Use of drones and Artificial Intelligence (AI) in optimizing logistics of air medical emergency missions

Zastosowanie dronów i sztucznej inteligencji (AI) w optymalizacji logistyki misji lotniczego ratownictwa medycznego



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DOI:

10.35117/A_ENG_26_09_06

Abstract: Advanced technology implementation including artificial intelligence (AI), adds influence and shaping the efficiency of air medical operations. Use of Artificial Intelligence tools in supporting the necessary dispatch of rescue teams, optimizing flight routes, and selecting resources confirms the need for technological innovation. Time, determining the precise location, the ability to quickly and remotely assess the condition of injured persons and coordinating cooperation in evacuation and medical transport are among the decisive factors in rescue missions. AI can support not only pilots and medical personnel on board aircraft or helicopters, but also subsequent teams and services involved in the transport system during air medical rescue. Optimization process through AI allows for effective shortening of response times, eliminating or reducing potential delays, mitigating errors and in consequence improving patient outcomes. Given the priority role of air medical teams, drones are an excellent complement to manned air medical aviation. In crisis situations or unexpected events and in difficult-to-access areas, drones can and should be the first step in providing assistance at the scene of an accident/disaster. Globally and in Europe, public safety and healthcare organizations are increasingly utilizing drones to accelerate lifesaving operations in situations where response time and first aid are crucial. Drones are used to transport medical kits, emergency and medical equipment and even deliver automatic defibrillators. Logistics in air medical search and rescue is the art of ensuring the right resources, in the right place, and at the right time. In the face of conflicts observed in Europe [1] and worldwide and the demand for rapid medical care for injured and wounded, the use of drones and AI support have taken on a new dimension and significance. Currently, it is not a need, but a necessity that determines human life and health. This article presents the use of drones and Artificial Intelligence as a support system for optimizing air medical rescue logistics. Factors directly impacting the success of rescue and reconnaissance missions using manned aviation are considered, as well as their limitations resulting from the complexity of air medical operations. The article highlights the benefits of incorporating innovative technologies into drones and artificial intelligence, as well as challenges related to, among other things, building a modern air rescue system, the resilience of data processing systems, and the need to train medical and rescue personnel. The article also addresses the ethics of engaging and relying on artificial intelligence, i.e., the issue of trust and oversight of AI, which in missions for human life and health should be treated as an advisor, not a commander. Leaving final decisions to human discretion remains a priority in rescue missions.

Keywords: *Air Medical Emergency Missions; Medical Logistics; Medical Drones; Artificial Intelligence (AI); Air Ambulance; Search And Rescue*

Streszczenie: Rozwój i wzrost poziomu implementacji zaawansowanych technologii, w tym sztucznej inteligencji (AI), wpływają i kreują efektywność operacji lotnictwa medycznego. Użycie AI w procesie wsparcia zapewnienia niezbędnej dyspozycji zespołów ratowniczych, optymalizacji tras lotu oraz selekcji zasobów, potwierdzają potrzebę zaangażowania innowacji technologicznych. Czas, ustalenia dokładnej lokalizacji, możliwość szybkiej zdalnej oceny stanu poszkodowanych oraz koordynacja współpracy w zakresie ewakuacji i transportu medycznego, należą do decydujących czynników w misjach ratowniczych. AI może wspierać nie tylko pilotów czy personel medyczny na pokładzie samolotu, śmigłowca, ale również kolejne zespoły i służby zaangażowane w system transportu w procesie lotniczego ratownictwa medycznego. Optymalizacja procesu dzięki AI pozwala skutecznie skrócić czas reakcji, eliminować lub ograniczać ewentualne opóźnienia, niwelować błędy, a w konsekwencji poprawiać wyniki leczenia pacjentów. Wobec priorytetowej roli lotniczych zespołów medycznych, drony stanowią wyśmienite uzupełnienie w systemie załogowego lotnictwa medycznego. W sytuacjach kryzysowych oraz na terenach trudnodostępnych, to drony mogą i powinny stanowić pierwszy etap niesienia pomocy na miejscu wypadku/katastrofy. Na świecie oraz w Europie organizacje zajmujące się bezpieczeństwem publicznym i opieką zdrowotną coraz częściej angażują drony, aby przyspieszyć działania ratujące życie w sytuacjach, w których decydującym czynnikiem jest czas reakcji i pierwsza pomoc poszkodowanym. Z wykorzystaniem dronów odbywa się transport: apteczek medycznych, niezbędnych materiałów opatrunkowych i zabezpieczających, wyposażenia ratunkowego i medycznego, czy dostarczanie automatycznych defibrylatorów. Logistyka w lotniczym ratownictwie medycznym to sztuka zapewnienia właściwych zasobów, we właściwym miejscu i we właściwym czasie. W obliczu obserwowanych w Europie [1] i na świecie konfliktów i potrzeb w zakresie szybkiego niesienia pomocy medycznej poszkodowanym i rannym, zaangażowanie dronów oraz wsparcia ze strony AI nabrały nowego wymiaru i znaczenia. Obecnie to nie potrzeba a konieczność, która warunkuje życie i zdrowie ludzkie. W artykule przedstawiono zagadnienia zastosowania dronów oraz sztucznej inteligencji jako zespołu wsparcia dla optymalizacji logistyki lotniczego ratownictwa medycznego. Uwzględniono czynniki mające bezpośredni wpływ na powodzenie misji ratunkowych i rozpoznawczych z wykorzystaniem lotnictwa załogowego a także jego ograniczenia wynikające ze stopnia skomplikowania medycznych operacji lotniczych. Wskazano zalety zaangażowania innowacyjnych technologii w postawi dronów i sztucznej inteligencji, a także wyzwania związane m.in. ze zbudowaniem nowoczesnego systemu ratownictwa lotniczego, odpornością systemu przetwarzania danych oraz koniecznością szkolenia kadr służb medycznych i ratowniczych. W artykule poruszono także aspekt etyki wobec zaangażowania i polegania na sztucznej inteligencji, czyli kwestii zaufania i nadzoru nad AI, która w misjach o życie i zdrowie ludzkie powinna być traktowana w roli doradcy, a nie dowódcy. Pozostawienie ostateczności decyzji w gestii człowieka pozostaje priorytetem w misjach ratowniczych.

Słowa kluczowe: *Logistyka Medyczna; Drony Medyczne; Sztuczna Inteligencja (AI); Lotnicze Ratownictwo Medyczne; SAR*



1. Involvement of an Air Ambulance helicopter in a rescue mission during a road accident (landing on the street)



2. Involvement of an Air Ambulance helicopter in a rescue mission following a road accident (landing in an uninhabited area)

In crisis or emergency situations requiring immediate action in life-threatening situations, where the condition of injured and wounded deteriorates, and where air ambulances are involved, ground (vehicular) transport using ambulances has many limitations on the effectiveness of rescue missions. The unquestionable potential of rescue aircraft and helicopters used to transport organs for transplantation, seriously injured patients requiring urgent care, or patients from remote or difficult-to-access areas (injured in road or mountain accidents) is confirmed by the number of missions in which they are used. Effective air medical transport requires seamless coordination and integration with ground-based emergency medical services, dispatch centers, hospitals, and often also emergency services. Communication systems, including radiotelephones, satellite phones, and electronic medical records, enable efficient collaboration and the transmission of key patient information. Air medical transport has proven its effectiveness in saving lives, providing rapid access to necessary medical care, improving the prognosis of patients with severe injuries, acute illnesses or in emergencies requiring immediate intervention and transport of the injured, sick and sick.

The specific nature of rescue and medical missions, the appropriate adaptation and deployment of rescuers and equipment, and the need to assess the need for the necessary medical resources and resources in air rescue missions mean that traditional air transport—helicopters and airplanes—faces limitations. Despite the irreplaceable role of air medical teams (physicians providing assistance), drones are an excellent complement to manned medical aviation. These technologies do not replace, but perfectly complement, the process, offering almost immediate response in emergency situations or in difficult-to-access areas, constituting the first step in reconnaissance, situation assessment, and provision of assistance at the scene of an accident/disaster. The limitations of traditional manned aviation (Fig. **1**, **2**) in reaching crowded, difficult-to-access, or risky areas are addressed by the decisive factor of response time in saving lives and health. Rescue logistics using drones and AI support address these challenges, reducing or eliminating these limitations. The results of air rescue missions clearly confirm that the speed and efficiency of air transport significantly contribute to reducing mortality. In an era of technological advancements that support the efficient utilization of the air component's potential, air medical aviation should also leverage and modernize its rescue mission system.

The use of drones and artificial intelligence could revolutionize air medical rescue. A rescue system in which unmanned aerial vehicles (UAVs) supported by artificial intelligence (AI) create entirely new efficiencies in the lifesaving chain, thus ushering in a new era of air medical rescue.

The development of artificial intelligence (AI) is experiencing undisputed growth, which – based on current results – will impact many aspects of emergency medical services in the future.

The key logistics elements of air rescue missions, such as:

- shortening response times,
- quickly assessing the extent (scope) of casualties and losses,
- increasing rescuer safety,
- optimizing mission costs,
- efficient aircraft fleet management,
- making better decisions,
- limiting the impact of the human factor on the success of a medical rescue mission,

are no challenge for the drone (unmanned aerial vehicle, pilot-operator) + AI (artificial intelligence) team. UAVs are very good at navigating difficult or inaccessible terrain for helicopters (mountainous, forested, off-road).

A support system in the form of a drone equipped with transmitters and AI capable of quickly analyzing huge amounts of data, generating suggestions, and simulating the effects of decisions based on trained patterns have enormous potential that can significantly impact the efficiency of air medical transport.

Helicopter flights require properly trained crews and equipment maintenance. However, despite the best preparation and maintenance, they are dependent on weather conditions. Drones are flying machines that can operate autonomously or be remotely controlled by operators on the ground. Flights can occur within or beyond the pilot's line of sight. The main types of drones available on the market include fixed-wing systems (comparable to a miniature airplane), multi-rotor systems, and hybrid systems with various specifications (e.g.,



***3**. Farad G1 Drone [2]*



***4**. On February 24, 2022, the first historic 60-kilometer flight of the Farada G1 drone took place in Poland under the supervision of inspectors from the Civil Aviation Authority. After approximately 30 minutes of flight, the drone landed at a hospital landing pad in Sochaczew.[3]*

payload capacity, drop system, range).

Conventional drones are powered by batteries to power their motors. Charging time and frequency depend on the capacity (size) of the batteries. The use of base stations enables autonomous, wireless charging without the need for active user (pilot/operator) intervention.

Besides military applications, drones are also gaining popularity in commercial applications, such as cargo delivery, terrain mapping, target monitoring, and facility surveillance. From a logistical perspective and for the needs of rescue and medical missions, drones offer the distinct advantage of being able to reach areas inaccessible to land transport, at lower costs and with significantly reduced risk compared to traditional means of transport (e.g., helicopters).

Humanitarian organizations, hospitals, and air rescue services, recognizing these advantages, confirm that drones can contribute to more effective rescue operations throughout the entire aid process, including: situation assessment, first aid equipment delivery, medical transport, and preparing medical air crews for on-site response.[4] Drones are also used in medicine outside Poland, for example, in the city of Lugano, Switzerland. Drones equipped with special containers are used in hard-to-reach areas to transport blood samples collected for analysis. This type of solution is especially useful for helping people living far from urban areas, where access to various services, including medical ones, is difficult.

Special sensors ensure ongoing monitoring sample blood temperature by thermometers installed on the drone and those in the operator's devices. If sample parameters are disrupted or exceed the required parameters, they are disposed of after delivery. These examples confirm that unmanned systems are no longer simply "flying cameras" capable of taking photos. Their scope of use and functionality in medical missions includes not only the transport of blood and plasma, serum, and blood products, but also the ability to transport AEDs, conduct searches using thermal and night vision, assess the scale of damage after disasters, and provide preliminary assessments of the injured and casualties. This is particularly useful in mountain accidents and natural disasters in areas where land transport is lengthy, difficult, or even impossible. Responding to emergencies in mountainous or forested areas is quite challenging, as air ambulance and mountain rescue services often struggle with logistical challenges and adverse weather conditions. In these types of incidents, a drone equipped with a portable AED can fly from the mountain air ambulance base station to the injured person's location, and a bystander can effectively begin treatment by following simple AED instructions.

Equipped with high-intensity lighting and cameras, drones can effectively provide rescue teams with real-time aerial surveillance and monitoring of the situation before an ambulance or helicopter arrives and rescuers personally begin operations. Additionally, in search and rescue missions, drones equipped with thermal imaging and searchlights can aid in the effective locating of missing persons in remote or difficult-to-access areas. Their video and audio recording capabilities



***5**. Transporting a medical kit using a drone*



***6**. Transporting an AED using a drone*

also enable paramedics to establish communication with missing persons and monitor their condition during helicopter preparation and flight or ambulance arrival. The potential of using AI-enabled drones is not limited to individual missions, but rather to complex logistical operations requiring precise planning and coordination. Optimal logistics are the invisible backbone of every air rescue mission. Knowledge and skills in preparing and piloting drones effectively reduce takeoff times to a few minutes (significantly shorter than with a helicopter). To compare the performance of a drone + pilot system and AI support for defibrillator delivery missions with a conventional ambulance helicopter, it is necessary to identify at least the key elements of the helicopter rescue system (Mountain Volunteer Search and Rescue or Air Rescue).

Interviews with experts from both the Mountain Volunteer Search and Rescue and Air Rescue indicate the high complexity of the mission, and its feasibility depends on weather conditions and terrain accessibility. In addition to specialized medical equipment and appropriate skills, the predispositions of the helicopter crew and medics/paramedics, ongoing helicopter maintenance and mission logistics are essential. High requirements for flight time and piloting experience for aircrew members ensure effective selection of candidates for these types of units. Recruitment conditions impact air rescue personnel resources. Given the need to maintain staff resources and provide support for employees and pilots, the use of drones and AI is advisable. Including air rescue in the system becomes a key element in optimally deploying medical resources, optimizing rescue mission costs, and reducing the cost of repairs and operational inspections of helicopters. Another undisputed advantage is the ability to verify the current situational picture from the air, providing an invaluable resource for emergency commanders. An air rescue mission, beginning with the deployment of an unmanned aerial vehicle (UAV), which enables effective verification and assessment of the situation, needs, losses, and injuries, allows for precise deployment of human resources.

The use of AI enables decision-making based on advanced analysis of large amounts of information: terrain, meteorological conditions, glocalization and terrain, navigation support, and the designation of optimal helicopter flight paths. AI-powered reconnaissance drones can also control a swarm of drones that automatically scan a vast search area, while computer vision algorithms analyze the transmitted image to search for survivors (e.g., in seawater, lakes, mountainous or forested areas). Autonomous delivery of supplies in the form of life-saving medications, thermal emergency blankets, transmitters, and medical devices monitoring vital signs significantly impacts the behavior and condition of injured people. In a life-saving emergency requiring immediate assistance, an AI-assisted drone can deliver blood, plasma, or medical equipment directly to the helicopter landing site, replenishing its supplies. At the same time, AI can provide effective decision-making support for medical crews during flight. With access to patient medical data from sensors (ECG, oxygen saturation, blood pressure) and medical history data entered by medics, AI can, among other things:

- assist paramedics by supporting the implementation of medical procedures based on analyzed symptoms,
- predict the dynamics of the patient's condition based on AI algorithms and support the helicopter crew in deciding to change the flight destination to the nearest hospital in the event of progressive or rapid deterioration of the patient's condition.

In addition to the benefits of using drones and AI to support aircrews and medics, the intelligent Drone + AI system can optimize fleet management and predictive maintenance of helicopters, ambulances, and vehicles used in rescue and medical missions. AI transforms helicopter fleet maintenance from an "emergency" model to a "preventative" one. Predictive maintenance of helicopters and mission equipment, based on algorithms analyzing data from helicopter sensors (vibration, temperature, pressure, oil level, and others), effectively predicts which parts are close to failure or require repair or replacement due to factors such as deformation or service life. AI can also independently order necessary parts and schedule their delivery to the base before a failure occurs. Automating spare parts logistics, along with predictive maintenance and repair management for medical helicopters, allows for optimal scheduling of repairs and maintenance over time. This approach dramatically increases operational availability during anticipated peak periods.

Air medical rescue logistics using drones and AI is no longer a niche or under-recognized topic. In the modern world of technological engagement, it provides the foundation for building a modern, intelligent, and above all, effective life-saving system for Mountain Volunteer Rescue (GOPR) or Air Rescue (LPR) missions. At the same time, the Drone + AI support system, or "intelligent medical drone," can be successfully implemented in the Police, Fire Department, and Border Guard.

The main challenge is no longer the technology, which is developing at a dizzying pace, but the training system, the human factor, and the administrative and regulatory framework (law and procedures). The effective use of drones and AI in support of medical and rescue services requires the introduction of specialized training specifically related to the use of drones and AI into the training system. Theoretical and practical training with equipment must become a standard element of the training process for pilots, helicopter medics, dispatchers, and those responding to medical transport calls. In the case of assistance provided by other services,

training should also be provided for mountain rescuers, firefighters, police officers, border guard personnel, and emergency and crisis management services. For drones to become a permanent fixture in the arsenal of services participating in life-saving and aid missions, investment in human resources and the development of practical skills is essential. The scope and level of cooperation between humans, drones, and Artificial Intelligence (AI) must be verified and expanded. Investment in training is an investment in the safety of paramedics, rescue and medical helicopter pilots, and the safety of emergency and law enforcement personnel on the ground: police officers, firefighters, and law enforcement officers. In this case, this investment not only effectively eliminates risks for the services but also optimizes the costs of rescue missions and increases the operational efficiency of helicopters, vehicles, and rescue equipment. At the same time, the introduction of drones into service is not without challenges. The most important include:

- limited payload capacity – the weight of drones, i.e., the supplies they can carry;
- legal regulations – the constantly evolving legal and regulatory environment regarding the use of drones in urban areas, near critical infrastructure facilities, in military training areas, or restricted areas;
- the resilience of the communication system, data security, which must often operate in extreme conditions, without access to the cloud or with the possibility of interference, and limited response capabilities (flights within the line of sight of the pilot/drone operator and flights beyond line of sight);
- public perception and acceptance, as well as concerns about privacy and security issues, image protection of individuals and property, and privacy violations, which must be addressed for broader implementation (easing restrictions) regarding data collection during flights for medical and rescue missions.

The ethical issue of trust and reliance on AI prompts and suggestions remains extremely important. The final decision should always remain in the hands of a human – a medic, paramedic, or pilot – and AI can only act as an advisor, not as a mission commander. Another factor that determines the effectiveness of AI support is the quality of the data on which the algorithm was trained.[5] The result provided by AI will only be as good as the data it was trained on – relevant, reliable, and accurate. Insufficient or biased data can lead to erroneous recommendations, thus contributing to errors and mistakes in the diagnosis or treatment of the injured, sick, or wounded.

Summary

Drones and artificial intelligence in air rescue logistics are a practical tool that sets a new standard in providing aid to the injured. A shift from reactive to proactive and precise rescue. Thanks to AI, helicopters not only fly faster but also smarter. Every minute saved, every failure predicted, and every optimal decision is a building block contributing to the most precious asset – human life. Investing in the development and implementation of these systems is an investment in a future where aerial rescue is not only faster but also smarter than ever before. ◄

Source materials

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