Emergency and rapid response systems: a bibliometric analysis

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Background: The emergency rapid response system (RRS) can reduce the mortality of hospitalized patients, and its core is the activation criteria and the rapid response team (RRT). This study adopted a bibliometric method to analyze the research status of RRSs for hospitalized patients.

Methods: The Science Citation Index Expanded (SCI-E) database was searched using the keywords "emergency" and "rapid response system", and the search results were analyzed using CiteSpace software. The retrieved data included the annual distribution of studies and literature citations; the source country of the literature; the distribution of institutions and authors of the literature; the cooperation between countries, institutions, and authors; the distribution of journals that published the literature, and the use of keywords in the literature.

Results: A total of 1,320 research papers were found, with a total of 29,920 citations. The number of papers and their citations increased yearly. The top 5 countries in terms of number of publications were the United States, Australia, China, the United Kingdom, and Canada. The top 5 countries in terms of centrality were the United States, the United Kingdom, Argentina, the Czech Republic, and Switzerland. The research institutions were mainly located in developed countries, such as the United States and Australia. There was relatively little collaboration between researchers. The journals that published the literature mainly specialized in critical care medicine and emergency medicine. The keyword analysis revealed that most studies focused on medical emergency teams (METs) and mortality.

Conclusions: There were few studies related to the emergency RRS for hospitalized patients. The majority of studies were from developed countries and mainly focused on the impact of team building and the effect of the RRS on mortality.

Keywords: Emergency; rapid response system (RRS); bibliometrics analysis

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Introduction

At present, relatively comprehensive outpatient emergency systems have been established in various countries. These systems significantly shorten the time for patients to receive treatment and reflect a country's medical and social management levels (1,2). However, since the establishment of the outpatient emergency system, the demand for related services has increased rapidly, and the types of service problems have also increased significantly, thus promoting continuous improvements in outpatient emergency systems (3). However, the proportion of hospitalized patients experiencing emergencies is considerably higher than the outpatient population. For example, more than half of all deaths occur in hospitals in Canada, approximately 46% of deaths in the UK, and nearly one-third of deaths in the

Table 1 Literature types

Type	Records	Percentage (%)
Article	1,096	83.03
Review	157	11.89
Editorial	51	3.86
Proceedings	47	3.56
Online	11	0.83
Letter	7	0.53
Meeting abstract	6	0.45
Book	3	0.23
Re-publication	2	0.15
Note	1	0.08

USA (4). Although the time to treatment in a medical facility is shorter, many patients still die during hospitalization due to a dramatic change in their condition. Therefore, the rapid response system (RRS) in hospitals has been gradually developed (5). The RRS performs an early intervention role based on the patients' respiratory rate, heart rate, blood pressure, and state of consciousness to identify those in need of emergency treatment in a timely manner and provide multidisciplinary medical care services (6). Numerous studies have shown that using an RRS significantly reduces inpatient mortality (7,8). Moreover, it is also beneficial for assessing the physical condition and medical needs of patients at the end of life (9). The core of the RRS is the start-up criteria and the rapid response team (RRT) (10,11). Furthermore, RRS was also applied in outpatient settings, while related study was few (12). This study adopted a bibliometric method to analyze the research status of emergency RRSs for hospitalized patients.

Methods

Data source

The data source for this study was the Science Citation Index Expanded (SCI-E) database in the Web of Science Core Collection (WOSCC), a commonly used database for bibliometrics. This database was founded and published by the American Institute for Scientific Information in 1957. The SCI-E database contains papers and their citation information from more than 8,000 journals. It is an important citation retrieval source and an essential database for metrology research and scientific research evaluation.

Search strategy

This study adopted the "topic word" retrieval strategy, and the search terms were "emergency" and "rapid response system". There was no restriction on the publication date of the literature, and all related articles included in SCI-E were retrieved, with the latest retrieval time being 2021-11-07.

Data collection and bibliometrics analysis

All the records of the retrieval results and the citations were exported in plain text format as source files for subsequent analysis. This source file was analyzed using CiteSpace software. The content of the analysis included the annual distribution of the literature and the literature citations; the source country of the literature; the distribution of institutions and authors of the literature; the cooperation between countries, institutions, and authors; the distribution of journals that published the literature, and the use of keywords in the literature.

Statistical analysis

This study mainly used quantity and percentage to describe the indicators statistically. There was no difference analysis involved, and there was no need to set a test level.

Results

General information

There were 1,320 research papers, with 29,920 total citations. The average number of citations per paper was 22.67, and the H-index, which reflected the paper's influence in specific research field, was 79. Among these documents, 1,096 were original articles, 157 were reviews, 51 were editorial materials, 47 were proceedings papers, 11 were online publications, 7 were letters, 6 were conference abstracts, 3 were book chapters, 2 were reprints, and 1 was a presentation (*Table 1* shows that 61 papers were classified repeatedly, so the total records in the table are 1,381, but the actual number of papers was 1,320 when calculating the percentage). The statistical results show that the number of documents and citations increased yearly (*Figures 1,2*).

Country

The country visualization map was drawn by CiteSpace V software (*Figure 3*), where the number of network nodes

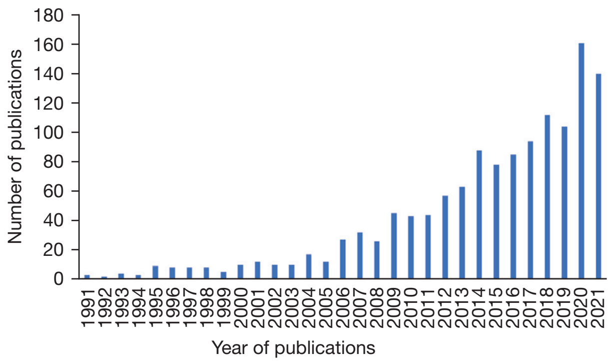

Figure 1 Annual publications: the number of publications increased annually.

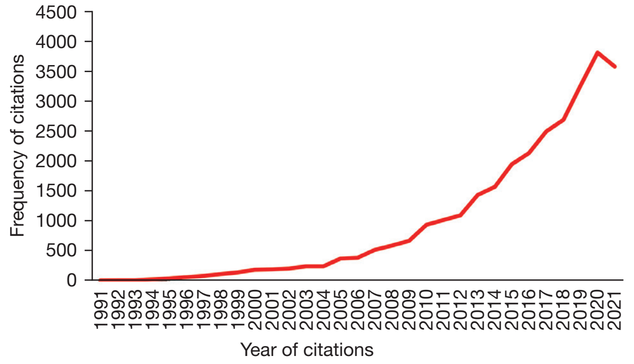

Figure 2 The frequency of citations increased annually.

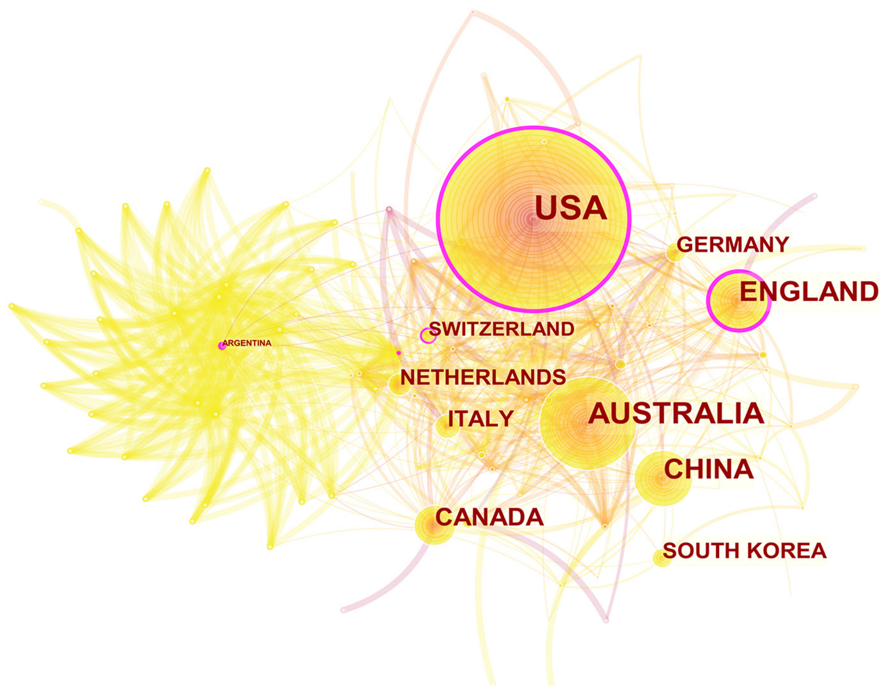

Figure 3 Visualization map of countries.

(N) =105, and one node represents one country; that is, the authors of these documents came from 105 countries. The connection between any two nodes (E) =711; that is, the number of times any two countries appeared in a document at the same time was 711. The top 5 countries for the number of publications were the United States, Australia, China, the United Kingdom, and Canada (*Table 2*). The top 5 countries for centrality, which reflected the status of collaboration of one (individual, institute, countries) with others, were the United States, the United Kingdom, Argentina, the Czech Republic, and Switzerland (*Table 3*).

Research institutions

Similarly, the number of nodes (N) in the institutional visualization map (*Figure 4*) =609; that is, 609 research institutions participated in research in this field, and

Table 2 Top 10 countries by number of publications

Rank	Countries	Records
1	USA	526
2	Australia	212
3	China	143
4	England	136
5	Canada	90
6	Italy	55
7	Germany	46
8	South Korea	43
9	Netherlands	42
10	Switzerland	32

Table 3 Top 10 countries by centrality

Rank	Countries	Centrality
1	USA	0.29
2	England	0.24
3	Argentina	0.23
4	Czech Republic	0.14
5	Switzerland	0.12
6	Canada	0.08
7	France	0.08
8	Chile	0.07
9	Australia	0.05
10	Bangladesh	0.05

Figure 4 Visualization map of institutions.

the number of times any two institutions appeared in a document at the same time (E) totaled 1,224. The top 10 institutions in terms of number of publications and centrality are shown in *Tables 4,5*, respectively. The institution with the most publications was Monash University in Australia, and the one with the highest centrality score was Stanford University in the United States. However, we can see (*Tables 4,5*) that research institutions in the United States and Australia are leading in both the number of publications and the centrality score.

Table 4 Top 10 institutions by number of publications

Rank	Institutions	Records
1	Monash University	46
2	Austin Hospital	32
3	University of Washington	32
4	Deakin University	28
5	University of Pittsburgh	28
6	University of Melbourne	27
7	University of New South Wales	24
8	University of Pennsylvania	21
9	Harvard University	17
10	University of Adelaide	16

Table 5 Top 10 institutions by centrality

Rank	Institutions	Centrality
1	Stanford University	0.07
2	Monash University	0.05
3	Austin Hospital	0.05
4	University of Pennsylvania	0.05
5	University of Washington	0.04
6	University of Pittsburgh	0.04
7	University of New South Wales	0.04
8	Harvard University	0.04
9	University of Toronto	0.04
10	University of Antwerp	0.03

Author

The results show that in this field, there were some researchers who published significantly more literature, notably Associate Professor Daryl Jones from Austin Hospital in Australia (*Table 6*). However, the centrality score of the researchers was not high; only eight authors reached 0.01, and the highest centrality score was 0.02 from Jones, suggesting that there was relatively little cooperation between authors (*Table 7*). The results were consistent with the visualization map (*Figure 5*). The co-citation map shows that the literature cited by the authors had a wide intersection (*Figure 6*). The most cited author was Dr. Paul Chan from the University of Missouri-Kansas in the United States (*Table 8*), but the highest cited centrality score was only 0.02, indicating that the cited literature was scattered and lacked classic research literature quality (*Table 9*).

Table 6 Top 10 authors by number of publications

Rank	Authors	Records
1	Jones D	28
2	Bellomo R	23
3	Hillman K	17
4	Considine J	16
5	Flabouris A	14
6	Chen J	12
7	J Currey J	12
8	Devita MA	11
9	Welch J	9
10	Edelson DP	8

Table 7 Top 8 authors by centrality

Rank	Authors	Centrality
1	Jones D	0.02
2	Bellomo R	0.02
3	Parr M	0.02
4	Nadkarni VM	0.01
5	Van Der Jagt EW	0.01
6	Hillman K	0.01
7	Chen J	0.01
8	Welch J	0.01

Journals

The 1,320 articles in this study came from 608 journals, of which 17 had more than 10 articles. The top 10 journals by the number of articles published are listed in *Table 10*. There were 257 journal articles in total, accounting for 19.47% of the total literature (*Table 10*). These journals were dominated by critical care medicine and emergency medicine, but the more cited journals were either general journals or top critical care medicine journals (*Table 11*).

Figure 5 Co-author visualization map. Collaborations among authors were scattered and clustered.

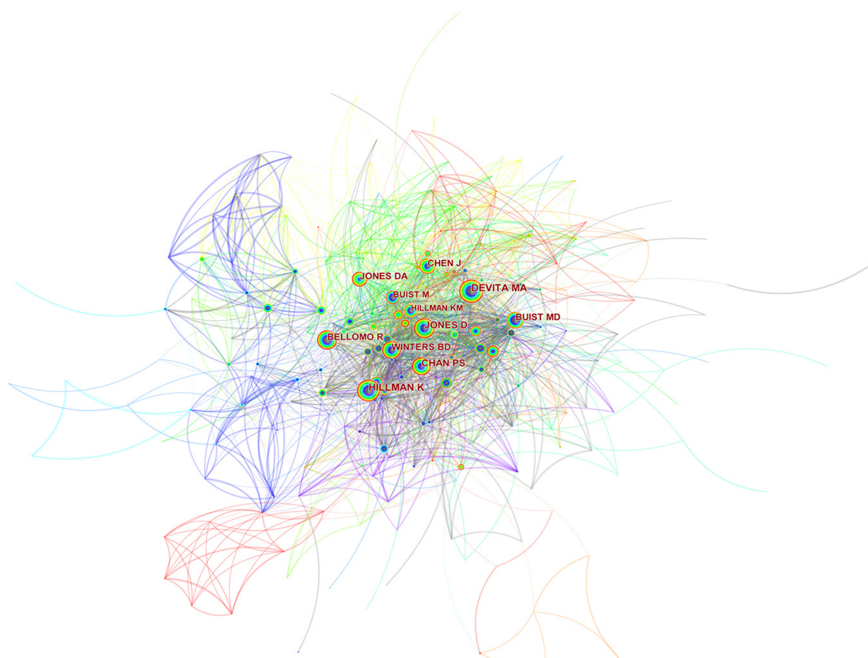

Figure 6 Authors co-citation visualization map.

Table 8 Top 10 authors by frequency of co-citation

Rank	Authors	Frequency
1	Chan PS	216
2	Bellomo R	187
3	Winters BD	178
4	Jones DA	176
5	Buist MD	169
6	Chen J	161
7	Buist M	114
8	Hillman KM	106
9	Subbe CP	93
10	Maharaj R	87

Table 9 Top 10 authors by centrality of co-citation

Rank	Authors	Centrality
1	Devita MA	0.02
2	Jones D	0.02
3	Subbe CP	0.02
4	Smith GB	0.02
5	Goldhill DB	0.02
6	Churpek MM	0.02
7	Eisenberg MS	0.02
8	Becker LB	0.02
9	Alberts MJ	0.02
10	Hillman K	0.01

Table 10 Top 10 journals by number of publications

Rank	Journals	Records	Percentage (%)
1	*Resuscitation*	74	5.61
2	*Critical Care Medicine*	62	4.70
3	*Critical Care*	18	1.36
4	*Journal of Clinical Nursing*	17	1.29
5	*Prehospital Emergency Care*	16	1.21
6	*Australian Critical Care*	15	1.14
7	*Internal Medicine Journal*	15	1.14
8	*Journal of Critical Care*	14	1.06
9	*Journal of Hospital Medicine*	13	0.98
10	*Pediatric Critical Care Medicine*	13	0.98

Table 11 Top 10 journals by citations

Rank	Journals	Frequency
1	*Crit Care Med*	523
2	*Resuscitation*	514
3	*New Engl J Med*	465
4	*Jama-J Am Med Assoc*	446
5	*Lancet*	445
6	*Crit Care*	350
7	*Intens Care Med*	301
8	*Med J Australia*	260
9	*Arch Intern Med*	243
10	*Brit Med J*	237

Table 12 Top 10 journals by centrality

Rank	Journals	Centrality
1	*Nature*	0.16
2	*Clin Infect Dis*	0.10
3	*Am J Med*	0.10
4	*Ann Intern Med*	0.09
5	*Science*	0.09
6	*Am J Emerg Med*	0.09
7	*P Natl Acad Sci USA*	0.09
8	*Anal Chem*	0.09
9	*Ann Emerg Med*	0.08
10	*Am Heart J*	0.08

Major journals had higher centrality scores, especially authoritative comprehensive journals (*Table 12*).

Keywords

CiteSpace V software was used to analyze keywords and generate a co-occurrence map (*Figure 7*). The number of nodes (N) in the graph was 339; that is, in the 1,320 articles included in this study, 339 keywords were used; the total number of times (E) that the keywords appear in the same document in pairs was 2,089. The keyword with the highest frequency was "medical emergency team" (*Table 13*), and the keyword with the highest centrality score was "emergency" (*Table 14*). Further burst detection was performed on

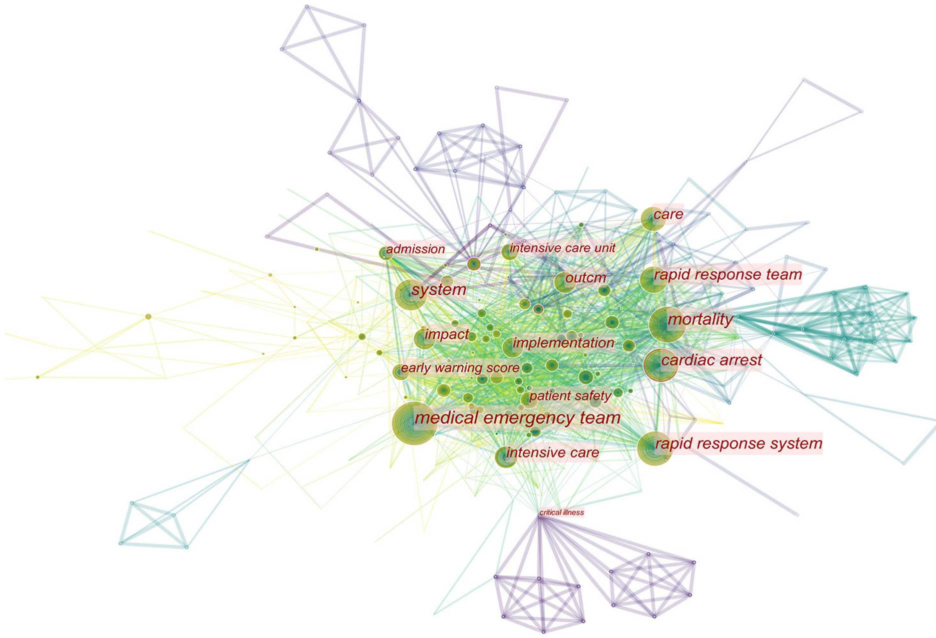

Figure 7 The keywords co-existence map. Each circle (dot) in the figure represents a keyword. The larger the number, the more times the keyword and other keywords appear in a document, which is consistent with the frequency in *Table 12*.

Table 13 Top 10 keywords by frequency of use

Rank	Keyword	Frequency
1	Medical emergency team	347
2	Mortality	219
3	System	206
4	Rapid response system	194
5	Cardiac arrest	193
6	Rapid response team	138
7	Care	117
8	Outcome	107
9	Impact	105
10	Intensive care	91

Table 14 Top 10 keywords by centrality

Rank	Keyword	Centrality
1	Emergency	0.15
2	Critical illness	0.12
3	Cardiac arrest	0.11
4	Emergency medical service	0.11
5	Mortality	0.09
6	Adverse event	0.09
7	Survival	0.08
8	Hospital cardiac arrest	0.07
9	Automated external defibrillator	0.07
10	Admission	0.05

keywords with high frequency, and the results showed that the use of popular keywords changed over time (*Figure 8*).

Discussion

This study is the first to conduct a bibliometric analysis of research literature on emergency RRSs. The analysis results showed that, before 2005, the number of research papers had been growing steadily, but after 2006, there was a period of rapid growth with a slight fluctuation in the middle period, followed by an especially significant increase in 2020, which may be related to the COVID-19 pandemic in 2020. The countries studied were mainly developed countries in Europe and the United States. Although China

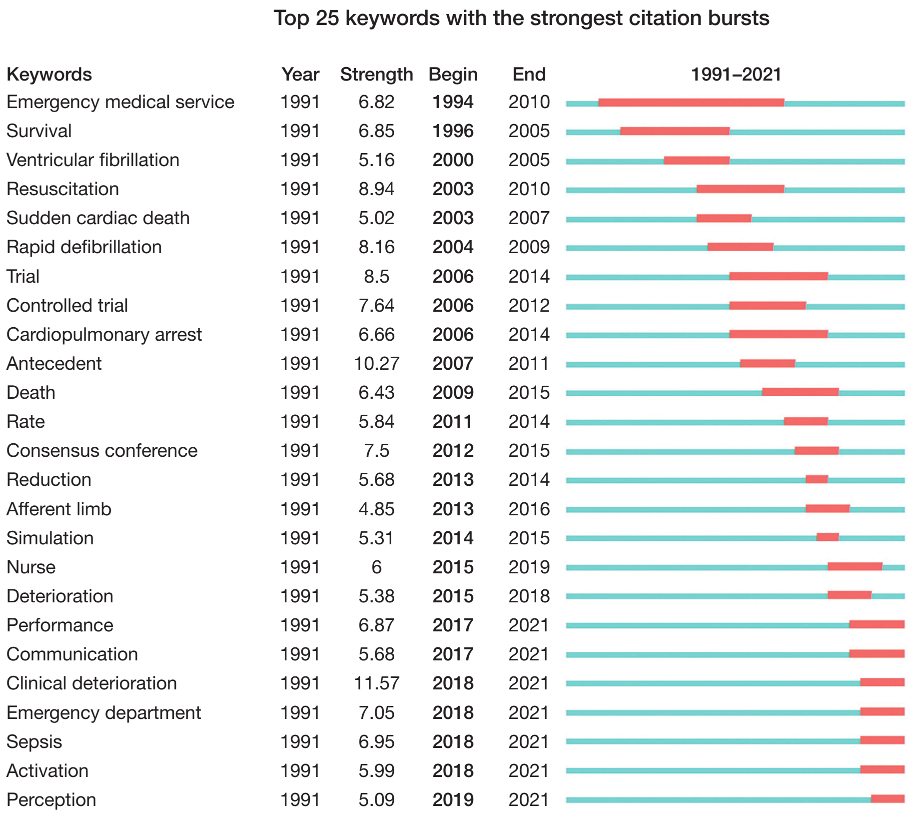

Figure 8 Top 25 keywords with the strongest citation bursts.

has published a large number of studies, it has been less involved in cooperation. The research institutions with more publications and collaboration were predominantly from the United States and Australia. Similarly, the most influential authors were mainly from these countries and institutions. The keyword analysis showed that the hotspots in this research field were "emergency teams" and "rapid response systems", but the hotspots changed over time.

The results of this study showed that in the field of rapid emergency response, most of the important research comes from developed countries in Europe and America. This is closely related to the country's economic level and medical facilities. The emergency response system conducts real-time monitoring, early warning, and response to the conditions of hospitalized patients. It provides patients with rapid emergency resources and interventions on the spot, involving administrative management and evaluation (13). At the heart of the RRS is the RRT (14). Unlike the traditional emergency team, the RRT mainly evaluates patients with respiratory, neurological, and cardiac deterioration in advance to prepare for emergencies, allowing the response to adverse events to be more rapid and effective (14). During the COVID-19 pandemic, some hospitals adjusted their RRS to deal with the incoming challenges, most commonly through increasing resources and implementation of protocol changes (15). However, the current research does not have sufficient evidence to draw a clear conclusion on whether the RRS and RRT can bring benefits, and the related research results were inconsistent (16). In a meta-analysis published in 2010, Chan *et al.* analyzed data from 18 studies and found that the use of an RRT reduced the incidence of cardiopulmonary arrest in adults outside the intensive care unit (ICU) by 33.8% [risk ratio (RR) =0.66; 95% confidence interval (CI): 0.54–0.80], but did not reduce inpatient mortality (RR =0.96; 95% CI: 0.84–1.09); in children, it reduced the incidence of cardiopulmonary arrest outside the ICU by 37.7% (RR =0.62; 95% CI: 0.46–0.84), and also reduced hospital mortality in children by 21.4% (RR =0.79; 95% CI: 0.63–0.98) (17). In a systematic review and meta-analysis, Maharaj *et al.* found that the use of an RRS reduced the overall mortality of inpatient adults (RR =0.87; 95% CI: 0.81–0.95; P<0.001) and children

(RR =0.82; 95% CI: 0.76–0.89). The use of an RRT also reduced cardiopulmonary arrest in adults (RR =0.65; 95% CI: 0.61–0.70; P<0.001) and children (RR =0.64; 95% CI: 0.55–0.74) (18). In another systematic review and meta-analysis, Solomon *et al.* showed that the use of an RRT and medical emergency team (MET) reduced the mortality of hospitalized patients (RR =0.88; 95% CI: 0.83–0.93) and also reduced the number of non-ICU cardiac arrests (RR =0.62; 95% CI: 0.55–0.69) (19).

The above-mentioned studies concerned patients in general. The use of RRSs or RRTs for specific patients has also been analyzed by investigators. In particular, the use of RRTs for sepsis patients has attracted the attention of many researchers (20). In a study of postoperative patients, Bellomo *et al.* found that the use of ICU-based METs in teaching hospitals reduced inpatient mortality and the average length of stay (21). In a retrospective study of adults, Guirgis *et al.* included 3,917 sepsis patients. Their multivariate analysis showed that the use of electronic identification and RRT intervention was associated with reduced mortality [odds ratio (OR) =0.62; 95% CI: 0.39–0.99; P=0.046], reduced mean ICU length of stay (2.12 days before, 95% CI: 1.97–2.34 *vs.* 1.95 days after, 95% CI: 1.75–2.06; P<0.001), reduced overall mean length of stay (11.7 days before, 95% CI: 10.9–12.7 *vs.* 9.9 days after, 95% CI: 9.3–10.6; P<0.001), reduced risk of mechanical ventilation (OR =0.62; 95% CI: 0.39–0.99; P=0.007), and savings on medical costs (per case sepsis was reduced by $7,159; P=0.036) but not vasopressor use (OR =0.89; 95% CI: 0.75–1.06; P=0.18) (22). Other researchers have studied the use of RRTs in patients with dementia (23,24).

Our results show that current research in this field is predominantly concentrated in countries with strong economies and well-developed medical facilities. Interestingly, Japan, which has a relatively well-developed economy and health infrastructure, does not feature in the top 10 countries for number of studies or centrality, which may be related to Japan's medical and welfare system and cultural background. A Japanese study by Haga *et al.* investigated the establishment and application of pediatric RRSs in 34 medical institutions and found that only 14 medical institutions had an established pediatric RRS (41.2%). Among the 20 medical institutions that did not have an established pediatric RRS, 11 medical institutions hoped to establish an RRS, 14 did not have sufficient knowledge of RRSs, and 11 thought that establishing an RRS was difficult. Haga *et al.* concluded that the biggest obstacle to using an RRS was perceived personnel and/or funding shortages, which was unrelated to the number of beds in hospitals and pediatric departments (25). In a study by Loisa *et al.*, the authors found that when frequently participated in RRT, the nurses considered their work important and believed it fosters improved critical care skills (26). The authors also found that infrequent RRT participation, feeling overworked and/or undercompensated and conflicts between RRT and ward doctors were barriers for successful RRS among RRT nurses (26).

The results of this study demonstrate the general status of research in emergency RRSs and provide a valuable reference for researchers in this field. As a result of our findings, we hope that relevant literature can be retrieved more accurately. Development and cooperation provide important reference information. This study also has some limitations. Firstly, there were a large number of studies published in languages other than English, including Chinese, Japanese, German, and French, among which there were many high-quality studies. However, because this study only searched the SCI-E database, other studies that were not included in the database may have been overlooked, resulting in some deviation between the research results and the actual situation. Secondly, some studies did not use "rapid response system" as the topic term, but their content was closely related to RRS. These documents may have been missed during the search. Therefore, we suggest that efforts should be made in the future to standardize topic words and keywords to facilitate academic exchanges.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-709/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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