

The role of drones in delivering emergency medical and surgical support in conflict zones

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Summary

Armed conflicts such as those in Gaza and Ukraine highlight the urgent need for innovative solutions to deliver emergency medical and surgical support in inaccessible and high-risk environments. Traditional supply chains often fail in war zones due to blockades, damaged infrastructure and safety concerns for healthcare personnel. Unmanned Aerial Vehicles (UAV), commonly referred to as drones, have emerged as a promising tool to bridge these critical gaps. This narrative review explores the role of drones in delivering medical supplies, supporting casualty triage and enhancing emergency response in conflict settings. A structured literature search of MEDLINE and Embase (2000–2025) identified relevant studies assessing drone applications in healthcare, with particular focus on their deployment in war and disaster zones. Evidence demonstrates drones can significantly reduce delivery times for blood products, automated external defibrillators and essential medicines, while providing reconnaissance to locate casualties and assess hazards. Advantages include improved timeliness, reduced risk to rescuers and enhanced situational awareness. However, challenges remain, including limited payload and range, vulnerability to adverse weather and electronic interference, regulatory and legal barriers, and civilian mistrust linked to military drone use. Future integration of artificial intelligence, secure communication systems and harmonised regulatory frameworks may expand drone utility, ultimately transforming emergency medical care in conflict zones.

Introduction

The world is currently in a state of unrest, with substantial conflict occurring across multiple continents. Most notably and most prominent in the public consciousness are the ongoing conflicts in Gaza and Ukraine; there are still over 110 current conflicts and wars occurring around the world [1]. Gaza is a focus of the international community, with 75% of its residents displaced due to the current war and leading to grave difficulties in getting essential aid to where it is needed most [2]. Ukraine has also seen one of the world's fastest displacement crises in years, according to the United Nations Refugee Agency [3]. Countries are struggling to manage and supply due to the recent rise in conflicts, particularly with many of them being due to non-state groups such as international terrorist groups and political militias [2].

With a greater level of conflict severity, the need for rapid and efficient delivery of crucial aid, such as food and water, medical aid and medical supplies, is paramount. Challenges of accessing certain conflict areas and delivering emergency medical supplies have also risen, mainly due to political and social issues, regulatory barriers, military blockades and no easily accessible

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transport routes [4]. With the type of injuries and trauma that will inevitably occur in conflict and war, these are particularly time-dependent, and the faster the intervention, the better the patient outcome [5].

Unmanned Aerial Vehicles (UAVs), commonly known as drones, are being increasingly used for urgent medical delivery in more inaccessible areas or to reach the medical team in a more time-efficient manner. Drones are effectively robotic devices that do not require a human pilot and can fly autonomously through pre-set programming or by use of a remote control. In a medical context, drones have been explored as solutions for delivering critical supplies such as emergency blood units, medicines, vaccines and even transplant organs, especially in hard-to-reach or time-sensitive scenarios [6]. Their use is particularly advantageous in areas where traditional transportation is limited or delayed, including remote rural regions, congested urban settings and crisis zones with compromised infrastructure [7]. By enabling fast, direct delivery of life-saving aid, drones offer a time-efficient method that can significantly improve emergency response and patient outcomes.

Governments have put drone use on the national agenda for its potential as a reliable medical delivery platform for emergency medical equipment [8]. Public opinion also favours the use of drones for medical delivery; particularly after seeing footage of drones saving lives in emergency rescue missions [9].

This paper aims to further explore the current evidence for the utility of drone usage to deliver emergency medical support and supplies in war-torn areas and conflict zones. This paper will briefly look into the history of drone usage in emergency healthcare and subsequently discuss the importance of alternative medical delivery methods in conflict areas. The different reported medical uses of drones will be considered, particularly with their overarching importance in certain needs, as you would expect in war. Challenges and ethics of drone use will be considered, including technical issues related to infrastructure, digital solutions such as navigation algorithms and interoperability, communication reliability, microclimate sensitivity, regulatory frameworks and concerns about airspace management and noise pollution. Finally, the paper will explore potential future directions for expanding the use of drones in healthcare and emergency response.

History of drone usage

The first drone application was the Austrian Balloon in the 1840s as a vehicle without a pilot to transport explosives [10], after which it was adopted for various military purposes. Since then, its usage has broadly expanded to a number of different modern agencies, which include safety management, examining landscapes, surveillance and delivery [11, 12].

A lot of the current drones used in war are focused on war tactics and have played pivotal roles, particularly in the conflicts in Ukraine. The hugely increased scale of aerial vehicles in this particular conflict truly demonstrates the extent to which drone use for tactics such as autonomous weaponry systems has truly transformed warfare as we know it [13]. There has been such a shift that it has reached the extent of challenging international law [14]. The ethics of drone use, and the negative uses in warfare, pose a huge challenge to the debate over whether it should continue to be used, a point that will be further considered below.

Focusing once again on healthcare, drone use for medical purposes has shown great promise in helping life-saving treatments and interventions during emergencies [10]. Its ability to reach remote or harder-to-reach locations, as well as its time efficiency, is what has made its use seem more promising. Examples include use in Spain for medical triage of mass casualties, where they are used to assess a scene before the arrival of emergency medical services, which was found to successfully find more injured people compared to prior methods without drone use [15]. The Ghanaian government contracted a US-based company, Zipline, in 2017 to deliver medical supplies to hard-to-reach rural communities by use of drones [16]. Drones have been historically used to transport automatic external defibrillators (AED) to out-of-hospital cardiac arrests, which has the potential to improve survival rates and save costs [17]. More recent history demonstrates the use of drones in combatting the devastating effects of the COVID-19 pandemic; several different uses have shown their potential to enhance public health. Drones have provided and still can provide further healthcare support by efficiently transporting and delivering key medicines, vaccines and injections with needles to remote areas, which has helped reduce viral spread more effectively in

those areas [18]. This innovative model of drone-based delivery methods helped address the ongoing issue with health equity and ease of access to healthcare services, which worsened during the COVID-19 pandemic [19].

Importance of alternative delivery methods in war zones

In 2015, the United Nations launched the 17 Sustainable Development Goals (SDG), of which goal 3 (Good Health and Wellbeing) declared the right of individuals to have access to a good healthcare system, which includes access to emergency medical services [10]. The misfortune of being within a war zone does not and should not diminish this goal and basic right for civilians. There have been current news reports of the delivery of aid into Gaza being blocked [20]. This goes further back to 2007, when a blockade made access to basic and emergency aid more difficult [21]. Similarly, in Ukraine, other types of blockades are ever-present in modern warfare [22]. One would therefore need to consider alternative methods for delivering emergency and trauma aid for casualties due to any potential conflict.

Supply networks are therefore fundamental to ensure efficient and rapid delivery of items that are time-sensitive for many trauma-based injuries. In conflict zones, careful specialised organisation and planning are needed for delivering essential items in conflict zones [2]. It is therefore important to be able to scrutinise current supply routes for careful, diligent planning; unfortunately, challenges have emerged in gathering the necessary data required to do so effectively [23]. Some of the known challenges of ensuring effective delivery of essential items are the need to carefully consider safety and security, mitigating risks and finding innovative solutions [2]. The use of drones as a delivery method would guarantee safety as they are unmanned and this certainly provides a possible solution for effective delivery. The cost-effectiveness of adding drones to the essential medical supply chain further adds to their value as a genuine method of delivering emergency healthcare supplies, despite their logistic difficulties [24]. Coordinated planning of routes and distributions for drones to make drops can become a normalised method for conflict zones.

Methodology

This narrative review was conducted following a structured literature search of the Embase and MEDLINE databases. The MeSH function in PubMed was also used. The following Boolean search strategy was applied:

("unmanned aerial vehicle*" OR UAV OR drone* OR "remotely piloted aircraft" OR "unmanned aircraft system*" OR UAS OR "aerial robot*")

AND

("emergency medical service*" OR EMS OR "prehospital care" OR "medical delivery" OR "medical supply*" OR "healthcare delivery" OR "casualty care" OR "damage control surgery" OR "trauma care" OR "emergency response")

AND

("conflict zone*" OR "war zone*" OR "armed conflict*" OR "battlefield" OR "humanitarian" OR "disaster zone*" OR "mass casualty" OR "combat casualty" OR "crisis zone")

The search was restricted to articles published in English from January 2000 to May 2025. The year 2000 was chosen as the starting point to capture literature reflecting modern drone technology and its applications in healthcare, given that significant advancements in UAV design, autonomy and medical logistics have occurred in the past two decades. Earlier publications were excluded to ensure the evidence reflected contemporary operational capabilities and regulatory contexts.

Titles and abstracts were screened for relevance to the research question. Full texts of potentially eligible studies were then reviewed, and articles were excluded if they did not address the use of drones for delivering emergency medical or surgical support in conflict or disaster settings, or if they failed to provide relevant empirical or review-based evidence. Reports of effectiveness of drones not related to healthcare were excluded.

Utility of drones for emergency care in war zones

The utility of drones for emergency healthcare supplies offers more than just an alternative mode of delivery; it presents a feasible solution with significant potential. Considering the logistical challenges of accessing conflict zones due to geopolitical barriers, drones provide practical benefits to civilians in multiple ways. Strategic planning that prioritises risk minimisation and safety is paramount. Notably, drones reduce the risk to rescuers by avoiding direct exposure to threats such as shootings, fires or explosives, common hazards in war zones [8, 25–26].

Conflict inevitably produces numerous traumatic injuries and severe blood loss, often leading to cardiac arrest. Early resuscitation and defibrillation are critical to survival, regardless of social or wider determinants [27]. Systematic reviews indicate that drones can significantly improve care for out-of-hospital cardiac arrest patients by delivering automated external defibrillators (AEDs) faster than medical personnel can arrive [28, 29]. This rapid delivery can provide crucial first aid, bridging the gap until professionals reach the scene. Moreover, drones have shown promise in delivering time-sensitive treatments for other emergencies such as trauma, seizures and anaphylaxis, especially in rural or hard-to-reach areas where response times are typically longer [5, 30, 31].

Beyond delivery, drones enhance emergency medical assistance through reconnaissance capabilities. In vast or mountainous conflict zones, drones can rapidly survey large areas, increasing the chances of locating critically injured or immobile patients and acting as force multipliers in search and rescue operations [25]. After mass casualty incidents, such as bombings, drones can swiftly gather essential information, including the nature of the attack, casualty counts, hazards and evacuation routes [8, 32–34]. This rapid situational awareness enables safer, faster and more-accurate deployment of scarce medical resources, improving incident management and potentially saving more lives [15, 35].

Innovative applications continue to emerge, such as the use of ultraportable operating rooms deployed in war-like settings to perform damage control surgeries where resources are limited [36]. Such advancements underscore the expanding scope of drone utility in enhancing emergency healthcare in conflict zones [37].

Further, more technical and wider emergency healthcare uses of drones have been considered and effectively used. In an evaluative study comparing both utility and cost-effectiveness of drones to those of standard ambulances in delivering blood products, the significantly faster transit time of drones was found to offset the higher costs compared to ambulances [38]. Further evaluative studies have demonstrated similar findings, highlighting in particular the time-effectiveness of delivering blood products, particularly where time can be a rate-determining step of life-saving interventions in more urban areas [31, 38].

Complementing drone deployment, recent advancements in prehospital, en-route and damage control casualty care are shaping the future of combat medical support. Tactical Combat Casualty Care (TCCC) principles emphasise immediate haemorrhage control, airway management and pain relief, all of which can be supported by rapid drone delivery of critical medical supplies, including blood products and AEDs. Mobile medical units and aeromedical evacuation platforms improve timely access to advanced care, while telemedicine and wearable sensors facilitate continuous monitoring and real-time treatment adjustments during casualty transport [40].

Damage Control Resuscitation strategies – focusing on early blood transfusions, permissive hypotension and hypothermia prevention – further enhance survival prospects for severely injured patients. Point-of-injury blood transfusion, supported by drone logistics, addresses haemorrhagic shock more effectively on the battlefield [40].

Looking ahead, artificial intelligence (AI) and machine learning hold promise for optimising drone operations through predictive analytics, aiding triage and resource allocation. Simulation-based training and interoperability standards will be vital to prepare medical personnel and ensure seamless multinational coordination.

As Johnson et al. emphasise, the integration of drones can revolutionise emergency medicine by improving rapid response capabilities, expanding operational reach and supporting real-time decision making, all while addressing regulatory, ethical and logistical challenges [41]. Together with evolving casualty care protocols and technological innovations, drones are poised to transform healthcare delivery in conflict zones, ultimately enhancing survival and operational effectiveness.

Challenges in drone technology

Despite the growing potential for drone use to further enhance the delivery of healthcare in war zones, several factors challenge its feasibility and even challenge its use at all. These include technical limits of the aircraft, safety and security concerns, and regulatory or legal barriers.

The technical challenges include the limited battery life of electric drones. Long-distance deliveries commonly may require scheduled stops for battery replacement or recharging [42]. This necessitates forward charging stations or multiple relay drones for extended missions. The need for frequent landings and recharges slows mission tempo. There is a compelling need to balance payload versus range as adding medical supplies increases power draw and cuts flight time. Carrying heavier loads (like oxygen tanks or evacuation stretchers) also requires much larger UAV designs and makes them vulnerable to weather and enemy fire. Besides that, drones in war zones rely on onboard sensors for navigation, detecting casualties and avoiding obstacles for successful missions [43]. Sensor accuracy could, however, degrade in poor conditions often found on battlefields. Maintaining stable flight is also critical when traversing war zones, but small UAVs are especially sensitive to adverse weather conditions like extreme temperatures, strong winds or heavy rain. Drones also depend on robust wireless links for command-and-control, telemetry and data streaming. The potential risks in a war zone could include radio frequencies being jammed, networks being congested or blocked line of sight. Without safe encryption, drone systems are vulnerable to hacking and could reveal video feeds or payload status. This presents a significant challenge for UAVs, which must be equipped with precise calibration, durable hardware and advanced secure communication systems [43].

Furthermore, civilian and military law impose multiple layers of restrictions on UAV use. In most jurisdictions, airspace regulations limit drone flights. While intended for civilian safety, such rules can conflict with wartime needs, where drones may need to operate beyond line of sight, at night or in restricted zones. Waivers exist for humanitarian UAVs, but are slow, country-specific, and inconsistent. Harmonising airworthiness certification and establishing special combat-safe corridors is a huge policy challenge [44]. In terms of logistical and infrastructure laws, countries may restrict UAV importation or use, while conflict zones often lack any registration process. Insurance and liability frameworks remain undeveloped, and differing national standards create legal uncertainty for cross-border or occupied-territory operations [45]. Under International Humanitarian Law and the Geneva Conventions, marked aircraft used solely for medical transport are protected, but there are no explicit provisions for small UAVs. Sensors or defences can compromise neutrality, so medevac drones must be unarmed, clearly marked and coordinated with combatants [46]. Creating a clear operational framework remains an open challenge.

The technology and functionality of drone use in this setting are still constantly evolving and thus there is scope to create more variable models and functions going forward [41]. Aside from utility, cost-effectiveness should be considered, particularly with other or more novel models, particularly with the limited resources one would expect in a conflict zone. More novel models were deemed to be less cost-effective [7] despite their more rapid delivery time. Further research into more dynamic models has been conducted recently [47], with calls for further evaluation into this, given its potential effectiveness in emergency health aid.

Beyond machines and rules, successful drone deployment also depends on people. Drones have long been used for military purposes, predominantly in modern warfare for combat operations. They serve a variety of tactical roles and are increasingly integrated with AI to execute precision airstrikes [48, 49]. The significant impact of these operations has left lasting impressions on civilian populations in conflict-affected regions, often fostering fear and anxiety due to traumatic experiences associated with drone presence [16]. In war zones, gaining civilian trust in drones remains a major challenge, as they are frequently perceived as surveillance tools or weapons. Onboard cameras raise privacy concerns, and drones risk hostile misidentification. Without proactive community engagement, clear communication and training of local operators, medical and humanitarian drone missions risk failure or even attacks [45, 50]. Furthermore, a critical obstacle to successful drone deployment is the shortage of trained pilots, maintainers and analysts, particularly among NGOs and medics operating in underdeveloped or conflict zones. Effective integration of medical drone fleets, therefore, requires not only new skilled personnel but also significant organisational adaptation [51]. Addressing these social and human resource challenges is essential before advancing logistical planning or resource allocation for expanded drone use [12].

Possible future directions

The current benefits of drones in emergency healthcare, such as safely and efficiently delivering medical supplies and assisting with triage planning, are already evident. Their speed and effectiveness offer significant advantages in conflict and disaster zones, making drone-assisted healthcare delivery a promising field with substantial potential.

Building on existing benefits, the integration of AI is fundamentally transforming drone operations in conflict zones. AI-enabled drones can navigate autonomously through complex, dynamic environments beyond pre-programmed routes to find optimal delivery paths for medical supplies, even under real-time threats. Equipped with machine learning algorithms and computer vision, these drones can analyse sensor data in detail to assess ground conditions, identify injured persons, detect potential hazards and perform victim triage independently. This enhances search and rescue efficiency, improves triage accuracy and reduces operator workload. Crucially, AI supports more objective decision-making by prioritising care based on quantifiable data rather than subjective judgement. From a technical perspective, this enables more precise, adaptable and life-saving interventions in unpredictable conflict scenarios with minimal human interaction [52].

Awareness campaigns and education programmes for the general public and civilians living in a war zone should be initiated to both reduce the possibility of civilian mistrust in drones and to increase the workforce to operate drones for further use [52].

Another systematic review of drone use in emergency medical services demonstrated other ways the utility could be further enhanced [10], such as for public announcements to help with crowd control or using larger drones to transport patients to safety or to emergency healthcare workers to deliver lifesaving treatment, without compromising the safety of the workers. The scenarios left from conflict are unpredictable and can continue to change at any given moment; hence, the need to match its dynamic nature by being adaptable and flexible with how to best deliver emergency care.

Conclusions

The future of drone use in conflict zones remains uncertain due to the unpredictable and chaotic nature of war, which often leaves civilians vulnerable. However, effective deployment of drones requires careful planning and adherence to standardised operating procedures, especially when applied to healthcare. In austere environments created by conflict, drones offer significant advantages by mitigating risks and enabling rapid delivery of critical medical supplies, capabilities that are urgently needed in war casualty scenarios. To maximise their potential, further research focused on needs-based analyses is essential to determine optimal applications and prioritise delivery efforts, particularly given the ongoing and escalating global conflicts.

Potential competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest related to the content of this manuscript was disclosed.

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