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EDITED BY
Muhammad Waseem,
Lincoln Medical Center, United States

REVIEWED BY
Philipp Dahlmann,
Deggendorf Institute of Technology, Germany

*CORRESPONDENCE
Sudip Bhattacharya
drsudip81@gmail.com

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Elevating emergency care: unleashing the potential of unmanned aerial vehicles in shaping the future of emergency medicine

Sudip Bhattacharya[1]*, Saurabh Varshney[2] and Amarjeet Singh[3]

[1]Department of Community and Family Medicine, All India Institute of Medical Sciences, Deoghar, Jharkhand, India, [2]All India Institute of Medical Sciences, Deoghar, Jharkhand, India, [3]Department of Community Medicine and SPH, Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, India

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Introduction

An unmanned aerial vehicle (UAV) is described as a powered flying vehicle that lacks a human operator, relies on aerodynamic forces for lift, can operate autonomously or under remote piloting, and is capable of carrying both lethal and nonlethal payloads; details are given in Table 1 (1, 2). It comes in a wide range of sizes, from small handheld models to large aircraft-like devices. The utilization of UAVs in warfare began during the 19th century, starting with the Navy in Italy using a balloon carrier (3). Details are given in Table 2 Over time; significant advancements in aerospace engineering have improved the structure and functionalities of UAVs (4).

Originally confined to military applications, their usage has now expanded rapidly to include various modern uses such as air quality sampling, monitoring harmful gasses, industrial hygiene, safety management, studying road traffic accidents, tracking flora and fauna, and examining landscape ecology, such as studying malaria in rubber plantations.

However, the application of UAVs in emergency medicine remains less explored compared to their implementation in other fields. In this article, we explore the potential of utilizing UAVs or drones in emergency medicine. Additionally, we discuss the advantages, potential obstacles and future research avenues that need to be addressed for successful integration of UAVs in emergency medicine initiatives.

Applications of drone in emergency medicine

Emergency medical services (EMS) plays a pivotal role in the U.S. emergency medical and trauma care system, responding swiftly to transport millions of Americans annually. The patient survival chain depends significantly on prehospital assessment, initiation of care, stabilization, and timely transportation. Extended EMS response and scene times are linked to unfavorable outcomes, particularly for significant traumatic injuries and shock. In time-sensitive emergencies like cardiac arrest and stroke, a prompt EMS response is crucial for optimizing neurologically intact survival. Despite strategically locating EMS stations for optimal access, median EMS arrival times in the United States vary from 7 to 8 min and can exceed 14 min in challenging areas. Changes in the U.S. healthcare system, trauma center closures, and shifts in EMS funding have introduced complexity. The COVID-19 pandemic

TABLE 1 Working principles of drones.

Power source	Drones are powered by batteries or fuel cells, depending on the model. Most consumer-grade drones use rechargeable lithium-polymer batteries
Propellers	Drones have multiple propellers that provide lift and control. Quadcopters, for example, have four propellers, while hexacopters have six
Flight control	Drones have an onboard flight controller that processes inputs from sensors and the remote control or an autonomous flight system
Sensors	Drones are equipped with various sensors, including GPS, accelerometers, gyroscopes, and altimeters. These sensors help the drone maintain stability and navigate accurately
Remote control or autonomous system	Drones can be controlled by a human operator using a remote control or be programmed to fly autonomously along a predefined route
Communication	Drones communicate with the remote control or ground station through radio signals, enabling the operator to send commands and receive telemetry data (such as altitude, battery level, and GPS coordinates)
Camera and payload	Many drones have built-in cameras that capture images and videos. Advanced drones can carry additional payloads, such as thermal cameras, LiDAR sensors, or even packages for delivery purposes

has further impacted EMS, affected 9-1-1 calls and increased response times. In this dynamic landscape, EMS is exploring innovative solutions, with drones emerging as a promising option (5).

Annually, around 350,000 individuals in the U.S. experience out-of-hospital cardiac arrest, with a survival rate of only 10%. Swift intervention is critical, as neurologically intact survival decreases by 10% per minute without resuscitation. Bystander-administered defibrillation and CPR within the first 5 min significantly improve survival. However, in rural areas, EMS arrival times often surpass the national median of 8 min. Mathematical models suggest that drones can substantially reduce AED arrival times, potentially improving survival rates. Simulation studies in Sweden, Canada, and the U.S. support the feasibility of drone-delivered AEDs, indicating significant time savings. Real-life tests in Sweden in 2021 successfully delivered AEDs by drone, demonstrating the practical integration of drone-delivery systems into emergency response protocols (6–8).

Uncontrolled hemorrhage remains the leading cause of preventable death in trauma. Timely blood transfusions enhance survival rates, and studies affirm the feasibility of drone transport for blood products. In Rwanda, drone technology efficiently delivers whole blood during trauma events and maternal emergencies. In Ghana, drone delivery of blood serves numerous health facilities. In the U.S., where regulations and air traffic congestion impact drone operations, feasibility is still being evaluated. A recent simulation study showcased the feasibility and time savings of drone delivery compared to ground transport for temperature-controlled simulated blood samples in urban areas (1, 9).

Naloxone, an FDA-approved antidote for opioid overdose, faces low bystander administration. A potential solution involves dispatching a naloxone-equipped drone concurrently with ambulance dispatch. In a feasibility study, participants successfully administered intranasal naloxone to a simulated opioid overdose victim within 2 min of the initial 9-1-1 contact (10). Drones are under evaluation for delivering rescue medications like epinephrine, antiepileptics, and insulin, with studies demonstrating the feasibility of drone transport for various emergency medications (11).

EMS, including Search and Rescue (SAR) in remote or coastal areas, benefits from drone support in simulated SAR events and evaluating recognition of human gestures for future SAR operations. Drones contribute to EMS in rescuing individuals in challenging terrains like mountainous or avalanche-prone areas, and in coastal regions, they play a dual role in surveillance and locating distressed swimmers (12). Drones play a crucial

TABLE 2 Evolution of drones.

Early concepts (1849–1917)	The concept of unmanned flying machines can be traced back to the mid-19th century. In 1849, Austrian soldiers used unmanned balloons loaded with explosives for military purposes. In the early 20th century, various inventors experimented with radio-controlled aircraft, but the technology was still in its infancy
Aerial Target (1916–1917)	During World War I, the British Royal Flying Corps developed the "Aerial Target," a radio-controlled aircraft used as a flying bomb to counter the threat of Zeppelin airships. The Aerial Target was not a true drone as it lacked autonomy, but it marked a significant step in the development of unmanned flying machines
Radioplane OQ-2 (1939-1940)	During World War II, actor and inventor Reginald Denny created the Radioplane OQ-2, one of the first mass-produced remote-controlled aircraft. It was initially used as a target for anti-aircraft gunnery training but later adapted for reconnaissance purposes
The Birth of UAVs (1950s-1960s)	The term "Unmanned Aerial Vehicle" (UAV) was coined in the 1950s when the United States military started developing drone aircraft for reconnaissance and surveillance. During this period, the U.S. produced several UAVs, including the Ryan Firebee series
Predator and Global Hawk (1990s)	In the 1990s, the U.S. military made significant advancements in drone technology with the introduction of the MQ-1 Predator, which became the first drone capable of carrying and firing missiles. Additionally, the RQ-4 Global Hawk, an advanced surveillance drone, was introduced during this time
Consumer and commercial drones (2000s)	In the early 2000s, advancements in miniaturization, battery technology, and GPS led to the emergence of consumer-grade drones. Companies like DJI played a pivotal role in making drones accessible to the general public. These drones were mainly used for photography and recreational purposes
Widening applications (2010s)	Throughout the 2010s, the range of drone applications expanded rapidly. Drones found applications in industries such as agriculture, filmmaking, construction, environmental monitoring, search and rescue, and more
Drone regulations (2010s)	As drone usage increased, so did concerns over safety and privacy. Governments around the world began introducing regulations to govern drone operations and ensure safe integration into airspace
Future prospects (2020s and beyond)	Drone technology continued to advance, with research on-going into swarming capabilities, AI-driven autonomous flight, longer endurance, and beyond-visual-line-of-sight operations. Drones are expected to play an essential role in various industries and continue to evolve in the years to come

role in disaster response and management, offering emergency surveillance, telecommunication services, SAR operations, and supply deliveries in challenging areas. Drones undergo testing for hurricane response scenarios, proving their value in disaster management in remote areas. In mass casualty incidents where resources are overwhelmed, drones enhance response by providing visual oversight, ensuring scene safety, and aiding in operations and logistics. Drones not only augment command roles but also impact direct field operations, improving triage speed and casualty evacuation (13).

In telemedicine, drones present a viable and cost-effective means of delivering emergency communication and services to patients with limited access. Trials explore drones as communication hotspots for emergency telesurgery and "tele mentoring" of surgical procedures (14).

Challenges

Drone technology, while promising in various fields, faces several challenges that impede its seamless integration into everyday applications. One significant hurdle lies in regulatory frameworks, as airspace management and safety concerns necessitate stringent rules for drone operations. Ensuring compliance with these regulations and mitigating potential security risks pose ongoing challenges. Another critical aspect is limited battery life, constraining the flight duration and range of drones. Addressing this issue requires advancements in battery technology to enhance endurance. Additionally, privacy concerns have arisen as drones equipped with sophisticated cameras become more prevalent, necessitating clear guidelines on data collection, usage, and storage. Autonomous navigation and collision avoidance in complex environments also pose technical challenges, requiring advancements in artificial intelligence and sensor technologies. Weather conditions, such as high winds or precipitation, can affect drone performance, requiring resilient designs for adverse conditions. Lastly, public perception and acceptance, influenced by factors like noise pollution and perceived invasions of privacy, present social challenges that need careful consideration for widespread drone adoption. Overcoming these challenges will be crucial for unlocking the full potential of drone technology across various industries (5).

Future research avenues

The future trajectory of drone technology is teeming with potential, and ongoing research endeavors are delving into diverse avenues to propel its capabilities and applications to new heights. A pivotal focus is on the evolution of artificial intelligence and machine learning, steering research into autonomous drone navigation. Innovations in algorithms aim to empower drones to adeptly maneuver through intricate environments, circumvent obstacles, and make instantaneous decisions sans human intervention. Concurrently, investigations are underway to facilitate collaborative efforts among drones in swarms, enhancing their proficiency in tasks such as large-scale mapping, search and rescue missions, and surveillance through the seamless sharing of information and coordinated actions. Current drone regulations often mandate visual contact, prompting researchers to delve into technologies and protocols enabling beyond-visual-line-of-sight operations. This expansion of operational range holds the potential for applications like extended-range delivery and comprehensive infrastructure inspection. Energy efficiency and prolonged flight endurance stand out as critical research areas, with a focus on advancements in battery technology, solar-powered drones, and energy-efficient propulsion systems, paving the way for extended flight durations and heightened mission capabilities. Environmental considerations also take center stage in drone research, with a keen exploration of eco-friendly materials and technologies to minimize the ecological impact of drone operations. Sustainable manufacturing practices, the use of biodegradable materials, and the implementation of noise reduction technologies are areas under scrutiny.

Conclusion

With the increasing prevalence of drones, the imperative of comprehending and refining human-drone interaction cannot be overstated for ensuring user approval and safety. Investigations in this domain delve into creating interfaces for drone control and communication that are intuitive and user-friendly. Collectively, the continuous research and innovation in drone technology are anticipated to yield more streamlined, secure, and adaptable drone systems, consequently opening up novel possibilities across diverse industries and enhancing the overall quality of life for individuals globally.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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