a simple system and high maneuverability. However, they have a very high power consumption due to their aerodynamic disabilities. Weight and energy are also serious barriers for multi-rotors.

Multi-rotor drones are more reliable in motor failures than quad-rotor or tri-rotor drones and are suitable if high efficiency is desired. However, bi-rotor drones are inefficient systems and always require other mechanisms such as tilt rotors or moving masses to control (Siddhardha 2018). If the torques of the opposing motors of the quad-rotor are unequal, the drone can rotate about the longitudinal and lateral axes.

Quad-rotors

Quad-rotors have been one of the most popular drones among drone designers due to their simplicity of construction and control. A lot of research is being done on these types of drones. The general structure of quad-rotors consists of four motor-propeller pairs mounted at all four corners of the frame. The quad-rotor drone movement has been designed to turn the same direction on the same handle and the opposite direction in the neighbor motor. The engine speed or the rotor speed must be increased or decreased while climbing and descending with these drones accordingly. Also, the rotor speed change allows the quad-rotor drone turn around the yaw axis and vice versa (Ghazbi et al. 2014).

This drone has many advantages: low cost, high maneuverability, simple dynamics, and a fixed-pitch propeller. Like multi-drones, energy management is an issue in those drones—the dangers of use in an urban environment are another issue

(Sabatino 2015). As a result, their simple structure, ease of use, and hovering capability in the air increase the interest in this type of drone. Compared to fixed-wing drones, their efficiency and cruising speed are lower, and their maximum altitude is limited.

Fixed-Wing Drones

Fixed-wing is a classified version of a classic drone application that uses its wings for takeoff. These drones have different wing designs. Depending on the task they perform (Hassanalian and Abdelkefi 2017), there can sometimes be more than a pair of wings (Stempeck et al. 2018). Configurations of fixed-wing drones may vary by the shape of their tail, the number of wings placed, and the shape of the wing. However, the flight phenomenon is realized by the created lift using the wing surfaces dynamically. The differences in fixed-wing drones increase the maneuverability, payload capacity, and performance characteristics.

Fixed-wing drones consist of a wing, tail configuration, and fuselage. The engine produces the necessary forward movement to create lift. These drones have a simple structure and generate propulsion using fuel motors (Guido et al. 2019), solar energy, and battery-powered electric motors (Hassanalian et al. 2014a, b). Compared with the other types of drones, fixed-wing drones' endurance or operational ceiling is more remarkable. They need a runway for takeoff and landing, and they cannot hover. Despite these current shortcomings, the most widely used drones are fixed-wing drones.

Compared to other drones, fixed-wing drones have the most advanced design and are easiest to manufacture. Search, rescue, surveillance, delivery, imaging, defense, and fire extinguishing activities are the most used application areas. Because of this wide usage area, many companies and researchers worldwide are developing fixed-wing drones. At the same time, it has many advantages such as low cost of use, flight durability, and use in dangerous missions (Panagiotou and Yakinthos 2020). The available fuel limits the longer endurance of fixed-wing drones. More potential is available as long as performance characteristics can be improved.

Large fixed-wing drones perform very well at high altitudes and speeds, while small-wing drones may face difficulties due to their low speed and size. These drones are susceptible to wind speed and direction and can fly at low altitudes with a high level of turbulence.

VTOL Operations

Vertical Take-off and Landing (VTOL) drones can land and take off vertically using helicopter mode and perform high-speed forward flight in airplane mode. These drones are excellent aircraft that combine fixed-wing aircraft's speed and fuel efficiency with the hovering and flexibility of rotary aircraft. It can fly at varying altitudes depending on the body profile, but this flight is usually at low altitudes.

Thanks to its high maneuverability, it has a significant potential for building damage analysis and rescue operations in a complex urban building environment and the detection and image transfer of an incident area with its hovering ability. Their small size dramatically increases the potential for these drones to be used in scientific research applications (Watts et al. 2012).

The fact that VTOL drones do not need a runway for landing and takeoff and can fly for a long time by floating in the air causes them to attract close attention from researchers and commercial companies (Jo and Kwon 2017). The fact that they can land and take off vertically and have the advantages of both multi-rotor and fixed-wing drones increases the demand for these drones (Yu et al. 2016). Countries are investing to do more research on these drones to improve the advantages of VTOL drones (Zhao and Zhou 2018).

5.2 Operational Usage of Drones in Health Industry

A drone is a flying device remotely controlled by a person or computer. It is used as an actual study. It has a wide range of audio-visuals (Amukele 2019), security, surveillance, energy (Sreenath et al. 2020), and health (Mallek et al. 2020). The possibilities offered by drones allow researchers, manufacturers, and other organizations to conduct research that increases the efficiency of these devices and improves their medical results (Tucker 2017).

Drones are used in health industry due to their technical possibilities and ease of use. In the healthcare industry, drones can be used to ensure disaster assessment when the disaster area is severely restricted to human access. Also, drones can be useful for delivering medicine, vaccines, blood, and other medical supplies to remote locations in disaster areas. Furthermore, medical staff can benefit from drones by transporting test samples, and medical kits, if it is not a disaster case.

As a result of the extensive literature research, it has been observed that the resources related to medical applications are gathered under three main headings. These main topics are public health/disaster relief, telemedicine, and medical transport. We can examine public health/disaster relief under the headings of mass casualty care, data collection, infectious diseases, disaster relief, and emergency medicine. Diagnosis–treatment and telesurgery categorize telemedicine applications into two subjects. We can divide the medical transportation application into tissue, medication, medical device, and patient subheadings.

5.2.1 Public Health and Medical Surveillance

There is an advantageous use of drones in disaster areas, primarily used for surveillance of disaster areas, in monitoring activities of the regions where epidemic disease is present, and in places where biological and chemical hazards occur. They

Fig. 5.1 Five people in search with the classic line (Karaca et al. 2017) technique

effectively collect real-time information that makes up the current data of victims and patients in high-risk areas where urgent intervention is needed (Hlad 2015).

After Typhoon Haiyan hit the Philippines in 2013, drones evaluated the initial damage and prioritized required tasks before the rescue operations (Hlad 2015). The use of drones is being investigated to estimate injuries caused by chemical, biological, and nuclear materials to increase the effectiveness and improve the response field teams in England (Aron 2016).

Drone technology is used to combat severe chemical hazards that threaten health, such as heavy metals, aerosols, and radiation. A high-resolution-equipped drone was used to accurately detect and predict cancer risk from high concentration of copper present in the agricultural region in Southern Italy (Capolupo et al. 2015). Brady et al. (2016) used a quad-rotor drone to measure aerosol and gas levels in complex terrain. In addition, drones are used to map radiation from uranium in nuclear accidents (Tang et al. 2016) and to detect radionuclides (Martin et al. 2016). Fornace et al. (2016) used drones to identify the distinctive features of the terrain and the shape of deforestation patterns of malaria parasites in Malaysia. Also, researchers mentioned using drones to detect *Staphylococcus aureus* and Ebola virus in recent studies (Priye et al. 2016).

Disinfecting large areas and hard-to-reach areas in the fight against the coronavirus is critical in changing the course of the epidemic. The use of drones in such regions will minimize the struggle with humans and ensure the protection of human resources. In many public areas, spraying disinfectant is carried out by drones. This process increases work efficiency and safety compared to manual disinfection (Poljak and Šterbenc 2020). Figures 5.1 and 5.2 show the application of the classic line technique.

Drones integrated with a thermal camera can detect each person in crowded areas with high-sensitivity infrared rays. Thanks to these possibilities of drones, it is possible to detect people with high fever and take precautions by detecting the

Fig. 5.2 When any image that was judged to be representative of the mannequin was detected, the drone began descending to sharpen the image (Karaca et al. 2017)

human body temperature in the group. The use of drones, which can be integrated with all kinds of cameras and sensors, as a public health surveillance tool is applied in many life-saving events. Recently, police units have been using drones for surveillance to identify criminals (Bennett 2011).

In reaching victims stranded in mountainous areas, drones have proven to be an essential tool by detecting victims in 10 minutes, which search and rescue teams can do in 60 minutes (Karaca et al. 2017).

Drones are also useful in finding and identifying water areas, which are the habitats of mosquitoes, with their surveillance activities such as video and photography. In a study conducted in the Zanzibar archipelago, drones' detection of mosquito habitats has been done effectively (Hardy et al. 2017). Drones have a wide range of use in the surveillance/epidemiology of infectious diseases, especially vector-borne diseases. Drones equipped with sensors and artificial intelligence can access geographically referenced information about water, salinity, vegetation, and temperature (Peckham and Sinha 2019).

5.2.2 Telemedicine

The health industry encourages using drones for telemedicine applications—the application of diagnosis and treatment of patients remotely via telecommunication is a well-known approach (Breen and Matusitz 2010). The most crucial element in the field of telemedicine is telecommunications. On the other hand, telesurgery enables surgical procedures to be performed using robotic technology at a distance from the surgeon and patients (Harnett et al. 2008).

Medical and aviation experts in the United States have also developed a drone with special sensors, infrared devices, and telemedicine capabilities as part of the Health Integrated Rescue Operations (HIRO) Project. With this technology, which combines medical and aviation technologies, it has been ensured that healthcare professionals provide guidance services by using telemedicine, which is the need during the first response. Drones perform vital tasks as a point of contact for telesurgery use in military battlefields to reduce delays in surgical intervention (Harnett et al. 2008).

5.2.3 Drones as Medical Transport Systems

In recent years, rapid developments and growth in robotization and process automation have enabled companies to turn to drone technology. When drones' speed and low costs are added to these rapid developments in technology, the use of technology-integrated drones in solving transportation problems becomes attractive (Kim, 2020; Euchi, 2020). The effectiveness of drones is felt most in the distribution of medical drugs and materials to critical areas and the transport of test samples from these areas to the relevant laboratories (Spring 2017).

In healthcare, the use of drones in medical transportation is presented in a wide range of areas, including the delivery of drugs (Hackman and Nicas 2015), defibrillators, blood samples (Preimesberger 2016), and vaccines to the areas where they are needed (Prigg 2014). For example, autonomous drones used by Matternet use GPS and other sensors to deliver medicines to hard-to-reach areas (Raptopoulos 2013). After the earthquake in 2010, the Matternet drone took part in the distribution of drugs in Haiti and the Dominican Republic (Choi-Fitzpatrick et al. 2016) and New Guinea and Switzerland (French 2015). Matternet also works with United Nations International Children's Emergency Fund (UNICEF) and the Doctors Without Borders group. Figure 5.3 shows an example of inaccessible locations.

Matternet drones can carry payloads between 1 and 2 kg (French 2015). It has the opportunity and ability to cover a distance of approximately 10 km at a speed of 40 km per hour (Raffaello 2014), including takeoffs and landings, in 18 minutes (Prigg 2014). With a smartphone application, senders can choose from the list of possible destinations. The drones automatically create a route in the next stage depending on the terrain, weather, airspace, and population density. Airports, schools, squares, hills, and buildings should be avoided while creating the route.

The German logistics company DHL Parcel has explored four generations of medical delivery with drones called Parcelcopter (DHL 2016). The first generation drone shown in Fig. 5.4. has completed its mission of delivering blood samples, covering the 1 km route along the Rhine in Bonn. The second generation was tested in 3 months' delivery of medicines and other urgently needed supplies to Juist, Germany's most remote settlement in the North Sea Islands (Agatz et al. 2015). During this delivery, the drone covered 12 km in open seas (Varnholt 2016). The third-generation drone was tested between January and March 2016 as part of the

Fig. 5.3 Difficulties due to inaccessible roads, use of Matternet drone (What to Know When Using Humanitarian UAVs for Transportation 2015)

Fig. 5.4 Parcelcopter: DP/DHL's future air courier (DHL 2016)

aging activity between two Bavarian Alpine Villages and Skyports of more than 130 parcels of urgently needed medicines and sporting goods. This drone achieved serious success by making deliveries in 30 minutes under winter conditions in as little as 8 minutes (DHL 2016). The fourth-generation drone was tested over 6 months for drug delivery to an island in Lake Victoria, Tanzania.

This drone is a fixed-wing trimotor that can carry medical supplies up to 4 kg, has a flight range of 65 km, and can reach speeds of up to 140 km per hour (Deutsche post DHL group 2018).

It is indisputable how vital the concept of time is in emergency medical situations. The logistics company UPS and Zepline companies continue to work on a network of drones to transport vaccines and blood samples to 20 long-distance clinics in Rwanda (Preimesberger 2016; Tilley 2016). Rwanda has one of the highest rates of maternal death and infant mortality in the world due to malaria. Because the roads become unusable during the rainy seasons in this region, the urgently needed rabies vaccines can be transported to the relevant regions using drones. Only one third of the people in Africa live 2 km from the highways that can be used all year (Khazan 2016).

Zepline drones deliver medical supplies by launching them from a slot and dropping them into needed areas with paper parachutes. After the drone completes its mission and returns to its home, blood or vaccines are loaded for the next delivery, and the activity is continued by inserting a sim card and a new battery. Zeppelin drones can fly 45 miles in 30 minutes, and delivery routes are tracked with a tablet application, and this route can be changed if desired (Khazan 2016).

The first medical supplies delivery using an FAA-approved drone has been successfully made to a healthcare clinic in southwestern Virginia (Pepitone 2015). This clinic can serve 3000 patients at the end of each week of the year (Hackman and Nicas 2015). Flirtey drones took the prescription products from the Wise County regional airport and delivered them to the clinic at the fairground, about 3 minutes away.

In 2007, a study with drones was conducted by the National Health Laboratory Service (NHLS) and Denel Dynamics researchers to more efficiently transport microbiological samples from rural clinics to NHLS centers for HIV testing. As a result of this research, the capabilities of drones that facilitate rapid diagnosis and medical decision-making have been determined (Mendelow et al. 2007).

In 2014, Me'decins Sans Frontie'res (MSF) used a drone-based system to send tuberculosis test samples to hospital laboratories. It was observed that the samples sent using drones took only 25% of the time taken for delivery by road (Médecins Sans Frontières 2014). Other studies determined that the integrity samples in fixed blood samples were similar to the blood samples carried by drones (Thiels et al. 2015). With the government's approval, the first medical delivery by drone in the United States was carried out at a clinic in Virginia. Thanks to this process performed by drones, the drug delivery process has been accelerated, and patient care has been improved (Hackman and Nicas 2015).

A similar practice was carried out between the UN Population Fund and the Dutch government, delivering birth control pills and gynecological materials to the relevant women's health clinics by drones to Ghanaian women (Cousins 2016). The US Postal Service has cooperated with Zepline company to deliver medicine, blood, vaccine, and medical supplies needed in Rwanda (Rosen 2017). Similar projects have started to be implemented in other developing countries such as Ghana (Mogombo 2016) and Rwanda (Mis 2016).

Although half of the world's population lives in rural areas, only a tiny part of them is located near the areas where professional health studies are carried out (World Health Organization 2010). Even in the United States, which is considered the most developed country globally, only 11% of doctors can serve people living in rural areas (University of Washington School of Medicine 2010). When the lack of health personnel, especially doctors, in these regions is added to the lack of appropriate diagnosis, testing equipment, and infrastructure problems, health services are faced with serious limitations. In addition, the lack of communication, Internet, and telephone can prevent healthcare professionals from reaching remote specialists and laboratories, which negatively affects patient treatment (Anticona Huaynate et al. 2015).

Amukele et al. conducted a study comparing the results obtained by transporting chemistry, hematology, and coagulation samples from healthy individuals using drones with the same type of samples in the laboratory environment. The test results determined that there was no significant difference between the two applications (Amukele et al. 2015). Preliminary reports of biological samples' routine chemistry, hematology, and coagulation analysis are appropriate for short-haul flights with drones at room temperature or colder (Amukele et al. 2017).

Drone activity is carried out successfully in Tanzania, one of the countries with the highest maternal mortality (556/100,000) globally. Drones could deliver the needed blood, vaccine, antiretroviral, and malaria drugs to more than 1000 health facilities with biodegradable parachutes faster than land transportation (Makoye 2019). Currently, organ/tissue transport uses a complex network of couriers, transport personnel, and commercial and private charter aircraft. Recently, a six-rotor drone has been used to model parameters related to organ transport (Scalea et al. 2019). In the kidney biopsy activities performed by keeping the temperatures constant and below 2.5 °C in 14 drone transport missions, no damage caused by drones was detected before and after the flight (Scalea et al. 2018). The first successful transport of a donated kidney to the University of Maryland Medical Center with a custom-built drone was carried out in April 2019 (Freeman 2019).

The ability of drones to move at high speed has made them vital in the transportation of AED devices that out-of-hospital cardiac arrests (OHCAs) need. This allows for reducing the defibrillation time in OHCA. In OCHA cases, the use of external defibrillators before the arrival of EMS makes a significant contribution by increasing the survival time by up to 30 days. Drones integrated with AED can reduce the defibrillation time in OHCA. Drones are used to deliver defibrillators to people to assist patients suffering from cardiac arrest. Researchers at Delft University in the Netherlands found how drones make things easier by providing AEDs within 2 minutes to any location within a 1.2 square mile radius (Hornyak 2014). In a computer-aided simulation study conducted in Salt Lake County, Utah, it was observed that drones could reach 96% of the county's population in less than a minute. In the traditional intervention by ambulance, only 4.3% of the cases could be born during this time (Pulver et al. 2016). In addition to these advantages, studies should increasingly continue to further improve the efficiency and performance of drones (Lippi and Mattiuzzi 2016).

Approximately 300,000 people in Europe are affected by out-of-hospital cardiac arrest (OHCA), which indicates that OCHA ranks among the top causes of death (Perkins 2015). The emergency medical services unit (EMS) in Sweden records about 5000 OHCA cases each year in the Swedish cardio-pulmonary resuscitation (SRCR) records (Herlitz 2015). Early defibrillation interventions have been shown to increase survival in OHCA cases. Delivery of the AED to the area of the OHCA event within the first minutes of the event results in significant increases in survival rate (Nordberg 2015). Studies show that in serious accident situations and for video

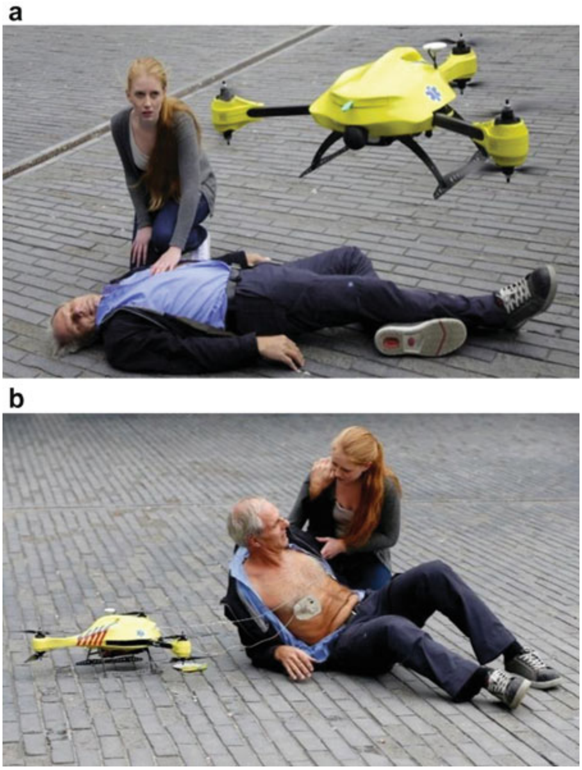

Fig. 5.5 The usage of drone in heart attack of a patient (Momont 2019). (**a**) Landing of AED-equipped drone. (**b**) Intervene with the patient

surveillance, drones will continue to be used by EMS to replace medical equipment (Floreano 2015, 85).

The ambulance drone used to resuscitate people who had a heart attack includes one AED. The ambulance drone moves at a speed of 100 km, has a 10-minute battery life, six propellers, and is painted yellow for easy identification. The drone in the ambulance has AED 50 shock delivery feature. A drone ambulance is integrated with GPS to locate the incoming emergency call. Figure 5.5 shows how a drone can intervene during a heart attack situation.

When the emergency call comes to the command center, the drone ambulance is directed to where the call was made. The webcam on the ambulance drone is the most important assistant of the health personnel in the call center. Thanks to this camera, instructions can be given to the personnel who will intervene with the person who has a heart attack. The AED is removed from the hatch with the instructions given from the emergency center using the webcam. The responder applies the AED according to the instructions from the webcam.

5.3 Assessment of Advantages and Disadvantages of Drone Types

Four primary types of drones can be addressed in the health industry. Those have been compared in Table 5.1 as fixed-wing, quad-rotor, multi-rotor, and VTOL drones. Multi-rotor and quad-rotor drones have been differentiated because of their fast maneuver and carry capacity. On the other hand, VTOL can describe both multi-rotor and quad-rotor drones; however, a particular function of operational endurance of fixed-wing and vertical movement capacity must have been highlighted. This capacity can be the powerful active function to be flexible through the long-range and limited takeoff and landing possibilities. Table 5.1 presents performance data of drone types used in health applications.

Operational usage of drones can be divided into two main branches: rigid-wing-type drones and rotational-wing-based drones. We may assume the first one as rotational-wing drones that we named them quad-rotor and multi-rotor ones. Also, the rigid-wing, also known as fixed-wing drones, can be divided into fixed-wing and VTOL drones. All the four categorized types of drones can be seen in Table 5.2.

The rotary-wing drones offer greater reachability and cost-effective solutions as described in the left two options. However, the need for energy and stability problems in windy meteorological conditions fails to conserve stability and control. Conversely, fixed-wing-style drones can be more stable and hard to reach because of non-cost-effective production properties. However, those drones have great endurance of the same amount of energy. Compared to the VTOL-capable fixed-wing drones, they have higher endurance than the rotary-wing drones, and they do not need a specialized long runway investment in crowded city areas. But both need long hours of training and experience to operate in congested areas.

Table 5.1 Drone types and health applications (Braun et al. 2019)

	Cargo capacity	Range	Maximal speed	Takeoff	Application in healthcare
Fixed wing	1.75 kg	160 km	128 km/h	Runway	Blood sample, vaccines
Quad-rotor	2.2 kg	20 km	40 km/h	VTOL	Blood sample, medications, equipment
Multi-rotor	2 kg	32 km	–	VTOL	Blood sample, medications,
VTOL	4 kg	65 km	140 km/h	VTOL	Blood sample, organs

Table 5.2 Operational usage reasons and drone types (Heutger and Kückelhaus 2014; Kelek 2015)

	Quad-rotor	Multi-rotor	Fixed-wing	VTOL
Advantages	Low cost High maneuverability Low energy consumption	Low cost High accessibility Great maneuverability Ease of use Vertical takeoff and landing (VTOL) Good camera control	Long endurance Large area coverage Fast flight speed Great stability Gliding capability	Long endurance Large area coverage Vertical takeoff and landing capabilities Easier to navigate in dense, urban environments, and even inside buildings Great stability Gliding capability
Disadvantages	Low endurance Limitation of battery capacity Small payload capacity Shallow stability in the wind	Higher energy consumption Short flight times Small payload capacity Low stability in the wind	High price Large take-off/landing zone required No VTOL/hover Challenging to fly; training is needed Low efficiency for area mapping	Shorter flying range Lower speed Smaller payload capacity High price Challenging to fly Challenging for landing

5.4 Future of Drones in Health Industry

Considering the growth in the drone industry, with the help of technology, the hearth of the operation will be the automation and the regulating legislation. The main question is to oversee and answer the future of artificial intelligence (AI) in the three-dimensional world (Li et al. 2016). Moving forward to the health industry's use of drones to help the patient recover, what if the drone injured somebody? Furthermore, what if the drone kills someone? Will there be a person responsible for this autonomous delivery?

Most of the problems of autonomous drones have not been discussed; however, the authorities listed below minimize the impact of the legal difficulties globally:

- International Civil Aviation Organization (ICAO)
- Joint Authorities for Rulemaking of Unmanned Systems (JARUS)
- European Aviation Safety Agency (EASA)
- Federal Aviation Authority (FAA)

The primary use of drones is to gain from time and the cost from the process of human interference and to ensure the operational processes are successful. It does not matter whether the operation is a cargo or paper delivery. Monitoring a process by drones remotely with a high-definition video camera is another way of drone use in our world. Shortly, the health industry will find ways to integrate drones. Technology will answer the request from fast deliveries of blood samples, vaccines, medications, organs, and types of equipment.

The lack of infrastructure limits drone use in any industry as the persisting technical issue is another problem. As discussed earlier, the current quad-copter and multi-copter operational times are limited because of energy storage problems. Those drones cannot change the batteries automated or the next step interchangeable with other carrier companies. There may be ideas to use current gas station rooftops for automated interchangeable battery stations. But who will standardize the global battery standards for those devices? How could the stations account for the use of battery life cycle out of a thousand?

Using VTOL and fixed-wing drones for longer distances needs runway and heliport-like infrastructure investments, which seems it would not be possible in the current cost profiles. On the other hand, those drones need experienced pilots to be managed under control, especially on takeoff and landing phases. Certainly, there will be considerable time and cost-saving for those operations if the drones are integrated into the health industry.

Nonetheless, air traffic rules cannot be evaluated under only the traffic congestion in the urban areas; there are undoubtedly many risks carried with its operations by the health industry (Merkert and Bushell 2020). There can be a chaotic, uncontrolled environment with many drones in urban areas. So collision scenarios and collision avoidance must be in place as hardware-embedded rules if the autonomous flight and air rules are primary focus area. There is a ruling system that has been offered by Foina et al. (2015) UAS Traffic Management (UTM) system. This system provides three-dimensional parcel maps for landlords to approve or disallow the drone flights above their real estate boundaries. Another literature entry has been found to discuss the separation distances between the drones by Tan et al. (2017) in urban areas in two scenarios: (i) direct flight path and (ii) direct flight path with limited speed. The authorities mentioned namely ICAO, JARUS, EASA, and FAA will undoubtedly continue to discuss air traffic studies for the drones.

The size of the drone will be another issue in the future. Open skies will have significant and small players like ships in the open seas. There are sailing boats, giant cargo ships, and small boats in the open seas. The impact of a small drone and a heavy drone would not be equalized if an incident happens. The size of drones will change in the future to adapt to the needs of the health industry.

5.5 Conclusions

Drones have become a rapidly developing technology worldwide due to their technical features. Due to these features, UAVs have become significantly used in both military and civilian fields today. Since the health sector has sensitivities and the need to react quickly, it has started to use drones effectively. It has become a valuable tool in the field of medicine, thanks to its ability to quickly solve the problems faced by both health personnel and patients. In this study, it is seen how drones increase the quality and effectiveness of helping healthcare professionals and patients in certain applications. UAVs play an important role in delivering medicines, vaccines, blood, and other medical supplies to rural communities. The essential healthcare area where drones are used is prehospital medical systems. The medical use of drones can be summarized as follows:

- AED transportation to the scene, medicine, tissue, blood products transportation, trauma kit
- Transportation of other materials
- Guiding for applications such as telemedicine

The use of drones in the intervention of a heart attack, which is one of the most common conditions in health, significantly increases the patient's survival rate. AED transport with drones and the use of ambulance drones in the healthcare field have been a beacon of hope for patients who have had a heart attack. In the future, improvements in the technical features of drones (speed, battery life, enlargement of size) will make it inevitable to use them in many different applications in the healthcare field.

Drones play an essential role in nonhospital interventions in the health sector due to their technical features. It is known how vital even seconds are for the survival of a person who has had a heart attack. Drones can provide rapid intervention to patients who have had a heart attack with the AED they carry. As can be observed from this study, it has been determined how quickly drones can intervene in the transport of AEDs to patients who have had a heart attack. This study will make it possible for us to see drones taking blood tubes in the emergency departments of hospitals in a short time. Depending on the developments in drone technology, it will be possible to transport patients who met with an accident to the emergency services or hospitals after the first intervention. As a result, the use of UAVs in the health sector will be an area that offers many opportunities for effective future studies.

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