

A bibliometric and visualized analysis of safety culture research in healthcare during 1997-2015

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ABSTRACT

Safety culture research literature in healthcare has increased rapidly in last two decades, but there is no research to provide a macroscopic overview of this field. This bibliometric and visualized analysis was conducted based on Web of Science database to explore the characteristics of safety culture research. A bibliometric approach, along with CiteSpace software, was used to quantitatively and visually analyze the document type and language, publication trend, subject categories, journals, authors, countries, institutes, high-frequent citation articles and keywords in healthcare safety culture from 1997 to 2015. Meanwhile, the co-network and burst detection were also used to trace popular topics and frontiers in healthcare safety culture research. The amount of healthcare safety culture articles per year has a solid development in recent years. We identified the mainstream subject categories, core journals, productive first authors, leading countries and institutions, and their co-network relationship in healthcare safety culture research. There was an uneven distribution and poor collaboration of articles at authorial, institutional, and national levels. Except the search terms, the hottest keywords appearing in the articles were "quality", "management", "adverse events", "outcomes", "performance", and "teamwork". There were 22 burst terms concerning safety culture research in healthcare. The subject categories of "Health care sciences services", "Nursing" and "Health policy services" play a key role in safety culture research both in production and in the networks. "BMJ Quality and Safety" is the core journal of safety culture research. The USA and its institutions play a dominant role in the production, collaboration, citations and high quality articles in healthcare safety culture field. The research frontiers in healthcare safety culture research involve "children health", "infection control", "patient safety", "events/errors", "quality", "management", "intensive-care units", "measurement", and "strategy".

KEYWORDS

Safety culture research; Healthcare; Web of science; CiteSpace; bibliometric analysis

1 Background

The term "safety culture" first appeared after the Chernobyl nuclear power disaster in 1988, and then embraced in several industries, especially in high-reliability organizations. More recently, the focus on building a culture of safety has moved to the healthcare domain. Safety culture is the product of individual and group values, attitudes, competencies and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety programs^[1]. A positive safety culture will improve a healthcare institute's safety performance, while a negative safety culture not only threatens the patient safety, but also decreases the services quality,

image and branding of the healthcare organization ^[2]. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measure ^[1]. Safety culture has become a topic which cannot be ignored in health care field.

Since the publication of Institute of Medicine's landmark *To Err is Human* report ^[3], a growing body of peer-reviewed studies have demonstrated the importance of safety culture in healthcare safety improvement. At present, the research on safety culture in healthcare focuses on several points: (1) the concept, connotation, composition and characteristics of safety culture in healthcare ^[4]; (2) the evaluation tools, measurement dimensions and properties of healthcare safety culture ^[5-6]; (3) the current situation ^[7], evaluation and comparison of safety culture in different healthcare institutes (hospitals, nursing home) ^[8-9], various units (intensive units, surgical units) ^[10] and individual level (nurses, medial managers) ^[11]; (4) the relationship between safety culture in healthcare and the outcomes (patient satisfaction, adverse events, safety performance and so on) ^[12]; (5) Intervention and strategies for improving the safety culture in healthcare ^[13]; (6) systematic reviews ^[14]; (7) others ^[15]. The international research on safety culture in healthcare has made great contributions to patient safety insurance and safety performance improvement. All over the world, although there were systematic reviews on different aspects of safety culture research in healthcare, few studies have been performed to provide a macroscopic overview on healthcare safety culture research using the bibliometric method, probably due to language barriers and poor attention to the databases and international bibliometric softwares.

Bibliometrics is a statistical analysis of written publications ^[16], frequently used to provide quantitative analysis of academic literature. Many researchers use bibliometric methods to evaluate the scientific research patterns of authors, journals, countries, and institutes in global trends studies of specific fields ^[17]. The quantitative information related to spatial distribution of authors and the country/institution collaboration network could also be visually presented in bibliometric study by using some supplementary means ^[18]. Recent years have witnessed a great number of publications on safety culture in healthcare and related fields. From 1997 to 2015, the Science Citation Index Expanded (SCI-Expanded) and Social Science Citation Index (SSCI) of the Web of Science (WoS) database collected 1995 publications on safety culture in healthcare. Although much attention has been paid to the development of safety culuture, few papers attempted to gather global systematic data and conduct a large-scale review of scientific studies. In that respect, using bibliometric methods to quantitatively and visually explore global research trends in safety-culture-related research in healthcare is illustrative for providing evidence for the current status and trends in safety culture research all over the world, as well as clues to the impact of this popular topic, thus helping researchers understand the panorama of global safety culture research, and predict the dynamic directions of research. In this study, the records of literature are analyzed using several aspects of bibliometric methodology. The main body of this article includes bibliometric analyses in the document type and language, publishing year, subject categories, publication distribution, patterns of journals, countries/regions, institutes and authors ^[19-20]. In addition, appropriate statistical tests are used in the authors' keyword yearly to predict the developing trend of safety culture research in healthcare. Moreover, citation data will also be used as a bibliometric tool to indicate the intellectual impact of the research output.

2 Methods

2.1 Data resource

We collected the publications on safety culture in healthcare using the WoS database online

version published by Thomson Router ISI, operated by Thomson Scientific, Philadelphia, PA, USA ^[21]. The terms searched were extracted using text-supplied keywords from the National Library of Medicine's Medical Subject Headings thesaurus. Based on the literature sources ^[22], the search strategy of WoS was "TS= (safety culture* OR safety climate* OR culture of safety*) AND TS= (healthcare* OR hosp* OR long term care* OR nursing home* OR community*) AND TS= (patient safety* OR public safety*)".

2.2 Information extraction

CiteSpace is specifically designed to facilitate the detection of emerging trends and abrupt changes in scientific literature. Relevant publications can be retrieved via the publishing year, journal, affiliations of first author and keywords by using CiteSpace. Based on citation analysis theory, Citespace II software was developed by Doctor Chaomei Chen in Drexel University in America through JAVA computer programming language ^[23].

To be eligible for inclusion in the review, the studies had to be peer-reviewed and published before 1997. The reason we choose the start point of 1997 owes to few literatures related to safety culture in healthcare before 1997. The providers of health service system include clinicians, nurses, medical laboratory workers, hospital managers, or supervisors and medical students. Articles on safety culture element, safety culture scale/questionnaire, safety culture with medical error, patient safety culture with system were also included. However, studies with only hospital management, medical error, and culture innovation were excluded ^[24].

2.3 Data analysis

CiteSpace is used to generate and analyze networks of co-cited references based on bibliographic records retrieved from the WoS. In this paper, CiteSpace were employed to analyze the articles for knowledge mapping. The Thomson Data Analyzer™ desktop software which often offers a powerful function for managing and extracting scientific data within databases gives a statistical results for research work ^[25]. The distribution of the document types and language, the publishing year, subjects, journals, authors, countries, institutions, high-frequency articles as well as collaboration of WoS articles were thoroughly examined. Hotspots were analyzed through high-frequency keywords which had a frequency of ≥ 100 times. Then the research frontier was generalized according to the keywords with strongest citation bursts. Figures and tables were employed to describe the production and future trends of safety culture research in healthcare. Papers from the WoS database were studied carefully using bibliometric analysis.

3 Results and discussion

3.1 Document types and language of publications

Ten document types were identified in a total of 1995 publications. Journal articles (1745) were the most frequently used document type accounting for 87.47% of the total publications. They were followed by reviews (158; 7.92%), proceeding papers (106; 5.31%), and editorial materials (30; 1.50%), with the remainder of less than 3% including meeting abstract (13), book chapter (6), letters (3), reprint (1), a correction (1) and a book review (1). Following the conventions used in other bibliometric studies, we restrict further analysis to articles, which are peer-reviewed and represent original scientific development. Publications of all other types are thus removed from the analysis for the rest of this article.

The 1745 journal articles were published in ten languages, and 95.36% of the articles were published in English in the Web of Science. The non-English articles were published in German (31), Spanish (23), French (11), Korean (9), Portuguese (3), Italian (1), Japanese (1), Persian (1) and Slovenian (1), accounting for less than 5% of the total journal publications. One can see that most of the authors published their articles in English for wider dissemination. The other reason is that the SCI-Expanded and SSCI database mostly collected English journals instead of journals written in other languages.

3.2 Global publication trend

Figure 1 shows that a correlation between the number of publications and the publication year was observed, resulting in a linear curve (1997–2005) and a power curve (2005–2015), respectively. The power curve indicates a high growth rate for publications from 2005 to 2015, which may also predict a respective double or triple increase in the number of future articles published in 2017 and 2019 compared with those in 2015, based on the assumption that the growth rate will maintain at the same level found in 2005–2015. During the past two decades, WoS articles on safety culture in healthcare ranged from 8 in 1997 to 297 in 2015. WoS annual number of articles has overall grown gradually, especially after 2005, indicating that the research has recently garnered more attention. What's more, between 1997 and 2015, especially the last one decade, the percentage of articles on healthcare safety culture subject in WoS database increased from 0.46 to 17.02 %. The results agree with the publication trends, indicating that the research has recently garnered more attention compared with others. In 2005, several important articles were published, such as "Measuring patient safety climate: a review of surveys" by Colla, JB^[26] and "Assessing safety culture: guidelines and recommendations" by Pronovost, P^[27] all of whose citation frequency are in the top ten among 1745 articles. These may explain the reason why the number of publications and the attention to the healthcare safety culture research began to increase in 2005 and after. Moreover, WHO reports and related symposiums mentioned previously may also have played important roles during the process.

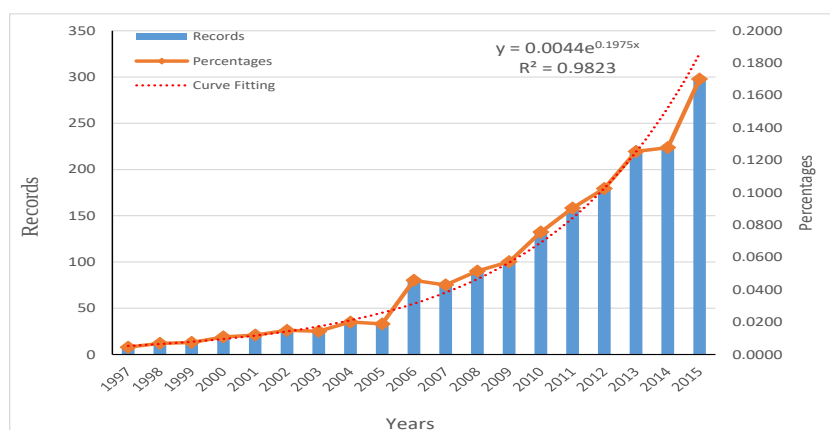


Figure 1 Safety culture research in healthcare and its related articles in WoS (1997–2015)

3.3 Subjects of research papers

Based on the classification of subject categories of WoS, the publications output data of safety culture research in healthcare was distributed in 135 subject categories during

1997–2015. The top ten subject categories based on the Journal Citation Report (JCR) are shown in Table 1.

Table 1 shows that the classification of subject categories of safety culture research in healthcare were all branches of medical science. The safety culture research in healthcare was mainly located in fields of health management (including health care sciences & services, health policy services) and clinical medical science (including nursing, medicine general internal, surgery, pediatrics, critical care medicine), where Pharmacology & Pharmacy also plays an important role. In addition, more studies have focused on public health science, including Public Environmental & Occupational Health and Infectious Diseases, wherein investigators study factors and interventions that influence the safety culture in healthcare to improve the medical quality. In addition, Table 1 further indicates that research in the 10 fields above began relatively early. The healthcare safety culture research in the subjects of Infectious diseases and Health care sciences services occupied a dominant position in the initial stages. At the same time, the number of scientific articles per category has seen a trend of rapid growth during the last decade, indicating that safety culture research in healthcare is in a stage of rapid development requiring more inputs.

To represent more synthetically the relations between categories, the subjects' categories co-occurrence network was drawn and visualized in Figure 2. In this network map, the centrality of a node representing a subject category is a graph-theoretical property that quantifies the importance of the node's position in a network. Figure 2 shows that in the scientific network map of safety culture research in healthcare, the centrality of the terms "health care sciences & services", "nursing", "health policy services", "Public" and "Infectious diseases" and so on is outstanding, indicating that these subjects play a key role in safety culture research in healthcare. These results all agree with the definition and prove that safety culture research in healthcare is not only interdisciplinary but healthcare safety culture researchers have to rise up to the challenge and acquire a multidisciplinary understanding to strengthen the cooperation between different disciplines.

Table 1 The main subjects of WoS papers on safety culture in healthcare research

No	Categories in WoS	1997-2005 (n=192)		2006-2015 (n=1553)		1997-2015 (n=1745)	
		Records	Percentages	Records	Percentages	Records	Percentages
1	Health care sciences services	25	0.1302	345	0.2222	370	0.2120
2	Nursing	4	0.0208	255	0.1642	258	0.1479
3	Health policy services	12	0.0625	240	0.1545	252	0.1444
4	Public environmental & occupational health	24	0.1250	203	0.1307	226	0.1295
5	Infectious diseases	38	0.1979	129	0.0831	167	0.0957
6	Medicine general internal	13	0.0677	128	0.0824	141	0.0808
7	Surgery	10	0.0521	76	0.0489	86	0.0493
8	Pediatrics	13	0.0677	58	0.0373	71	0.0407
9	Pharmacology & pharmacy	16	0.0833	54	0.0348	70	0.0401
10	critical care medicine	14	0.0729	52	0.0335	66	0.0378

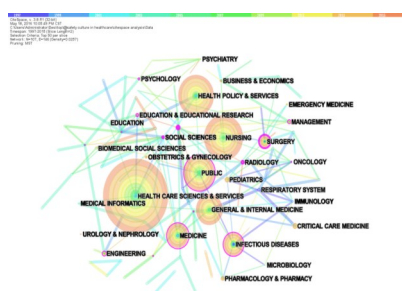


Figure 2 The co-occurrence network of subjects categories

3.4 Journals of publication

Thomson Reuters' WoS covers research published in more than 12,000 scientific journals and conference proceedings and is presently one of the most extensive sources of R&D outputs. In JCR 2012, 8,411 journals were listed as SCI journals and 3,016 journals were listed as SSCI journals. Healthcare safety culture research output was published in more than 500 journals, where the top-ranking 10 journals in the field of safety culture in healthcare are shown in Figure 3, which produced 20.34% of the overall safety culture studies in healthcare. The remaining journals make up a smaller percentage. The distribution of articles related to safety culture in the journals is relatively fragmented, where "BMJ Quality and Safety" (98) (also "Quality Safety in Health Care" before 2012), and "BMC Health Services and Research" (56) have published the most articles as a whole. There was a much lower concentration of healthcare safety culture research publications in these top journals, where just one-fifth of the articles are found in these top 10 core journals, a phenomenon that is not consistent with observation in other fields. Still and all, these journals are the core journals and they have played vanguard roles in the dissemination and exchange of knowledge in safety culture research in healthcare.

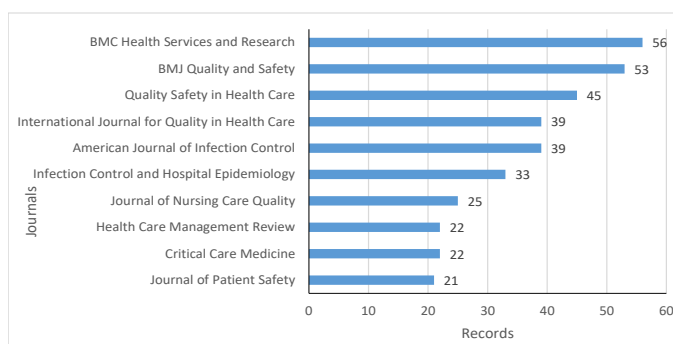


Figure 3 The top 10 journals publishing papers concerning safety culture in healthcare

Note: The journal "Quality Safety in Health Care" was the original name of the journal "BMJ Quality and Safety" before 2012.

3.5 Authorship and co-author

According to the WoS database, approximately 1535 researchers published 1745 articles related to safety culture and the average number of authors per paper is 1.14. The number of articles per author in safety culture field is relatively small, and few authors can publish more than 3 articles. Considering the volume of these published documents rather than their quality, the most productive authors in safety culture research in healthcare were Singer, SJ with 8 articles, followed by Naveh, E and Ausserhofer, D with 5 papers, El-Jardali, F, Vogus, TJ and some other authors with 4 articles. The 14 most productive authors whose name appears on more than 3 papers in WoS database are listed in Table 2 below, which can offer highly individualized scientific research information to other researchers.

A collaboration pattern for the productive authors was analyzed with Citespace, and the collaboration map is presented in Figure 4. The size of circles represents the amount of publications, and the link between two circles is inversely proportional to the collaboration between individual authors, i.e., more links suggest more collaboration, and the thicker the links, the stronger the collaboration. It can be noticed that many authors tended to cooperate with a small group of collaborators, generating several major clusters of authors, and these clusters usually have two or more core authors. Among all the authors, Peter J. Pronovost, Cordula Wagner, Rene Schwendimann

and J. Bryan Sexton are the top productive authors, who conduct the top 4 most cooperative positions. Similar to other bibliometric publications [28], author productivity analysis could be biased because two or more authors may have the same initial name, or authors may use different names in their publications (e.g., names changed due to marriage). So an “international identity number (IIN)”, which is offered to an individual when he/she first publishes in an ISI-listed journal, is exigently needed. It is certain that assigning and tracing IIN offers a method that would assess authorship more appropriately.

Table 2 The top 15 most productive authors

No.	First author	Records	Percentage(%)
1	Singer, S J	8	0.458 7
2	Naveh, E	5	0.286 7
3	Ausserhofer, D	5	0.286 7
4	El-Jardali, F	4	0.229 4
5	Vogus, T J	4	0.229 4
6	Castle, N G	4	0.229 4
7	Sexton, J B	4	0.229 4
8	Pronovost, P J	4	0.229 4
9	Dixon-Woods, M	4	0.229 4
10	Profit, J	4	0.229 4
11	Wagner, L M	4	0.229 4
12	Leape, L L	4	0.229 4
13	Kalisch, B J	4	0.229 4
14	Verbakel, N J	4	0.229 4

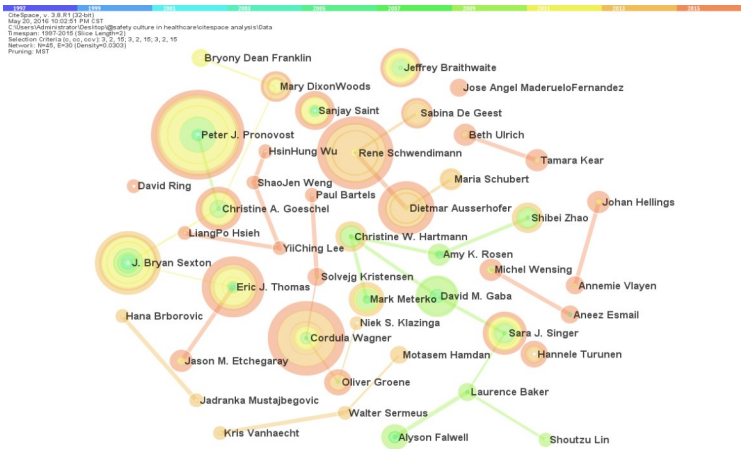


Figure 4 The combined mapping and clustering of productive authors

3.6 Countries of article and co-country

There are 74 countries/territories producing WoS papers on safety culture research over the investigation period. Among them, top countries producing these papers in Figure 5 note that most safety culture articles were contributed by the researchers from USA, then followed by England and Canada. Two North American countries, seven European countries, one Oceania country while no Asian, African and Southern American countries/territories ranked top 10 for WoS papers published. All of the top-ranking 10 countries are developed countries. It reflects the high economic activity and academic level of these countries.

Owing to the specialization of research activities of each nation, international collaboration could

be effective in promoting the creation, transmission, and sharing of knowledge, and in posing a serious obstacle to the diverse types of collective, exchangeable, and integrated knowledge [29]. Increasing globalization may increase of international collaboration in science and technology. The national cooperative network map of translational medical research has been drawn according to the national/regional cooperation data. As shown in Figure 6, a total network of higher density illustrates more cooperation between countries. Figure 6 shows that in the safety culture field in healthcare, various countries don't have close collaboration relationship with each other except England, Australia, Sweden, Germany and the Netherlands. Although USA is the country producing the most articles, it has little collaboration with other countries. Therefore, it is necessary to enhance the collaboration between different countries for more productive research on safety culture in healthcare.

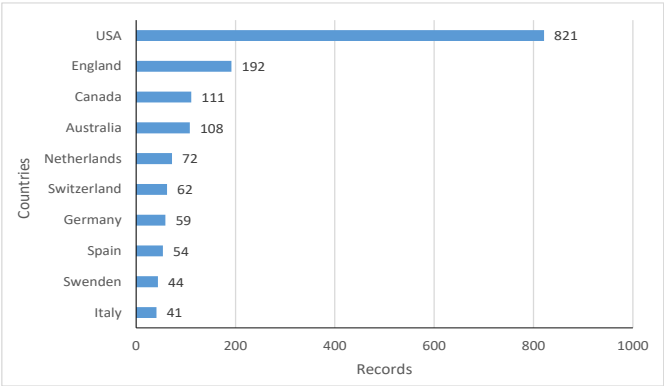


Figure 5 The top 10 countries contributing articles concerning safety culture in healthcare

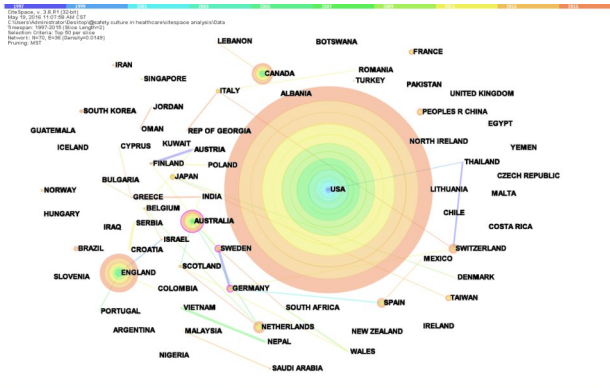


Figure 6 The co-authorship for WoS articles in different countries

3.7 Institutes of article and co-institution

The contribution of different institutes was assessed by the institute of the affiliation with at least one author in the published papers. According to Figure 7, Harvard University and the Johns Hopkins University performed well: they are two of the most powerful institutions in safety culture research. Researcher from Harvard University published 83 papers, ranking the first, followed by the Johns Hopkins University with 46 papers. In total, 11 of the 15 organizations belong to the United States, reflecting the overall dominating research power of the U.S. universities.

The independence and the dispersion of safety culture research in healthcare still exists in the co-institute map. Figure 8 shows that the density of the connection lines between various institutes is

low, reflecting the poor cooperation among them. Although the American institutes such as the Harvard University, Hopkins University, University of Pittsburgh, University of Michigan, and University of Manchester, have produced more safety culture articles, but they have less cooperation with other institutions from other countries. At the same time, apart from the little cooperation among the various agencies within the USA, the cooperation among different countries can hardly be seen. It can be found that the cooperation and collaboration between countries and institutions should be strengthened in the field of safety culture research to improve the contribution of the research in this field.

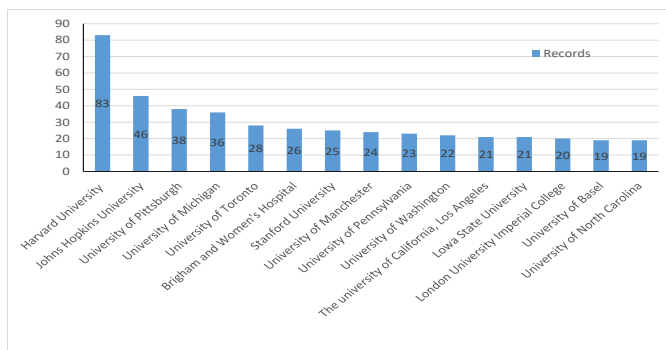


Figure 7 The institutes' distribution of WoS articles

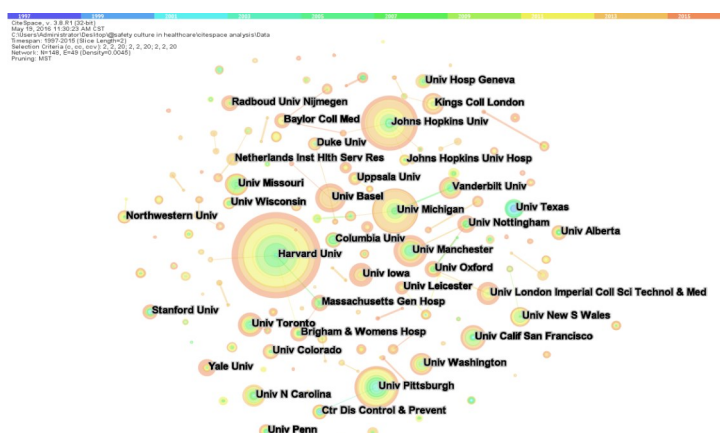


Figure 8 The co-authorship for WoS articles in different institutes

3.8 The most frequently cited articles

Although the number of citations in CiteSpace cannot indicate the quality of a publication, it can present its impact and/or visibility in patient safety culture research field. The top 10 most frequently cited articles from 1997 to 2015 were selected in Table 3. The most frequently cited article was "The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research", published in 2006 by Sexton, J B et al. It has been cited 133 times since it was published in BMC Health Services Research, which vastly exceeds the citation of the others publications on the health-care safety culture research field. These top cited papers were all authored by scientists from institutions in developed countries, and nine of them were conducted by American researchers with one English author exception.

Among these top ten most cited WoS articles in CiteSpace, many focus on the safety culture

measurement and evaluation in healthcare. For example, the 1st article ^[5] developed and validated the Safety Attitudes Questionnaire, the 2nd ^[26] and the 3rd ^[30] articles systematically summarized the safety culture measurement tools, and the 5th ^[31], 6th ^[32], 8th ^[33] and 9th ^[34] articles proposed the measure standards and advice of safety culture. The 4th ^[35] article explored the relationship between hospital safety climate and measures of hospital performance on selected indicators of patient safety, indicated that better safety climate was associated with lower risk of experiencing patient safety indicators. The 4th article is a much earlier article studying the relationship between the safety culture and the outcome variables. The 7th ^[36] and 10th ^[37] articles tried to improve the safety culture in healthcare through the intervention, which was an empirical exploration of safety culture promotion research.

Table 3 The top 10 most cited WoS articles in CiteSpace

No.	Time Cited	Authors	Title	Journal	Country	Year
1	133	Sexton J B, Helmreich R L, Neilands T B, et al	The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research	BMC Health Services Research	USA	2006
2	106	Colla J B, Bracken A C, Kinney L M, et al	Measuring patient safety climate: a review of surveys	Quality Safety in Health Care	USA	2005
3	85	Flin R, Burns C, Mearns K, et al	Measuring safety climate in health care	Quality Safety in Health Care	UK	2006
4	70	Sara Singer †, Lin S, Falwell A, et al	Relationship of Safety Climate and Safety Performance in Hospitals	Health Services Research	USA	2009
5	60	Singer S J, Gaba D M, Geppert J J, et al	The culture of safety: results of an organization-wide survey in 15 California hospitals	Quality Safety in Health Care	USA	2003
6	52	Huang D T, Clermont G, Sexton J B, et al	Perceptions of safety culture vary across the intensive care units of a single institution	Critical Care Medicine	USA	2007
7	62	Haynes A B, Weiser T G, Berry W R	A Surgical Safety Checklist to Reduce Morbidity and Mortality in a Global Population	New England Journal of Medicine	USA	2009
8	51	Singer S J, Gaba D M, Falwell A, et al	Patient Safety Climate in 92 US Hospitals Differences by Work Area and Discipline	Medical Care	USA	2009
9	50	Pronovost P, Sexton B	Assessing safety culture: guidelines and recommendations	Quality Safety in Health Care	USA	2005
10	48	Pronovost P; Needham D; Berenholtz S, et al	An intervention to decrease catheter-related bloodstream infections in the ICU	New England Journal of Medicine	USA	2006

Note: The journal "Quality & Safety in Health Care" was the original name of the journal "BMJ Quality and Safety" before 2012.

3.9 Keywords and co-words

Author keywords are the words used to uncover the internal structure of an author's reasoning. Author keywords provide the main information in articles and thus research trends can be obtained through analyzing these keywords. Based on the distribution of words in an author keyword

analysis, focused issues regarding safety culture research issues in healthcare could be explored.

Author keywords in safety culture research concerning healthcare field from 1997 to 2015 were calculated and ranked. The top 15 author keywords with the frequency no less than 100 used and distribution during the last 20 years are displayed in Figure 9 and Table 4, where research variations can be roughly grasped. Except for search words “patient safety”, “health-care”, “culture”, “safety”, “care”, “hospitals”, “climate”, “safety culture” and “nurses”, the top six most frequently used keywords were “quality”, “management”, “adverse events”, “outcomes”, “performance”, and “teamwork”. These high frequency keywords are the research hotspots in the field of health care safety culture.

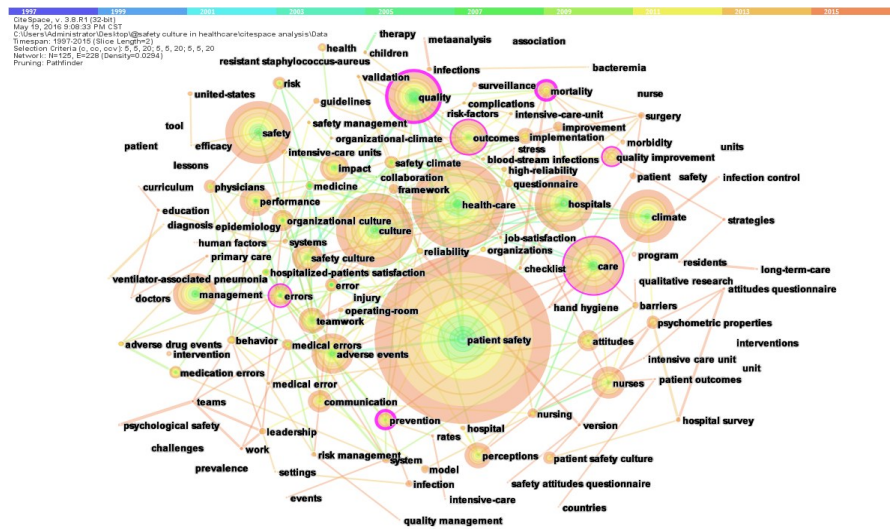


Figure 9 The clusters and Co-words maps of WoS articles

Table 4 The top 15 most cited keywords in CiteSpace

No.	Keywords	Frequency	Centrality
1	Patient safety	515	0.03
2	Health-care	285	0.02
3	Culture	236	0.03
4	Safety	226	0.07
5	Care	199	0.16
6	Hospitals	188	0.07
7	Climate	176	0.04
8	Quality	164	0.22
9	Management	159	0.01
10	Adverse events	152	0.06
11	Outcomes	131	0.05
12	Performance	116	0.03
13	Safety culture	110	0.00
14	Nurses	110	0.04
15	Teamwork	103	0.06

3.10 Research frontier of safety culture in healthcare

The research frontier is the most advanced and the best development potential research topic or research field in the scientific research. Dr Chen CM thought that the burst terms terminologies can

explore the emerging trends and sudden changes in disciplines development than the subject headings with the highest frequency [38]. We used the burst detection technology and algorithms provided by CiteSpace software to detect the words with high frequency changes from a large number of theme words through inspecting the frequency time distribution. Then the frontiers on safety culture research in healthcare were uncovered, depending on the frequency and change trend of theme words. This paper detected 22 burst terms on the basis of burst terms terminology, and we classify them into 9 kinds according to the research directions (Figure10 and Table 5).

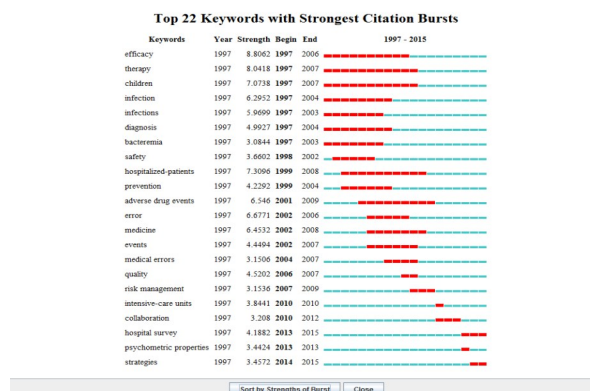


Figure 10 The top 22 keywords with the strongest citation bursts

Table 5 The frontier keywords of safety culture in healthcare in WoS

No. and frontier kinds	Burst Year	Burst words	Burst value
Children health	1997-2006	Efficacy	8.8062
	1997-2007	Therapy	8.0418
	1997-2007	Children	7.0738
Infection control	1997-2004	Infection	6.2952
	1997-2003	Infections	5.9699
	1997-2004	Diagnosis	4.9927
	1997-2003	Bacteremia	3.0844
Patient safety	1998-2002	Safety	3.6602
	1999-2008	Hospitalized-patients	7.3096
	1999-2004	Prevention	4.2292
Adverse events/eros	2001-2009	Adverse Drug Events	6.546
	2002-2006	Error	6.6771
	2002-2008	Medicine	6.4532
	2002-2007	Events	4.4494
	2004-2007	Medical errors	3.1506
Quality	2006-2007	Quality	4.5202
Management	2007-2009	Risk management	3.1536
Intensive-care units	2010-2010	Intensive-care units	3.8441
	2010-2012	collaboration	3.208
Measurement	2013-2015	Hospital survey	4.1882
	2013-2013	Psychometric properties	3.4424
Strategy	2014-2015	Strategies	3.4572

Table 5 shows that in the field of safety culture research in health care, the nine main frontier directions include "children health", "infection control", "patient safety", "events/errors", "quality", "management", "intensive-care units", "measurement" and "strategy". Of these frontiers, 2 kinds (measurement and strategy) including 3 keywords (hospital survey, psychometric properties and strategies) have shown significantly high burst strengths in the past 3 years, which are the recent

research frontiers.

Children health: No matter in the past or the future, the safety culture in the field of pediatric health care is attracting increasing interest of the researchers, and there has been virtually some analysis of the safety culture in pediatric hospital settings ^[39-40] so far, despite the development and psychometric assessment of safety culture.

Infection control: A growing body of evidence reveals the importance of evaluating and improving safety culture in efforts to eliminate healthcare-associated infections ^[41]. Efforts to improve safety culture together with continued training, monitoring and improvement in infection prevention practices, are likely to reap the benefit of changes in intended and actual behavior.

Patient safety: One crucial factor crucial that contributes to achieving patient safety falls under the term "safety culture". It is increasingly believed that safety culture is a major determinant of patient safety ^[42]. The ultimate goal of developing health care safety culture is to maintain and improve patient safety. Patient safety is the core of safety culture research. In the present and the future, it is the most popular and the hottest key words in the literature.

Events/errors: Events or errors in the field of health care safety culture mainly include: Adverse Drug Events ^[43], Error, Medicine, Events and Medical errors. Patient safety culture is an important factor in the effort to reduce errors or events in the hospital and improve patient safety. At present, a few studies have shown the relationship between patient safety culture and adverse events. In the future, the study on the relationship between events/errors and safety culture may continue.

Quality: Assessment of the safety climate can correlate with the safety outcomes in a unit. Sexton et al ^[44] demonstrated that Safety WalkRounds™ improve teamwork and decrease burnout. Those healthcare institutes with strong group and developmental cultures are considered more receptive to quality improvement. In terms of quality, some researchers also explored the relationship between safety culture, patient satisfaction, job performance, and so on ^[12], which shows the importance of quality in the study of safety culture.

Management: Improving management level is an important means and method to improve the safety culture in the field of health care. The research on safety culture management mainly focuses on the management as the means of intervention and strategy to improve the safety culture, such as lean management ^[45] and so on. Other aspects also include strengthening supervision, strengthening teamwork, and improving the relationship between managers and medical staff and patients, etc.

Intensive-care units: Intensive care units are generally considered as a highly hazardous section. Since the first published peer reviewed ICU Management Questionnaire was piloted by Sexton and colleagues ^[46], various methods have been used to enhance and work on the intensive-care-unit safety climate. However, the keyword "intensive-care units" just burst in 2010 and didn't appear from then on, implying little attention the researchers will concentrate on this field.

Measurement: Involving high risk for morbidity and mortality, the healthcare industry is considered to be a high hazard industry. Hence, assessing the current situation is a critical first step to improving the safety climate. Five years ago, the Institute of Medicine (IOM) recommended that healthcare organizations should work to enhance their patient safety culture. Since then, surveys measuring patient safety climate in healthcare organizations have begun to emerge ^[47]. So far, more than ten survey tools that measure safety climate are available. They vary considerably with regard to characteristics, dimensions covered, psychometrics performed, and uses in studies ^[30]. In the future, it is still an important frontier to measure the safety culture and to develop new testing tools in the field of health care safety culture.

Strategy: Positive safety climate has been reported to be associated with enhanced patient safety. Therefore, targeting practice change through safety climate is considered to be a key strategy for strengthening and enhancing patient safety and outcomes in healthcare institutes ^[48-49]. There

were a number of different safety culture strategies tested, including leadership walk rounds ^[50], structured educational programs ^[51], team-based strategies ^[52], simulation-based training programs ^[53], multi-faceted unit-based programs and multi-component organizational interventions ^[54]. In the future, it will be a research hotspot and frontier through different methods to improve the safety culture in health care field continually.

4 Conclusion

Safety culture is increasingly regarded as an important strategy and perhaps a necessary precursor to filling the widespread deficits in patient safety. Our research is the first time to make a macroscopic review on safety culture research in healthcare through bibliometric and visualized analysis. This study will help to understand the developing process and trends in safety culture for related researchers, institutes and journals. Based on 1745 articles in WoS database, significant points, collaboration network, and burst detection of keywords about safety culture research in healthcare were obtained using the bibliometric and visualized analysis, providing a systematic and microscopic overview of safety culture research from 1997 to 2015.

Ten document types relating to safety culture research in healthcare were found in a total of 1995 publications and almost all of the 1745 articles are published in English. The reason is that the WoS database mostly collects papers from English language journals rather than papers published in other languages. The number of publications has grown significantly each year, especially during the period of 2005–2015. Judging from this trend, we can predict that the number of related articles in this domain will keep this trend and continue to growth rapidly. The safety culture research articles in healthcare are mainly concerning in the fields of health management, clinical medical science and Pharmacology & Pharmacy. Meanwhile, “health care sciences & services”, “nursing”, and “health policy services” also play a significant role in safety culture research subjects’ categories co-occurrence network. Moreover, more attention has been paid to “Public”, “Environmental & Occupational Health” and “Infectious Diseases” in recent years. It is clear that safety culture research in healthcare will be a focus in the public health field besides clinical science in future. The top two most productive journals are “BMJ Quality and Safety”, and “BMC Health Services and Research”. The literature was published in more than 74 countries/territories, where USA, England and Canada were ranked as the top three countries for total articles on safety culture research in healthcare. The USA and its institutions play a dominant role in the production, collaboration, citation and high quality articles. In the perspective of collaboration, the research papers were mainly completed by multi authors, but each author produced fewer article. The top ten most cited WoS articles in CiteSpace mainly focus on the safety culture measurement and evaluation in healthcare, indicating the significance of culture assessment and tools development.

Except for the search terms, the top six most frequently used keywords were “quality”, “management”, “adverse events”, “outcomes”, “performance”, and “teamwork”, and these keywords are the mainstream topics in the study field. As for the frontiers, the nine main fields include “children health”, “infection control”, “patient safety”, “events/errors”, “quality”, “management”, “intensive-care units”, “measurement” and “strategy”.

5 Limitation

Related articles were extracted with text-supplied keywords from the National Library of Medicine’s Medical Subject Headings thesaurus. In order to improve the criteria, articles in journals related to “healthcare*” and “safety culture” were included, and the articles which do not belong to

the related subjects were excluded. However, the benefits of bibliometric and visualized analysis are debatable. The identification of the suitable terms identifying safety culture research in healthcare may be a matter for further studies. Due to limited resources and research levels, this paper only searched scientific articles in the WoS, whose content has certain limitations. In addition, methods of bibliometric analysis and visualization technologies are relatively fresh perspective but lacking innovation for its new application in this field. Moreover, a lack of regularity in the key words (extracting 20% keywords according to the law of two to eight) also impacts the analysis process and results.

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