Disaster Medicine and Public Health Preparedness

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Research Letters

Cite this article: Xie T, Wu J, Chen W-F, Wei Y-Y, Chen K. Pandemic and emergency manufacturing innovation: A scientometric analysis using CiteSpace. *Disaster Med Public Health Prep*. **17**(e502), 1–5. doi: https://doi.org/10.1017/dmp.2023.162.

Keywords:
CiteSpace; COVID-19; emergency manufacturing; pandemic; scientometric analysis

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Pandemic and Emergency Manufacturing Innovation: A Scientometric Analysis Using CiteSpace

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Abstract

Objective: Major epidemics have had a huge impact on the manufacturing industry. This study aimed to explore knowledge innovation in the field of emergency manufacturing during pandemics with a systematic quantitative analysis.

Methods: Based on the Web of Science (WOS) Core Collection, the bibliometric method and the CiteSpace tool were used.

Results: A total of 286 literature were obtained from the WOS database. During coronavirus disease (COVID-19), there was a surge in the number of publications. A new field of research on pandemic-triggered emergency manufacturing is gradually forming with accumulated research output. The analysis of the document co-citation showed how the research on pandemic situations and viruses brought emergency manufacturing into the research scope of scholars, and what attempts were made by the original scholars. Pandemic-triggered research hotspots and research trends in the post-pandemic era mainly boiled down to 3 aspects: technological innovation, material innovation, and management innovation in the field of emergency manufacturing.

Conclusions: COVID-19 strengthened academic exchange and cooperation and promotes knowledge output in this field. This study provides an in-depth perspective for emergency manufacturing research and helps researchers realize the panorama of this field and establish future research directions.

In recent years, pandemics such as severe acute respiratory syndrome (SARS), swine flu (H1N1), and coronavirus disease (COVID-19) have had a serious influence on global economic and social development. Outbreaks of major epidemics triggered the extraordinary and sudden surge in demand for the manufacture of emergency supplies.[1] The surge in demand for emergency supplies and equipment has brought new challenges to existing manufacturing systems and producing modes, leading to technological and management innovations in the field of emergency manufacturing.

Scholars had conducted studies on issues related to "emergency manufacturing" in the context of pandemics from different perspectives, including the development of new manufacturing technology, the optimization of manufacturing processes,[2] and so on, but there had not yet been systematic study on the impact of major epidemics on emergency manufacturing industry from a quantitative perspective. Based on this, the present study reviewed and summarized the current research results and developments in the field of emergency manufacturing.

Methods

Data Sources

A literature search was conducted based on the WOS Core Collection database with the keyword query formulation "(TI=(manufactur*)) AND (TI=(pandemic) OR TI=(epidemic) OR TI=(covid-19) OR TI=(coronavirus) OR TI=(h1n1) OR TI=(h2n2) OR TI=(h3n2) OR TI=(SARS) OR TI=(sars-cov*) OR TI=(personal protective equipment) OR TI=(PPE) OR TI=(N95) OR TI=(protective mask) OR TI=(respirator) OR TI=(vaccine) OR TI =(protective clothing) OR TI=(ventilator) OR TI=(surgical masks) OR TI=(testing swab) OR TI=(oxygen valves) OR TI=(face shield))" and an unlimited time span. The search results showed 592 articles. The literature was filtered to eliminate "noise," resulting in 286 articles.

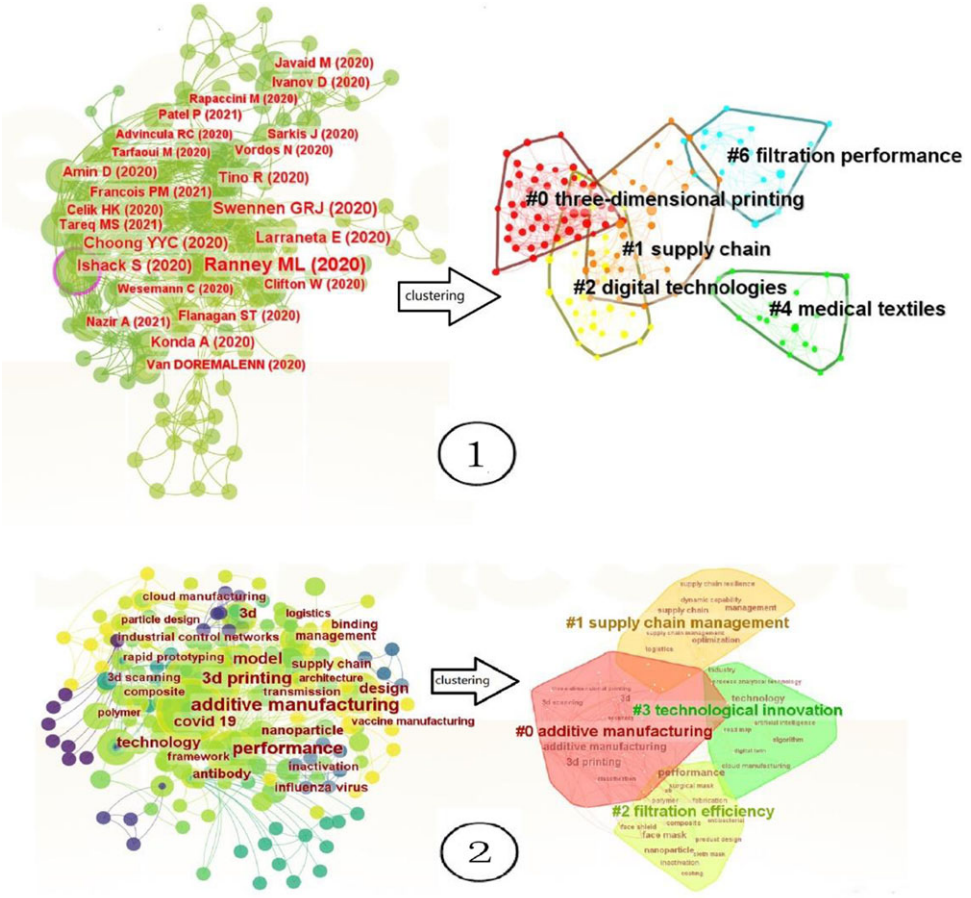

Figure 1. The document co-citation network and keywords co-occurrence network and their clusters map.

Research Methods

In this paper, first, the number of publications in the field of emergency manufacturing research from 2006 to 2023 was counted using Excel, and, second, the WOS data analysis panel of CiteSpace 6.2.R2[3] was used to visualize and analyze the knowledge mapping of document co-citation networks, keyword clustering, and keywords burst in the research literature in the field of emergency manufacturing.

Results

The number of publications for the period 2020 to April 2023 totaled 236, accounting for 82% of the total research sample. It showed that there had been an explosion of scientific research results during the last 3 years of the COVID-19 pandemic. The global COVID-19 had greatly triggered knowledge innovation in the novel field of emergency manufacturing.

From the analysis of the document co-citation network and its clusters (Figure 1-①), the surge in demand for emergency supplies and supply chain disruptions caused by the pandemic[1] laid the foundation for current emergency manufacturing innovation. Disaster information and virus characteristics[4] provided the research direction for this field (Figure 2-①), which in turn gave rise to subsequent research hotspots in the era of pandemics such as 3-dimensional printing technology, supply chain management, and medical textiles (see Figure 2-②).

The keywords co-occurrence network and its clusters (see Figure 1-②) showed that the field research hotspots focused on pandemic-triggered emergency manufacturing technology innovations, pandemic-triggered emergency manufacturing material innovations, and pandemic-triggered emergency manufacturing management innovations. Emerging technologies such as additive manufacturing technology, the digital twin, and the Internet of things are widely used in the emergency manufacturing process during major epidemics. The research covers various aspects such as some specific aspects of printing emergency supplies, using additive manufacturing technologies (including printed materials, model design files, the expansion of the types of emergency materials printed, and quality testing of the finished printed products); crisis simulation using computer simulation technology to mimic scenarios after an epidemic, achieving better control over resources in the manufacturing process; remote collaboration using cloud computing to maintain efficiency and productivity even when working remotely under an epidemic; and using blockchain technology for source identification and anti-counterfeiting of raw materials for emergency supplies.[5] Emergency manufacturing material innovations include the application of novel materials such as silicone rubber, stainless steel wheeled structures, and protein receptors in the manufacturing process of respirators[6] and vaccines. In the aspect of emergency manufacturing management innovations, supply chain responsiveness, supply chain resilience, and supply chain transparency have become research hotspots, and scholars have used technologies

https://doi.org/10.1017/dmp.2023.162 Published online by Cambridge University Press

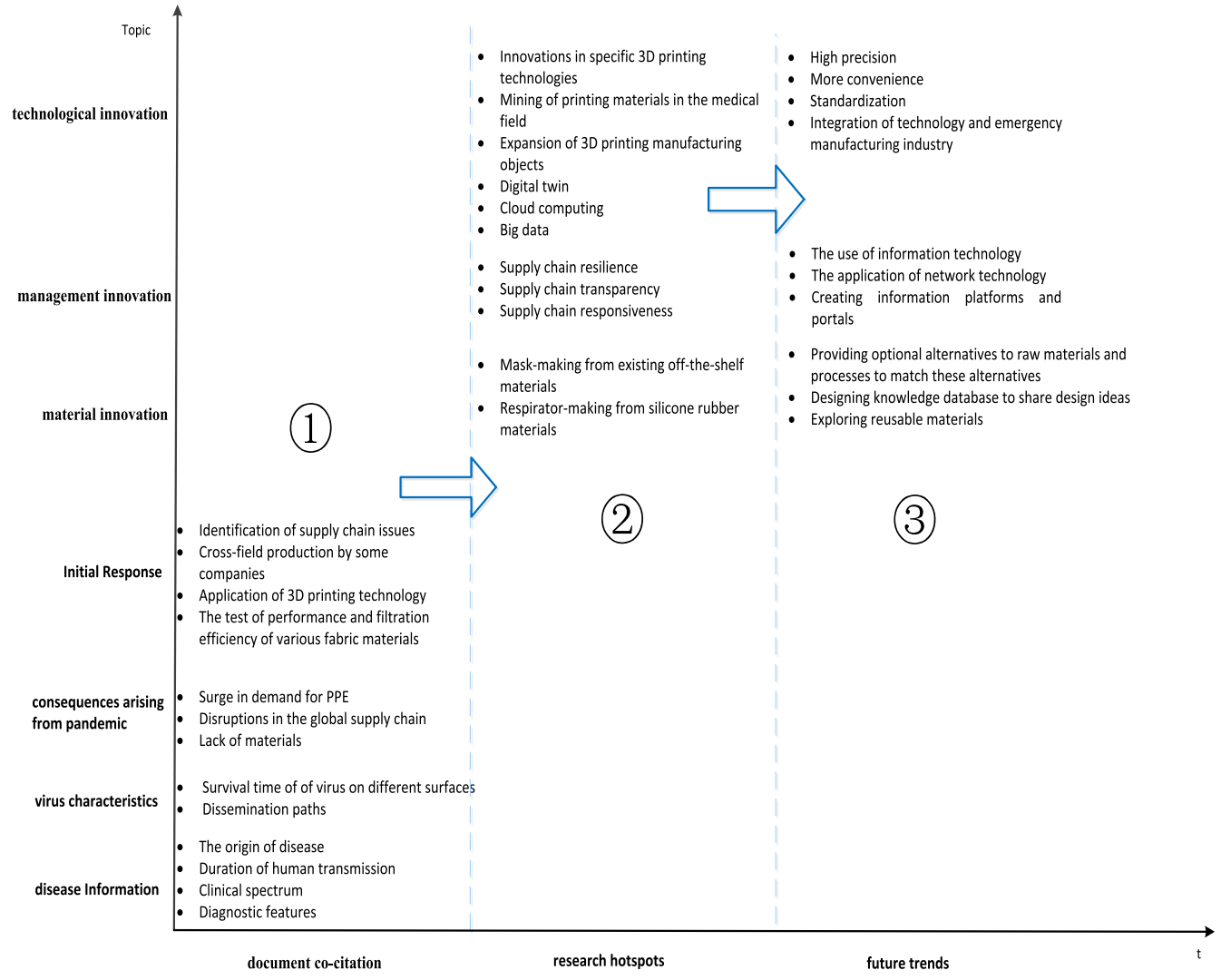

Figure 2. The evolution process of the topics.

such as block chain to provide traceability solution of emergency supply chains[7] (see Figure 2-②).

The high-burst keywords indicated that research trends in the post-pandemic era mainly focus on the application innovation of additive manufacturing and new information and communication technology (ICT), innovation of emergency manufacturing materials, and construction of an emergency supply chain system (see Table 1 and Figure 2-③). To meet the technological innovation of emergency manufacturing, additive manufacturing technology in the future will develop in the direction of higher precision, more convenience, safety, standardization, and networking.[8] New ICT will further need to be deeply integrated with the emergency manufacturing industry so as to strengthen the stress capacity of manufacturing application scenario transformation, and realize the supply chain collaborative arrangement from offline to online.[9] In terms of material innovation, in the future, during the design process of innovative personal protective equipment (PPE), attention should be given to providing optional alternatives to raw materials and processes to match those alternatives. This conceptualized design idea can be built into a knowledge database and shared on the web to guide people to use local materials and processes for more efficient emergency manufacturing and reduced reliance on global supply chains. In addition, there is also a trend to explore easily disposable and reusable raw materials to produce PPE. In the aspect of management innovation, the use of information and network technology, the collection and analysis of information flow within the supply chain, big data analysis, manufacturing intelligence, and control of logistics processes have all become future research targets for the management optimization of emergency supply chains. In addition, multilateral and regional entities and governments need to act together to create vaccine information platforms and portals and develop financial incentives and policies to attract all types of companies to share information related to the pandemic.[10]

Discussion

The rise of pandemic-triggered emergency manufacturing research is exposed through the document co-citation network, with keyword clustering to analyze current research hotspots and keyword bursts to explore future research trends. This study provides scholars with a systematic and quantitative analysis of emergency production innovations during major epidemics.

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Table 1. Top 25 keywords with strongest bursts

Keywords	Year	Strength	Begin	End	2006 - 2022
system	2006	1.04	2007	2009	
3d scanning	2006	1.31	2015	2016	
personal protective equipment	2006	1.58	2019	2020	
face shield	2006	1.85	2020	2020	
surgical mask	2006	1.85	2020	2020	
influenza virus	2006	1.38	2020	2020	
inactivation	2006	1.38	2020	2020	
transmission	2006	1.38	2020	2020	
pneumonia	2006	0.92	2020	2020	
medical face shield	2006	0.92	2020	2020	
filtration efficiency	2006	0.92	2020	2020	
three-dimensional printing	2006	0.92	2020	2020	
health care worker	2006	0.92	2020	2020	
efficacy	2006	0.92	2020	2020	
n95 respirator	2006	0.92	2020	2020	
influenza	2006	0.91	2020	2020	
optimization	2006	1.4	2021	2022	
design	2006	1.32	2021	2022	
polymer	2006	1.12	2021	2022	
digital twin	2006	1.12	2021	2022	
fit	2006	0.83	2021	2022	
personal protective equipment (ppe)	2006	0.83	2021	2022	
composite	2006	0.83	2021	2022	
logistics	2006	0.83	2021	2022	
supply chain management	2006	0.83	2021	2022	

There are limitations in this study. First, this research is conducted at a time when COVID-19 has not been declared over, and we are still in the post-pandemic era. It is not the best time to draw conclusions and reflect. Second, it only selects data sets from the Web of Science database, and it does not integrate data sets from other databases. In the future, as knowledge map software becomes more powerful, a comprehensive visual mapping of the emergency manufacturing field will be provided.

Conclusions

In this paper, we found that a novel study field of pandemic-triggered emergency manufacturing is evolving through literature research. The research hotspots and trends in this field are mainly focused on technological innovation, management innovation, and material innovation. The research summarizes the past and points out future research directions for subsequent studies.

Author contribution. The first author, Tian Xie, developed the study's main design and performed the main writing of the manuscript. Juan Wu performed the material preparation, data collection and analysis, and relevant writing of the manuscript. Yao-Yao Wei was responsible for concept design and software guidance. Wei-Fan Chen and Krista Chen were responsible for the results analysis and assisted in revising and embellishing the thesis for this study. All authors were involved in the writing of this article, discussed the results, and contributed to the final manuscript.

Funding statement. This work was supported by the National Natural Science Foundation of China (No. 71974090), Philosophy and Social Science Foundation of Hunan Province of China (18YBQ105), Youth Talents Support Program of Hunan Province of China (2018HXQ03), Key Scientific Research Project of Education Department (20A443), Social Science Key Breeding Project of USC (2018XZX16), Doctoral Scientific Research Foundation of USC (No. 2013XQD27), Philosophy and Social Science Foundation Youth Project of Hunan Province of China (19YBQ093), Scientific Research Project of Education Department (No. 20C1625), State Scholarship Fund (202108430098) from CSC, and State Scholarship Fund (202208430061) from CSC.

Competing interests. The authors report no conflicts of interest.

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