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Drones in Medicine: A Bibliometric Study of the Last 15 Years

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Abstract: As global healthcare systems evolve, particularly in remote or mountainous areas, traditional transportation methods often face challenges due to terrain, weather, and road conditions, making it difficult to deliver critical medical supplies on time and potentially affecting patient survival. The emergence of medical drones presents a solution, playing a vital role in emergency rescue operations, disaster response, and public health crises. Though still a niche field, medical drones have vast potential for future growth. This paper explores the trends of drones in medicine by analyzing literature from the SCI-EXPANDED database of the Web of Science, focusing on publications between January 2010 and June 2024. The analysis included factors such as publication year, country/region, author, citation frequency, and journal distribution. A total of 76 articles were screened, with the highest number of publications from developed countries like the United States and the United Kingdom, showing an increasing trend over the years. VOSviewer visual clustering analysis suggests that medical drones will be a significant research focus in the future. The results indicate that advancements in technology, along with the impact of epidemics, will likely drive continued growth in medical drone research and applications.

1. Introduction

A drone, also known as an unmanned aerial vehicle (UAV), is an aerial vehicle that is operated using radio-controlled equipment and self-contained programmed control devices[1]. The widespread use of UAVs is a remarkable sign of technological advancement.In recent years, drones have been used in various fields including transportation, infrastructure, disaster management, air quality monitoring, agriculture, media, and healthcare. Drones are revolutionizing the transportation sector by increasing shipment speed while reducing associated costs[2, 3]. In e-commerce, a vast majority of drones are used for courier deliveries, and studies have reported a growing consensus among e-commerce businesses, consumers, and logistics companies in favor of using drones for last-mile deliveries. [4]. In the mining industry, drones are often used to perform activities such as inspections,

automated surveys, measurements, and mapping[5]. In urban management, drones are used as a tool to support asset management, conduct flow, and water quality monitoring, and collect high-spatial-resolution data to help build the smart, connected cities of the future[6]. In agriculture, drones are commonly used to spray medicines and fertilizers on crops, assess the growth status of crops, and detect damage caused by pests via built-in sensors carried by drones[7, 8]. In the environmental field, drones monitor the composition of various gases in the air and identify certain odors using special sensors they carry[9]. In natural disaster response, drones are used for search and rescue options and logistical support for injured people and to assess the postdisaster situation[10, 11].

However, in the medical field, especially in emergencies and mass casualty treatment, drones have a substantial advantage because of their flexibility in overcoming the challenges posed by complex terrains, remote areas, and urban transportation. They are commonly used for prehospital emergency care and the transporting of medications such as serums, vaccines, and automated external defibrillators (AEDs)[11]. This will considerably reduce the transportation time and increase the patient's resuscitation time[12, 13]. Furthermore, drones can also be used to effectively control infectious agents. For example, during the coronavirus disease 2019(COVID-19) pandemic, drones were widely used for various critical tasks, including the aerial monitoring of containment and curfew areas, fast and contactless delivery of essential supplies, and the evaluation of post-massive epidemic contagious diseases[14, 15].

Bibliometrics is a method used for both quantitative and qualitative analysis of literature, it allows a scientific assessment of a research topic by examining correlations among indicators such as citations, authors, countries, subject headings, and publishers of the related literature. Based on our review of the existing literature, there is no comprehensive summary of the application of UAVs in the medical field. Therefore, we used VOSviewer software to visualize research hotspots in the field to explore the applications and development trends of UAV technology in the medical sector and provide future research direction for UAV technology in medical applications.

2. Methods and Materials

2.1. Data collection

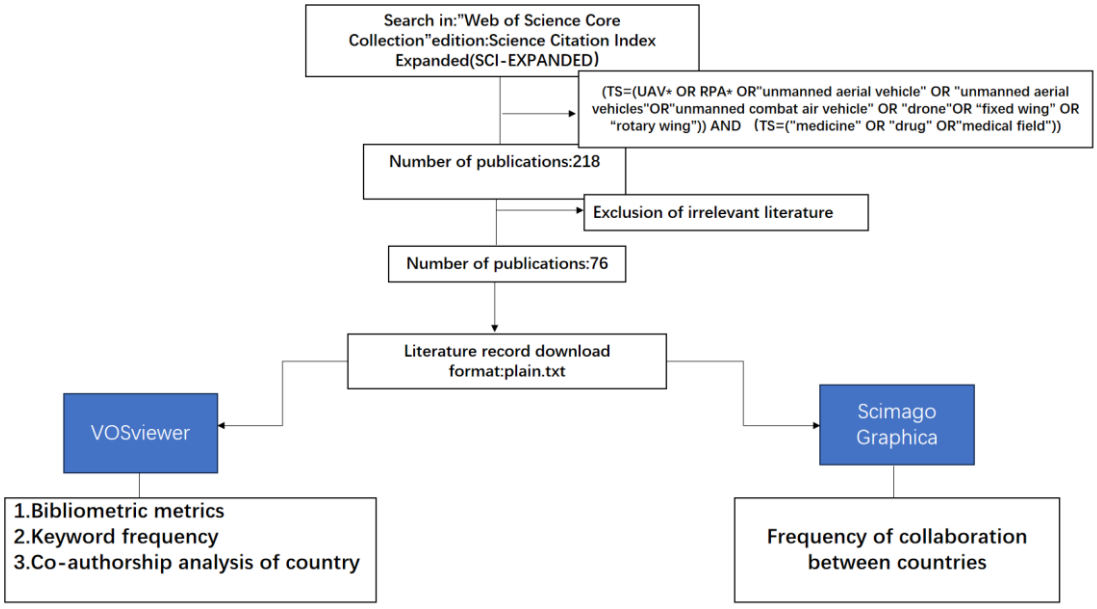


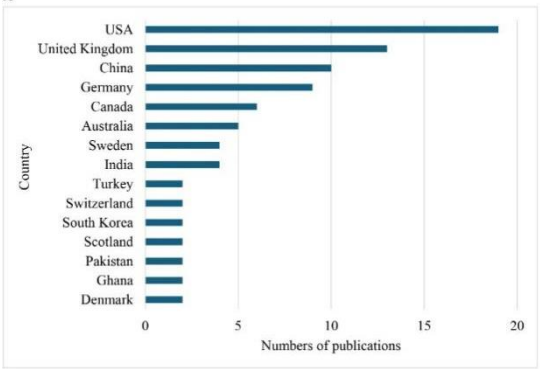
Figure 1. The flow chart of the study.

Bibliometric studies typically utilize three major databases, namely, Web of Science, Scopus, and PubMed. Because the Web of Science contains the most comprehensive collection of journals spanning numerous disciplines, it provides scholars with high-quality and reliable academic information [16]. Therefore, we selected the Web of Science Core Collection, using the SCI-EXPANDED index for our literature searches. All authors agreed on the search strategy after consultations with senior literature search experts. The following search criteria were used: (TS = (UAV* OR RPA* OR "unmanned aerial vehicle" OR "unmanned aerial vehicles" OR "unmanned combat air vehicle" OR "drone" OR "fixed wing" OR "rotary wing")) AND (TS = ("medicine" OR "medical field")). The time frame was set from January 2010 to June 2024, which yielded a total of 218 articles. After manually screening the literature not relevant to the field, the final selection included 76 articles. Figure 1 illustrates the flow of this study.

2.2. Bibliometric analysis of countries, organizations, and publication trends

Using a visual analysis of countries, institutions, and publications, we studied 381 authors, 237 institutions, and 40 countries, covering a total of 76 articles. The results show that the volume of publications is mainly concentrated in Western countries. Figure 2 shows the top 15 countries and institutions in terms of the number of publications, where the United States (19), United Kingdom (13), China (10), Germany (9), and Canada (6) are most notable according to the number of publications. As shown in Figure 2A, the United States has a significant lead in the number of publications. By contrast, Figure 2B shows that among all countries, the United Kingdom has the highest number of institutions (four institutions), with King's College London having the highest number of publications. As shown in Figure 3, the number of publications on the applications of drones in the medical field has been increasing every year since 2017, with a particularly significant growth rate between 2020 and 2021. This trend bodes well because it indicates more relevant research in the field will be published in the future.

A



B

Country	Research organizations	Publications
USA	**Beth Israel Deaconess Medical Center**	**3**
Australia	**Flinders Medical Center**	**3**
	Royal Adelaide Hospital	**3**
United Kingdom	**kings'College London**	**5**
	University of British Columbia	**3**
	University of Southampton	**3**
	Skyports	**2**
Poland	**Medical University of Warsaw**	**2**
China	**Shenzhen University General Hospital**	**2**
	Tianjin University	**2**
Poland	**Lazarski University in Warsaw**	**2**
Canada	**University of Prince Edward Island**	**2**
	University of Toronto	**2**
Belgium	**Vrije Universiteit Brussel**	**2**

Figure 2. Numbers of publications by research organizations and countries. (A) Top 15 countries in terms of number of publications. (B)Top 15 organizations in terms of number of publications.

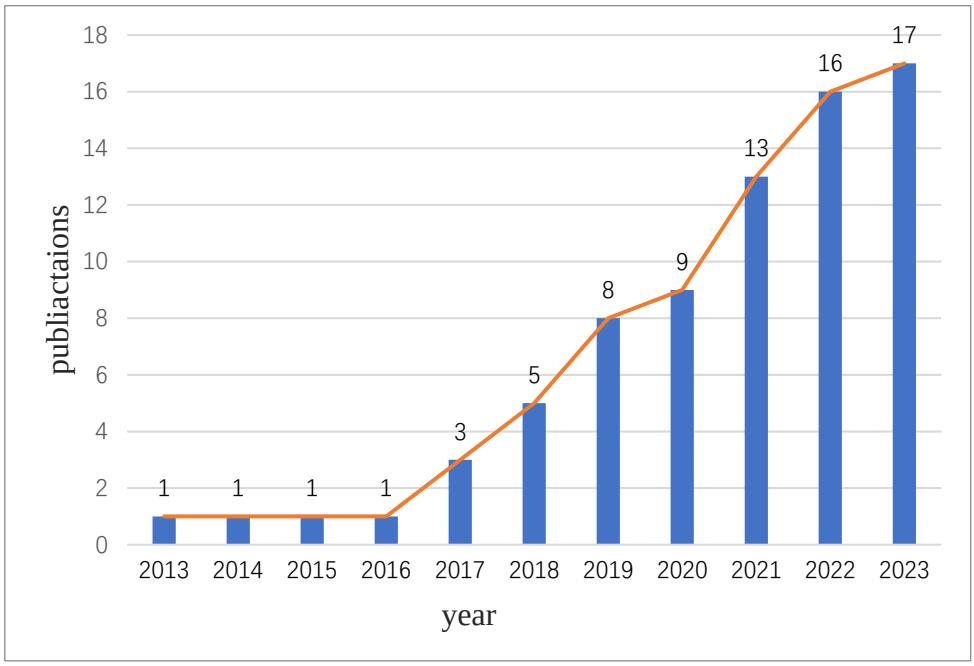


Figure 3. Annual publication volume and growth trend.

2.3. Bibliometric analysis of national, organizational and authors collaborations

The data in Figure 2 indicate collaborative relationships between institutions are significantly influenced by geography and collaboration mainly happens on a country-by-country basis. Despite the presence of transnational collaboration to some extent, regional collaboration still dominates the overall picture. Among all institutions, King's College London has the most frequent collaboration with other institutions. With collaborations with several leading research centers and hospitals, King's College London has made outstanding contributions to the healthcare sector. Figure 4A illustrates the collaborative relationships between countries, particularly between countries with the highest number of publications. In Figure 4B, different colors represent different clusters, with a total of three main clusters, showing that cooperative relationships among countries are mainly concentrated in Western countries, which further highlights the importance of regional cooperation in international academic exchanges. This phenomenon reflects the close ties between these countries in terms of scientific research resources, technological innovation, and knowledge sharing and also suggests that we may need to strengthen cooperation and exchanges with other regions, especially non-Western countries, in the future, to promote diversity of global scientific research and innovative development.And the top three authors in terms of publication rank can be seen from Figure 5.

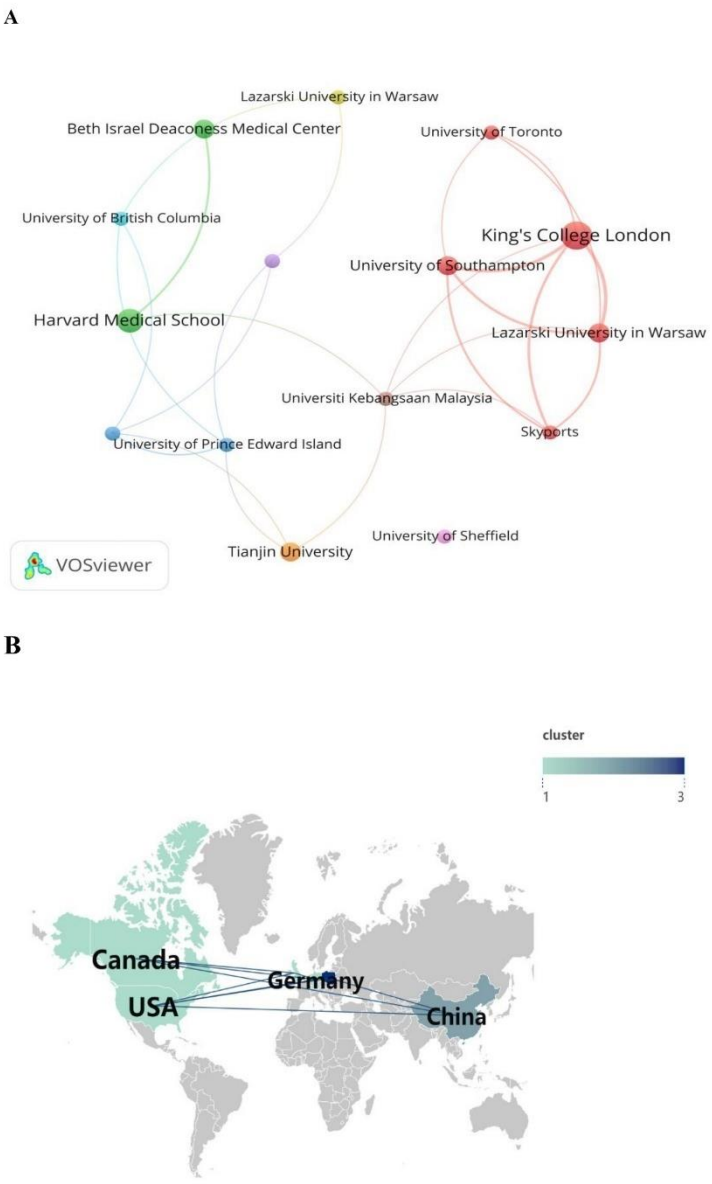


Figure 4. Map of cooperation between different national institutions.

A

Rank	Author	Documents	Citations	Average Citation/Publication
1	Paul G. Royall	5	94	18.5
2	Patrick Courtney	3	75	25
3	Gregory R.Ciottone	3	25	8.3
4	Derrick Tin	3	25	8.3

B

rank	source	Publication	Citations	Average Citation/Publication
1	Prehospital Disaster Medicine	6	54	9
2	Sensors	3	107	35.67
3	Emergency Medincine Australlasia	3	6	2

C

Article	Citations	Average Citation/Publication
Drone transportation of blood products	14	26
The potential use of unmanned aircraft systems (drones) in mountain search and rescue operations	11	21
Drones may be used to save lives in out of hospital cardiac arrest due to drowning	11	22
Time to Delivery of an AutomatedExternal Defibrillator Using a Drone for Simulated Out-of-Hospital Cardiac Arrests vs Emergency Medical Services	10	21
The economic and operational value of using drones to transport vaccines	10	20

Figure 5.Top cited journals, authors, literature. (A) Top 4 cited authors (B) Top 3 cited journals (C) Top 5 cited literature.

2.4. Bibliometric analysis of keywords

By analyzing the co-occurrence of keywords, we quickly identified the research hotspots in the field. We filtered keywords with a number of occurrences ⩾ 2, performed cluster analysis using VOSviewer, and finally obtained 7 clusters containing a total of 63 keywords. Among them, red clusters contain the highest number of keywords, with 14 keywords, followed by green clusters, with 13 keywords.Figure 6 shows that these keywords were most frequently used in publications between 2019 and 2023, with a concentration around 2020, where the green cluster has the highest frequency. This phenomenon is attributed to the COVID-19 pandemic that occurred in recent years, which prompted the widespread application of medical drones. The top five keywords with the highest frequency of keyword occurrences are drone (35), emergency (7), drone delivery (7), telemedicine (6), and COVID-19 (6).

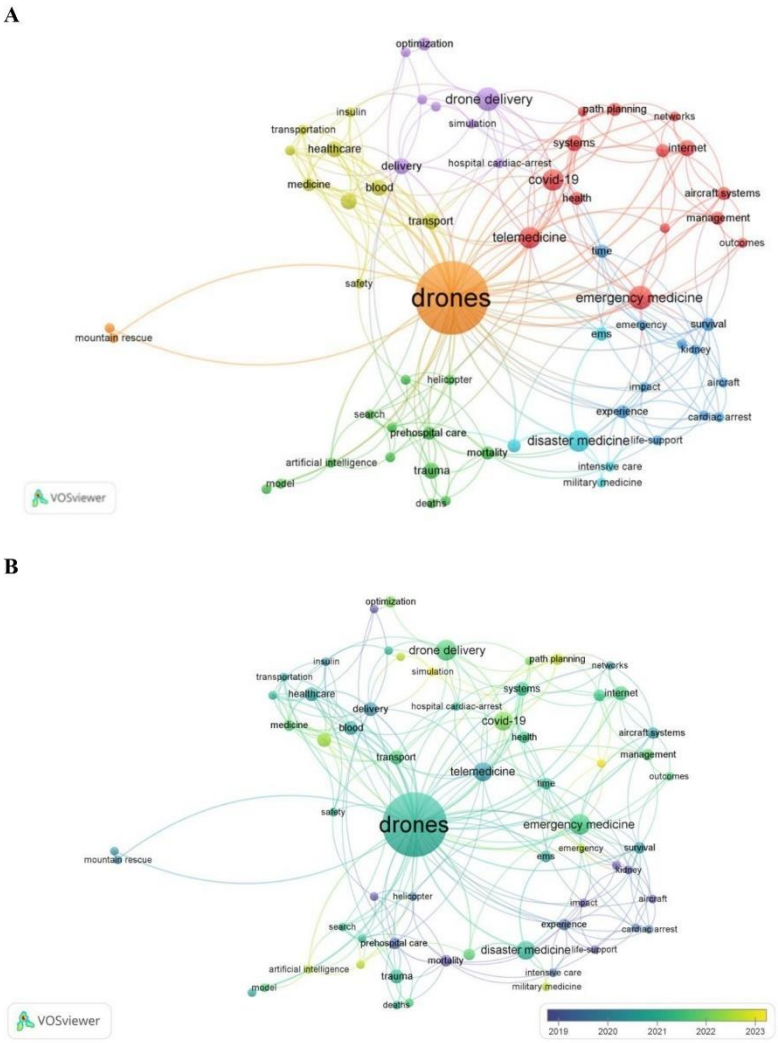


Figure 6. Research hotspots and relevance. (A)Network visualization of keywords. (B)Overlay visualization of keywords.

3. Discussions

Bibliometrics has provided insights into the integration of drones in medicine, highlighting their applications in telemedicine, prehospital emergencies, and medical supply deliveries, especially during the COVID-19 pandemic. Drones have proven to be highly effective in transporting medical supplies, particularly in areas with poor road infrastructure or during emergencies. For example, drones can quickly deliver blood, vaccines, antivenom, and AEDs to remote or congested areas, significantly reducing transport times and saving lives. While drone transportation of blood products may be more costly than road transport, it offers the advantage of faster delivery. Drones also play a key role in infection prevention, particularly in controlling vector-borne diseases. By spraying insecticides or tracking mosquito breeding sites in tropical areas, drones help prevent the spread of diseases like dengue fever. During the COVID-19 pandemic, drones were used to transport nucleic

acid samples and assist in social distancing enforcement in public spaces. Additionally, drones utilizing digital twin technology were employed to deliver medications and samples to isolated patients, helping to control the spread of infectious agents and ensure timely treatment.ibliometrics allowed us to visualize cutting-edge research on the integration of drones and medicine. The above reported results show that drones are commonly used in the medical field for assisting in telemedicine, prehospital emergencies, and medical supply deliveries. Especially during the COVID-19 pandemic, drones played an important role in drug delivery and epidemiological research. The following sections comprehensively discuss the use of drones in medicine.

4. Summary and Outlook

Herein, we used VOSviewer to visualize and describe publications, countries, institutions, influential authors, and highly cited papers in the field of medical drones over the past 15 years to understand the research hotspots and future trends in the field. The analyses of countries and authors show that the literature on UAV medicine is mainly published in Western countries, led by the United States, and interinstitutional and intercountry collaborations occur mainly in neighboring regions and do not establish a very broad linkage. An analysis of keywords reveals that the most common uses of drones in the medical field are for first aid and transportation of medical equipment. We found that drones have been widely developed for agriculture, forestry, the mining industry, and other fields. Although the research on drones in the medical field has increased in recent years, it is relatively backward in terms of development compared with other fields.

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