METHODOLOGY

Bibliometric Research on Surgical Scheduling Management from the Perspective of Web of Science

Ke Wang 🄳, Xuelu Wang, Chenying Xu, Lina Bai

Operating Room, Shanghai Key Laboratory of Maternal Fetal Medicine, Shanghai Institute of Maternal-Fetal Medicine and Gynecologic Oncology, Shanghai First Maternity and Infant Hospital, School of Medicine, Tongji University, Shanghai, 200092, People's Republic of China

Correspondence: Xuelu Wang; Chenying Xu, Operating Room, Shanghai Key Laboratory of Maternal Fetal Medicine, Shanghai Institute of Maternal-Fetal Medicine and Gynecologic Oncology, Shanghai First Maternity and Infant Hospital, School of Medicine, Tongji University, 2699 West Gaoke Road, Pudong New Area, Shanghai, People's Republic of China, 200092, Email wangxuelu@51mch.com; xuchenying@51mch.com

Objective: Reasonable surgical scheduling management is crucial to optimize the utilization rate of operating room. This study aims to understand the context, frontier and hot spots of surgical scheduling management research, in order to provide reference for surgical scheduling optimization.

Methods: Literature on operation scheduling management collected in Web of Science core collection database was searched from the database establishment to June 21, 2023. HisCite Pro 2.1 software was used to analyze the publication time, countries, research institutions, journals, authors, keywords and highly cited papers.

Results: A total of 1383 literatures were included, and research institutions in the United States, Canada and other countries played a leading role in this field. Among them, the combination of machine algorithm and system model optimization to improve the accuracy of surgical duration prediction is the future research focus in this field.

Conclusion: Improving operation efficiency is one of the key issues in operating room management. Managers should find the best operation scheduling plan from a more detailed and comprehensive perspective to improve operation efficiency.

Keywords: surgery, schedule, manage

Reasonable surgical scheduling is crucial to optimize operating room utilization. The operating room has the characteristics of randomness of emergency, uncertainty of human resources in place, and difficult to predict operation duration. In the problem of operation scheduling, the optimal operation order is sought to reduce the waiting time of patients and the overtime time of medical staff. It is the key to accelerate the operating efficiency of the operating room, reduce hospital costs, increase the number of inpatient surgical services, and improve the satisfaction of doctors, nurses and patients. Through literature reading, we have learned that there are currently unbalanced utilization of operating rooms, serious overtime work of operating room personnel, low professional matching degree and low resource utilization efficiency. With the help of bibliometric methods, this paper hopes to establish an overall view of current surgical scheduling programs, understand and master the current development of surgical scheduling programs, and provide directions for the improvement of surgical scheduling programs in our department in the future. This study intends to conduct a systematic search on the Web of Science core collection database. The research on operation efficiency management published since the establishment of the database was analyzed in order to provide theoretical basis for the operation optimization of our department.

Data and Methods
Data Sources

This study uses the Web of Science core collection database as a search platform. Inclusion criteria:[1] Research type: primary research, secondary research;[2] Research topic: surgical scheduling, reporting methods, techniques and schemes related to surgical scheduling, with or without effect evaluation.[3] Language limit: English. Exclusion criteria:[1] Duplicate publications;[2] Literature unrelated to the methods, techniques, schemes and effects of surgical scheduling;[3] Conference

Table 1 Search Mode

Serial number	Subject term	Logic & Retrieval
1	Operation schedule, surgical operation, operation time	Surgical scheduling, duration of a surgical operation, surgical time, surgery duration
2	Efficiency and effect	Product*, efficien*
3	Operating room	Operating room
4	1 AND 2 AND 3	(((TS=(surgical scheduling) OR TS=(duration of a surgical operation) OR TS=(surgical time) OR TS=(surgery duration)) AND (TS=(Product*) OR TS=(efficien*)) AND (TS=(operating room))))

papers, book chapters, letter briefs;[4] Non-English literature. The subject search terms and search methods are shown in Table 1. Search time: from the establishment of the database to June 21, 2023. This study was completed on June 30, 2023, and a total of 1571 literatures were retrieved, 6 duplicated literatures were removed, 69 literatures had nothing to do with the methods, techniques, schemes and effects of surgical scheduling, 36 conference papers, 7 book chapters, 4 letters and presentations, and 66 non-English literatures were included, with a total of 1383 literatures included. Search strategy, as shown in Figure 1.

Research Methods

Based on the core collection database of Web of Science, the records were imported into the Endnote 20 document management software for deduplication. Export the selected literature into plain text format, set the content as "full record and reference", import it into HisCite Pro 2.1 software, and analyze the publication time, country, research institution, journal, author and key words of the literature; At the same time, CiteSpace V6.2 visual analysis software was introduced to sort out the literature, and the graph was generated with keywords, authors and institutions as nodes respectively. The log-likelihood LLR algorithm was selected for keyword cluster analysis, and all the research results were timely confirmed with the research team.

Results

Publication Volume Distribution in the Year

Literature in the field of surgical scheduling management was first published in 1991, and the average number of articles published in 32 years was 43.22. The results showed that the research in the field of surgical scheduling management showed a fluctuating upward trend, reaching a peak of 146 papers in 2022, as shown in Figure 2.
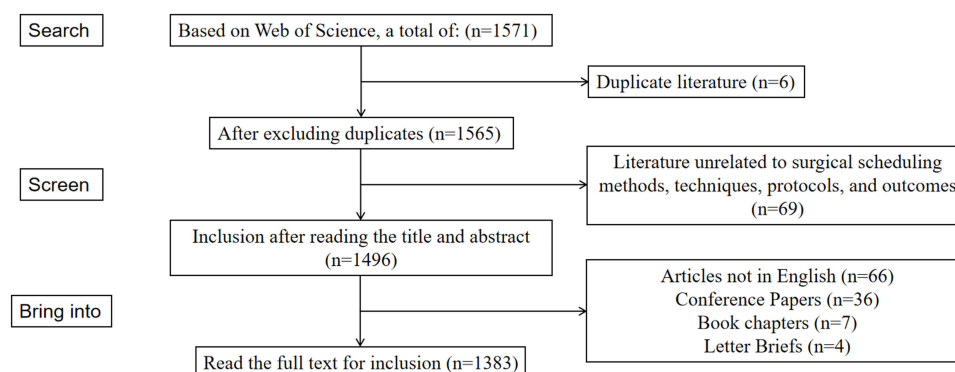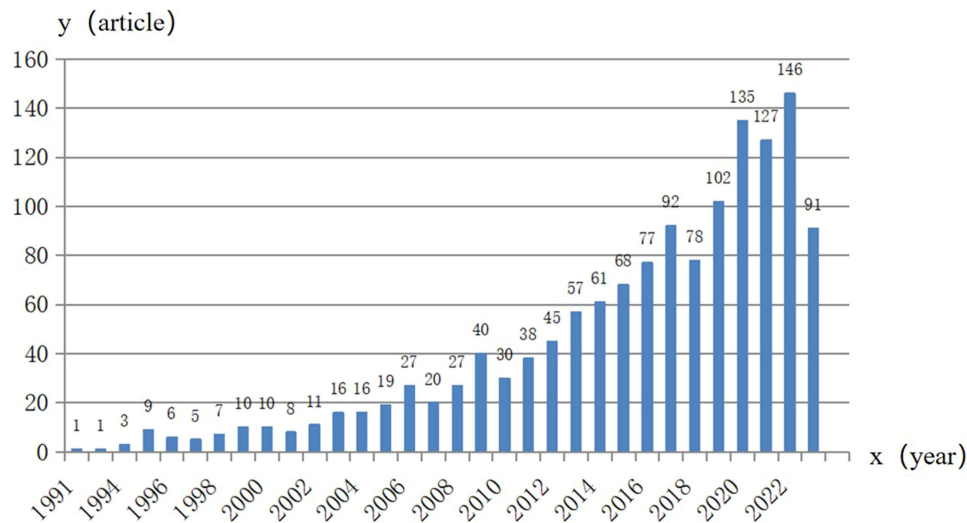

Figure 1 Search strategy.

Figure 2 Trend chart of publication volume in the past year (n=1383) Title: Article Volume.

Distribution of National Publications

A total of 76 countries/regions published articles in the field of surgical scheduling management, and the country with the largest number of articles was the United States, with a cumulative number of 772 articles, accounting for 55.82%. China ranked fourth, with 83 papers published in total, accounting for 6.01%. See Table 2 for national papers published.

Distribution of Issuing Institutions

A total of 977 institutions published surgery scheduling management studies, and nine of the top 10 publications were from the United States. Ranked first is Harvard University, ranked second is the University of Iowa, ranked third is the University of California, see Figure 3; The country distribution of the issuing institution is shown in Table 3.

Distribution of Authors

A total of 2233 authors were included in 1383 literatures. Seven of the top 10 authors are from the United States, with Dexter Franklin of the University of Iowa leading the list with 70 articles. Professor Epstein and Professor Richard H ranked second with a total of 38 papers. Author cooperation map, see Figure 4; See Table 4 for the top 10 authors, their affiliated institutions and their publications.

Table 2 The Number of Publications Issued by Countries (n=1383)

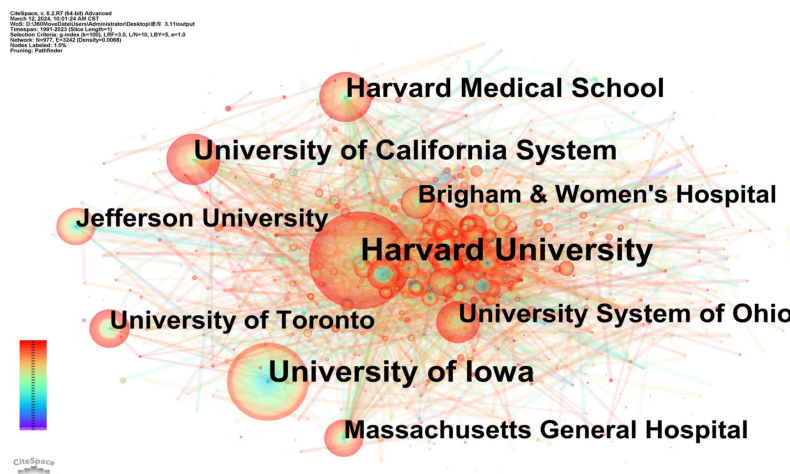| Ranking	Nation	Number of publications (articles)	Proportion of total literature (%)
1	USA	772	55.82%
2	Canada	109	7.88%
3	Germany	86	6.22%
4	Peoples R China	83	6.01%
5	UK	78	5.64%
6	France	48	3.47%
7	Italy	45	3.25%
8	Netherlands	44	3.18%
9	Australia	29	2.09%
10	Iran	26	1.88%

Figure 3 Co-occurrence map of issuing institutions.

Distribution of Published Journals

The 1383 articles included were distributed in 536 journals, of which the top 10 journals had 2292 articles, accounting for 21.11%. The journal publications ranked by impact factor are shown in Table 5.

Comparative Analysis of Published Documents

The published literatures from 1977 to 2018 and the published literatures from 2019 to 2023 were respectively imported into HisCite Pro 2.1 software, and the top 10 literatures with high Google Scholar Citation Index(GSC) in each group were compared, as shown in Table 6.

Keyword Analysis

High-Frequency Word Analysis

Keywords are words that can express the subject content of the literature, and can suggest or express the main content characteristics of the paper. To some extent, it reflects the research focus in the field of surgical scheduling, and the frequency of occurrence is proportional to the research heat. The high-frequency keywords of "operating room" are combined with synonyms "operating rooms, operating room", as shown in Table 7; Keywords co-occurrence map, see Figure 5.

Table 3 Country Distribution of the Issuing Institution (n=1383)

Ranking	Research institution	Nation	Frequency	Cooperation degree
1	Harvard University	USA	84	90
2	University of Iowa	USA	67	30
3	University of California	USA	44	78
4	Harvard Medical School	USA	43	88
5	University System of Ohio	USA	36	64
6	University of Toronto	Canada	33	41
7	Massachusetts General Hospital	USA	32	59
8	Jefferson University	USA	32	23
9	Brigham & Women's Hospital	USA	28	67
10	University of Texas	USA	27	23

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Figure 4 Author cooperation diagram.

Keyword Clustering

Keyword cluster analysis was conducted according to the keyword co-occurrence map. The Q value of literature clustering was 0.5789, and the S value was 0.8675, indicating that the clustering results of the two were effective. See Figure 6 for the keyword clustering map.

Keyword Breakout Analysis

The sharp increase in the frequency of keywords in relevant literatures within a certain period of time can reflect the research hotspot and development trend in the field of surgical scheduling. This study conducted a keyword emergence analysis diagram in chronological order for the included literatures, as shown in Figure 7. It can be observed that in 2018,

Table 4 The Top 10 Authors, Their Organizations, and Their Publications (n=1383)

Ranking	Author	Nation	Research institution	Number of publications (articles)	TLCS	Citation frequency of each article
1	Dexter F	USA	University of Iowa	70	1068	15.25
2	Epstein Rh	USA	University of Miami	38	512	13.47
3	Abouleish AE	USA	University of Texas	12	128	10.66
4	Ledolter J	USA	University of Iowa	12	196	16.33
5	Macario A	USA	Stanford University	11	214	19.45
6	Urman Rd	USA	Harvard University	11	5	0.46
7	Whitten CW	USA	University of Texas	11	117	10.64
8	Catchpole K	USA	South Carolina State University	10	33	3.3
9	Prough DS	USA	University of Texas	9	92	10.22
10	Wachtel RE	USA	University of Iowa	8	115	14.38

Table 5 Journal Issues Sorted by Impact Factor (n=1383)

Ranking	Journal title	Influence factor	Place of publication	Number of publications (articles)	Proportion of total literature (%)	TLCS	Citation frequency of each article
1	ANESTHESIOLOGY	8.8	USA	24	1.74	520	21.67
2	JOURNAL OF CLINICAL ANESTHESIA	6.7	Netherlands	22	1.59	82	3.73
3	ANESTHESIA AND ANALGESIA	5.7	USA	77	5.57	951	12.35
4	JOURNAL OF MEDICAL SYSTEMS	5.3	USA	23	1.66	5	0.22
5	JOURNAL OF THE AMERICAN COLLEGE OF SURGEONS	5.2	Netherlands	20	1.45	164	8.2
6	HEALTH CARE MANAGEMENT SCIENCE	3.6	Netherlands	12	0.87	73	6.08
7	SURGICAL ENDOSCOPY AND OTHER INTERVENTIONAL TECHNIQUES	3.1	Germany	37	2.67	66	1.78
8	JOURNAL OF SURGICAL EDUCATION	2.9	Netherlands	28	2.02	16	0.57
9	JOURNAL OF SURGICAL RESEARCH	2.2	Germany	27	1.96	101	3.74
10	AMERICAN JOURNAL OF SURGERY	1.9	UK	22	1.59	93	4.23

the first part of the research focuses on the aspects of "surgical cost, technical improvement, anesthesia time and reception efficiency, etc", and the latter part gradually evolved into the research focusing on "patient outcome indicators, medical quality improvement, machine learning and operating room efficiency, etc".

Discussion
Analysis of the Research Context in the Field of Surgical Scheduling Management

The number of published documents has been on the rise year by year, indicating that the research field of operating room operation has increasingly attracted the attention of the majority of scholars, among which the United States and Canada have dominated the research in this field, and most of the researchers in this field are from the United States. This may be related to national policy support and the level of multidisciplinary team research. Professor Dexter Franklin of the University of Iowa, Professor Richard Epstein of the University of Miami, Professor Alex Macario of Stanford University and their cross-regional cooperation team have been committed to the field of surgery and health medical technology for a long time. Considering the impact of operating room management on anesthesia and operating room efficiency, the team has paid attention to the collection and analysis of patient surgical data since 2006,[3] paying attention to each factor affecting the operation schedule, such as operation opening time, operation connection time, etc., and studying the impact of operating room personnel factors, attending physician factors and patient factors on operating room efficiency. By combining the algorithm, the operation time is segmented, the time series analysis is applied in the operating room management, and the allocation of the operation time is optimized by predicting the total hours of elective surgery cases. Moreover, the accuracy of calculation of operation time was monitored, so as to optimize patients' admission, surgery waiting time and nil by mouth time.[15] Prof. Pandit, Jaideep J and his research team from the University of Oxford in the UK, Prof. Abouleish, Amr E and his research team from the University of Texas in the US are committed to exploring the research of medical economic benefits, such as applying theoretical models to improve operating room performance.[21] And the impact of reducing personnel turnover time on personnel cost was predicted by using operating room information system data.[22,23] It can be observed that the rapid development of surgical operation

Table 6 Comparison of the Top 10 Cited Papers Between 1977–2018 and 2019–2023

Ranking	1977–2018					2019–2023				
	ID	Journal title	Author and year of publication	GSC	Average annual citations	ID	Journal title	Author and year of publication	GSC	Average annual citations
1	315	Health Care Manage Sci	Guerriero Francesca, 2011[1]	291	24.25	186	J Am Coll Surg	Prachand Vivek N, 2020[5]	211	70.33
2	332	J Am Coll Surg	Cima Robert R, 2011[2]	254	21.17	19	OMEGA-INT J MANAGE S	Moons Karen, 2019[6]	87	21.75
3	177	Anesth Analg	McIntosh Catherine, 2006[3]	225	13.24	181	Acad Radio	Ballard David H, 2020[7]	74	24.67
4	32	Anesth Analg	Overdyk FJ, 1998[4]	214	8.56	104	Health Care Manag Sci	Fairley Michael, 2019[8]	43	10.75
5	210	Eur J Oper Res	Pham D. -N, 2008[9]	210	14	88	J Am Coll Surg	Bartek Matthew A, 2019[10]	37	9.25
6	81	Anesth Analg	Dexter F, 2002[11]	180	8.57	172	KNEE SURG SPORT TR A	de Caro Francesca, 2020[12]	37	12.33
7	101	Int J Prod Econ	Guinet A, 2003[13]	172	8.6	51	Curr Urol Rep	Lee Daniel J, 2019[14]	31	7.75
8	133	Anesthesiology	Dexter F, 2004[15]	162	8.53	73	BMJ OPEN	Herrod Philip J. J, 2019[16]	30	7.5
9	558	SURG-J R COLL SURG E	Mason S. E, 2015[17]	162	20.25	107	J Med Syst	Bellini Valentina, 2019[18]	28	7
10	117	EUR J PEDIATR SURG	Yardeni D, 2004[19]	161	8.47	32	J Med Syst	Tuwatananurak Justin P, 2019[20]	26	6.5

Table 7 High-Frequency Keywords (Web of Science)

Keyword	Frequency (times)	Centrality
Surgery	264	0.2
Operating room	279	0.15
Efficiency	168	0.1
Impact	120	0.2
Time	104	0.18
Care	104	0.1
Management	101	0.16
Operating room efficiency	100	0.08
Performance	96	0.04
Outcome	72	0.06
Safety	56	0.07
Anesthesia	54	0.16
Model	53	0.05
Quality	53	0.07
System	49	0.12
Health care	48	0.03
Costs	42	0.05
Complications	42	0.09
Patient safety	41	0.04
Experience	39	0.07

efficiency research abroad is inseparable from the joint cooperation between universities and hospitals. Medicine is a multidisciplinary science. As can be seen from this study, the scheduling problem of operating room has gradually evolved from artificial to machine algorithm scheduling, which belongs to the field of computer science and technology. Clinical researchers of operating room in China can work with multidisciplinary teams such as universities to jointly promote the research on surgical scheduling based on foreign research. At the same time, interdisciplinary research cooperation can also avoid the disciplinary blind spots and technical shortcomings in the research, improve the accuracy and reliability of the research conclusions, and promote the improvement of operation efficiency and save hospital and national resources.
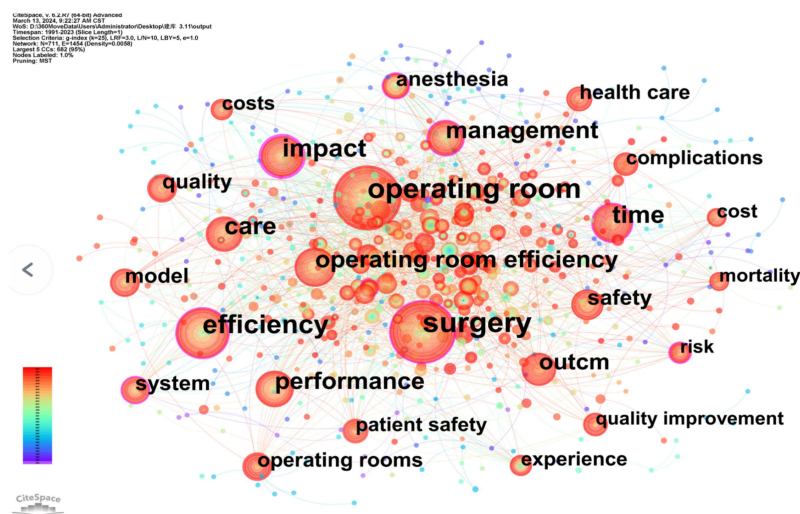
Figure 5 Keyword co-occurrence map.
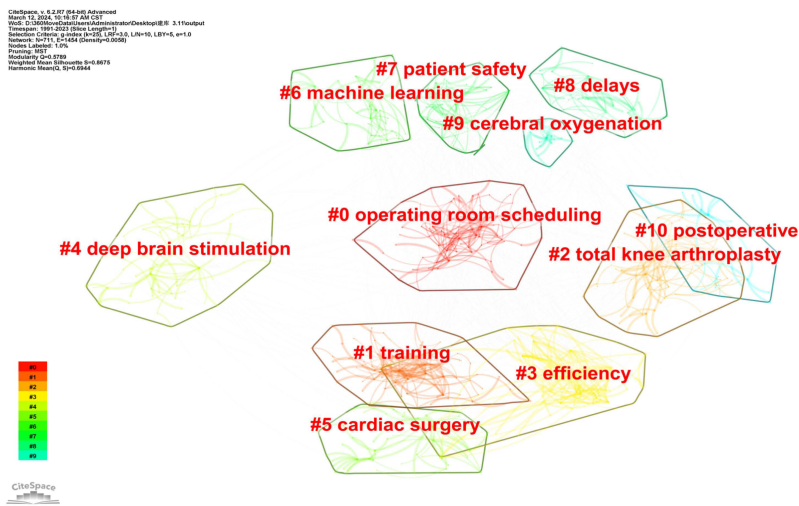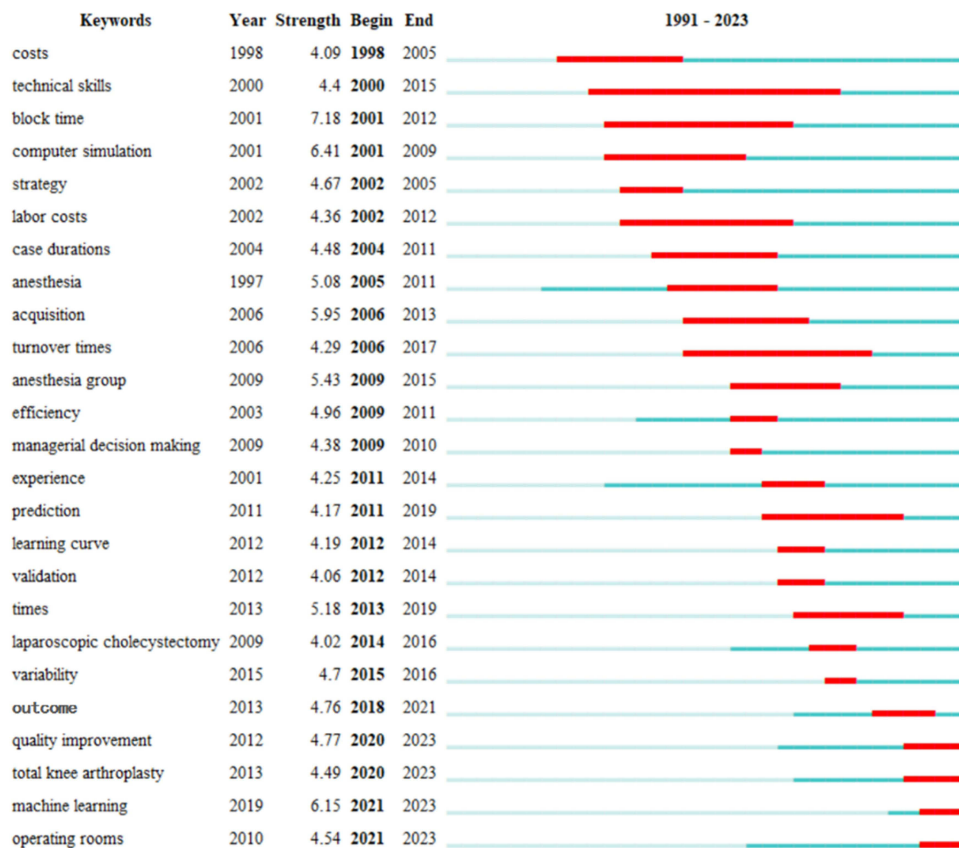
Figure 6 Keyword clustering diagram.

Figure 7 Keyword emergence diagram Title: Top 25 Keywords with the Strongest Citation Bursts.

Hotspot Comparative Analysis

Through the comparison of keywords, it can be observed that in the study of surgical scheduling management, surgical alignment, surgical duration and operating room efficiency analysis have always been the focus of research in operating room management.

From 1977 to 2018, the research focused on exploring the people-oriented management concept, supplemented by information technology to improve surgical scheduling management. For example:[1] Carry out refined scheduling management based on the surgical risk level. Considering that the work energy of the surgeon is gradually consumed with the completion of the task, the optimization strategy is proposed to minimize the total surgical risk of the day as the optimization goal. The elderly, children, and high difficulty surgeries are given priority, and the infectious and low risk surgeries are postponed. However, this method takes the doctor's personal experience as the main criterion for evaluation, and there will still be prolonged operation and accidents.[24] ② In view of the problems of on-time rate of the first operation, duration of operation, utilization rate of operating room and working hours of operating room staff, process reengineering, Six Sigma management model and Plan-Do-Check-Act (PDCA) quality improvement were adopted to optimize the management of surgical scheduling. For example, after the scheduling process is controlled through the joint cooperation of multiple departments, the operation connection time and average operation time are effectively shortened, and the utilization rate of operating rooms is improved, but such improvement effects are not stable.[2,3] To realize the interconnection of various information systems in the operating room to optimize the management of surgical scheduling, such as nursing management personnel based on surgical anesthesia system, patient management system, nursing information system, PDA sharing patient information, artificial control. For example, patient handover and room cleaning are important links that affect the efficiency of joint operation.[11] Patient terminal information is scanned by PDA to realize the sharing of patient status information in various systems, and the cleaning requirements of operating room are synchronized to the PDA terminal of cleaning staff through information and voice broadcasting, so as to improve the cleaning efficiency of operating room and patient handover.[25]

2019–2023 is a period of rapid development of information machine algorithms, which will still comprehensively improve surgical operation efficiency. Compared with 2018, the change in research direction is mainly reflected in the following two aspects:[1] The scope of adjustment of surgical operation efficiency will be more detailed and comprehensive: For example, the same type of surgery in different hospitals is taken as the type of surgery, the type of surgery, the type of surgeon and the type of surgery.[26] For the development of new surgery methods, the algorithm is used to quantify the utilization of operating room space, the cooperation of surgical team, the configuration of operating room instruments and equipment, the duration of patient transport, and the duration and steps of surgical implementation. To explore the best surgical path, reverse the improvement of surgical coordination steps and improve operational efficiency based on efficiency baseline and optimized steps.[2,27] Explore the impact of operating room efficiency on hospital finance: for example, the linear prediction model based on logical matrix decision tree analyzes the annual operation of a surgeon and the financial income brought by it, so as to explore the best surgical scheduling scheme to maximize the efficiency of surgeons and reduce the idle time and income loss of operating room;[28] And explore the correlation between the application of new surgical technologies and the utilization rate of operating room, postoperative patient outcomes, and surgical costs.[29]

Future Research Trends

The difficulty of surgical scheduling lies in the optimization of surgical scheduling and the reasonable allocation of related scarce resources by operating room managers in emergency situations.[30] We should establish an emergency management system for emergency events based on machine algorithm. When an emergency occurs, it is necessary for surgical management personnel to optimize the operation schedule to solve the problem of resource shortage and medical resource allocation. Through literature reading, it is found that the operation schedule should also fully analyze the operation time, surgeons and operation types, and the above contents should be comprehensively considered to evenly distribute the operations in each operating room, so as to avoid excessive pressure or excessive overtime due to the mismatch of nurses' abilities or the uneven distribution of operating rooms. At present, most surgical scheduling models in quantitative studies at home and abroad are single prediction models, and XGBoost model, random forest model and linear regression are used to predict the duration of surgery. However, the application of machine learning algorithms in different institutions and the selection of different operation modes will lead to differences in research results. Therefore, in order to cope with more different situations and advantages, different models should be reasonably applied. The

research finds that the prediction accuracy and effect of combined application of prediction models are superior to that of a single prediction model.[31]

To sum up, based on the Web of Science core collection database, this study used bibliometric methods to analyze from the aspects of countries, number of publications, authors and research hotspots, and found that foreign studies on surgical operation efficiency started earlier, machine algorithms were more mature in operating room management, and multidisciplinary teams were more adept in research cooperation. With the rapid development of China's medical technology, the improvement of operating room hardware facilities and information level, more and more high-precision, time-consuming operations, how to improve the quality and efficiency of operating room management, is the focus of attention of managers. China should learn from foreign experience, closely follow the national medical information policy, strengthen interdisciplinary cooperation between colleges and universities, and integrate machine algorithm into surgical scheduling management, so as to accelerate operating efficiency of operating rooms, save hospital costs, increase the number of surgical service patients, and improve the satisfaction of doctors, nurses and patients.

Registration Information

This study is not a clinical trial, so no registration information is involved.

Data Sharing Statement

All data and materials in this article are available.

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Disclosure

Ke Wang and Lina Bai are co-first authors for this study. The authors declare that they have no competing interests in this work.

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