

Original Article

Enteral nutrition bibliometry from 2010 to 2019

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Background and Objectives: This study aimed to describe and analyze the research outputs on enteral nutrition, which is the administration of food through the gastrointestinal tract for nutrition maintenance. **Methods and Study Design:** We searched the Web of Science Core Collection database for original publications on enteral nutrition research from 2010 to 2019. HistCite and VOSviewer software were used for analysis and visualization of the publication outputs, journals, institutions, keywords, cocitations, and collaborations among authors in different countries or regions. **Results:** A total of 963 relevant articles were included. The number of publications in 2010 and 2019 were 68 and 139, respectively. *Nutrition in Clinical Practice* and *the Journal of Parenteral and Enteral Nutrition* had the highest number of publications and cocitations (76, 7.89%; 2058), respectively. The United States and China were the top contributors, accounting for 24.1% and 22.3% of the total articles, respectively. Andrew S. Day and Stephen A. McClave were core researchers in this field. Primary authors collaborated closely. Enteral nutrition, parenteral nutrition, and support were the three most common keywords. The top 10 co-cited references concerned administering early enteral nutrition therapy in acutely ill patients and patients with acute Crohn's disease. Crohn's disease, acute pancreatitis, upper gastrointestinal malignancy, and other surgical diseases were among the research hotspots. **Conclusions:** Our findings can help researchers identify notable research trends and clinically relevant articles. New catheterization technologies are a future research direction.

Key Words: enteral nutrition, bibliometry, visualization analysis, developing trends, research hotspots

INTRODUCTION

Enteral nutrition is a treatment involving the provision of necessary nutrients through the digestive tract to maintain adequate nutrition for patients with functional digestive tracts but whose clinical conditions prevent them from orally satisfying their nutritional needs.¹ Enteral nutrition is associated with lower risks of infections and complications compared with parenteral nutrition.² Because of its cost effectiveness, safety, and effectiveness, enteral nutrition is the preferred nutritional support method for multiple diseases.³ Early enteral nutrition is the gold standard of nutritional treatment for patients with severe acute pancreatitis,⁴ who are undergoing major abdominal surgery,⁵ or who are critically ill.⁶

Enteral nutrition is also associated with satisfactory patient outcomes, including immunocompetence and intestinal integrity and motility.⁷ Enteral nutrition support is widely used to prevent malnutrition in patients with specific cancers, such as esophageal cancer.⁸ Notably, not all patients can tolerate enteral nutrition and may present with gastrointestinal symptoms, such as diarrhea, distension, gastric retention, and vomiting, all of which can lead to insufficient enteral caloric intake,⁹ prolonged mechanical ventilation and hospitalization, and increased mortality. Notably, the incidence of diarrhea associated with enteral nutrition ranges between 2.00% and 63.0%.¹⁰ Alt-

hough enteral nutrition constitutes a research hotspot, few studies have conducted bibliometric analysis on it.

The widely recognized Science Citation Index Expanded (SCI-E) database contains mostly high-quality scientific publications. Bibliometric analysis is useful for identifying developing trends and research hotspots as well as for predicting research foci in specific domains. In the present study, the annual publication number, journals, countries or regions, institutions, authors, keywords, and most cited articles related to enteral nutrition were determined.

METHODS

Data source and search strategy

On February 20, 2020, we searched the Web of Science Core Collection of the SCI-E database for publications on enteral nutrition between 2010 and 2019, using "enteral

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nutrition” as the primary search term. The language was set to “English”, and document types were limited to “article” and “review”. Of the 966 articles retrieved, 3 with unknown authors were excluded, leaving 963 articles for analysis.

Data analysis

The articles were imported into software applications for further analysis. HistCite 12.03.17 software (<http://www.histcite.com>) was used to analyze publication year and co-cited references.¹¹ VOSviewer v1.6.14 software was used to identify journals, co-cited journals, countries or regions, institutions, authors, co-cited authors, and co-occurring keywords; to create mapped visualizations of the authors co-authorship, countries or regions co-authorship and keywords co-occurrence.^{12,13} Journal impact factors were obtained from the 2018 Journal Citation Reports.¹⁴

RESULTS

Publication outputs

Of the 963 publications retrieved, 818 were articles and 145 were reviews. As shown in Figure 1, publication numbers were 68 in 2010 and 139 in 2019, indicating an increasing trend with slight fluctuations.

Journals

The articles retrieved were published in 323 journals. Table 1 presents the top 10 journals and co-cited journals

(i.e., journals cited with other journals). Among the top 10 journals, which accounted for 347 (36.0%) of the publications, *Nutrition in Clinical Practice* (76, 7.89%) ranked first. Four were from the United States, two were from England, and the remaining four were from Switzerland, Scotland, Spain, and Australia. The impact factors of the most productive journals (40.0%, 30.0%, 10.0%, and 20.0% in quartiles 1-4, respectively) ranged from 0.75 (*Nutricion Hospitalaria*) to 6.96 (*Critical Care*). Among the top 10 co-cited journals, *the Journal of Parenteral and Enteral Nutrition* (2058 citations) ranked first; eight were from the United States, and the remaining two were from Scotland and England. The impact factors of the most active journals (50.0%, 20.0%, and 20.0% in quartiles 1-3, respectively) ranged from 2.59 (*Nutrition in Clinical Practice*) to 19.8 (*Gastroenterology*).

Countries or regions and institutions

The articles were from 55 different countries or regions. The United States was the top contributor to publications (232 records, 24.1%), followed by China (215 records, 22.3%) and Japan (69 records, 7.17%; Table 2). The United States also had the highest citation number of 5416. The top 10 countries or regions contributed to 845 (87.8%) articles. The top three institutions were Nanjing University (39 records, 4.05%), the University of Louisville (16 records, 1.66%), and Nanjing Medical University (15 records, 1.56%). In total, the top 10 institutions accounted for 161 publications, and the University of



Figure 1. Publication outputs from 2010 to 2019.

Table 1. Top 10 journals and co-cited journals

Rank	Journal	N (%)	Country	IF (2018)	Quartile	Co-cited journal	Citation	Country	IF (2018)	Quartile
1	<i>Nutr Clin Pract</i>	76 (7.89)	USA	2.59	Q3	<i>Jpen-Parenter Enter</i>	2058	USA	4.11	Q1
2	<i>Jpen-Parenter Enter</i>	71 (7.37)	USA	4.11	Q1	<i>Clin Nutr</i>	1657	Scotland	6.40	Q1
3	<i>Nutrients</i>	42 (4.36)	Switzerland	4.17	Q1	<i>Crit Care Med</i>	1390	USA	6.97	Q2
4	<i>Clin Nutr</i>	34 (3.53)	Scotland	6.40	Q1	<i>Nutr Clin Pract</i>	927	USA	2.59	Q3
5	<i>Nutr Hosp</i>	31 (3.21)	Spain	0.75	Q4	<i>Intens Care Med</i>	681	USA	19.0	Q1
6	<i>Asia Pac J Clin Nutr</i>	26 (2.70)	Australia	1.38	Q4	<i>Nutrition</i>	669	USA	3.59	Q2
7	<i>Nutrition</i>	20 (2.08)	USA	3.59	Q2	<i>Ann Surg</i>	651	USA	9.48	Q1
8	<i>J Pediatr Gastr Nutr</i>	17 (1.77)	USA	3.02	Q2	<i>Gastroenterology</i>	584	USA	19.8	Q2
9	<i>Eur J Clin Nutr</i>	16 (1.66)	England	3.11	Q2	<i>J Pediatr Gastr Nutr</i>	536	USA	3.02	Q3
10	<i>Crit Care</i>	14 (1.45)	England	6.96	Q1	<i>Gut</i>	512	England	17.9	Q1

N: number; IF: impact factor.

Table 2. Top 10 countries and institutions

Rank	Country	N (%)	Citation	Institution (Country)	N (%)	Citation
1	USA	232 (24.1)	5416	Nanjing University (China)	39 (4.05)	474
2	China	215 (22.3)	1618	University of Louisville (USA)	16 (1.66)	1017
3	Japan	69 (7.17)	681	Nanjing Medical University (China)	15 (1.56)	111
4	Spain	59 (6.13)	1493	Zhejiang University (China)	15 (1.56)	45
5	Australia	56 (5.82)	1319	University of Tennessee (USA)	14 (1.45)	884
6	England	53 (5.50)	1575	Mayo Clinic (USA)	13 (1.35)	139
7	Canada	45 (4.67)	1128	University of Glasgow (England)	13 (1.35)	353
8	Brazil	41 (4.26)	386	Sun Yat-sen University (China)	12 (1.25)	104
9	Netherlands	40 (4.15)	1629	Tel Aviv University (Israel)	12 (1.25)	1007
10	Italy	35 (3.63)	908	University of Alberta (Canada)	12 (1.25)	186

N: number.

Louisville had the highest citation number of 1017.

VOSviewer was used to construct visualization maps of co-authorship by country or region. Out of the 55 countries or regions, 31 had at least five publications. Each frame on the maps represents a country or region, and the frame size indicates the number of publications. As shown in Figure 2, the largest set of connected countries or regions consisted of 30 countries or regions in five clusters. The maps provide valuable information for identifying potential collaborations. Researchers from the

United States frequently collaborate with those from China, Japan, Canada, and South Korea.

Authors

In total, 5168 co-cited authors (i.e., authors cited with other authors) were noted. Table 3 presents the top 10 authors, who contributed to 125 (13.0%) articles, and co-cited authors. Jieshou Li and Stephen A. McClave were the first ranked author and co-cited author, with 26 articles (2.70%) and 385 citations, respectively.

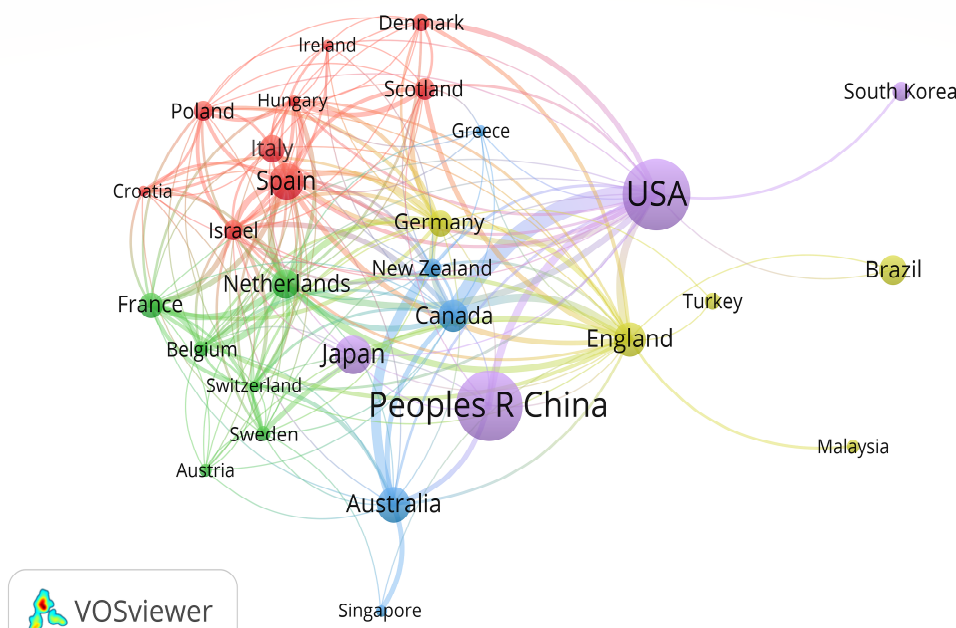


Figure 2. VOSviewer network visualization map co-authorship by country or region.

Table 3. Top 10 authors and co-cited authors

Rank	Author	N (%)	Co-cited author	Citation
1	Li JS	26 (2.70)	Mcclave SA	385
2	Li N	17 (1.77)	Heyland DK	300
3	Day AS	12 (1.25)	Doig GS	146
4	Gerasimidis K	11 (1.14)	Marik PE	146
5	Mcclave SA	11 (1.14)	Yamamoto T	113
6	Hur RT	10 (1.04)	Petrov MS	101
7	Li Y	10 (1.04)	Kudsk KA	99
8	Zhu WM	10 (1.04)	Day AS	96
9	Guenter P	9 (0.93)	Kreymann KG	93
10	Klek S	9 (0.93)	Mehta NM	93

N: number.

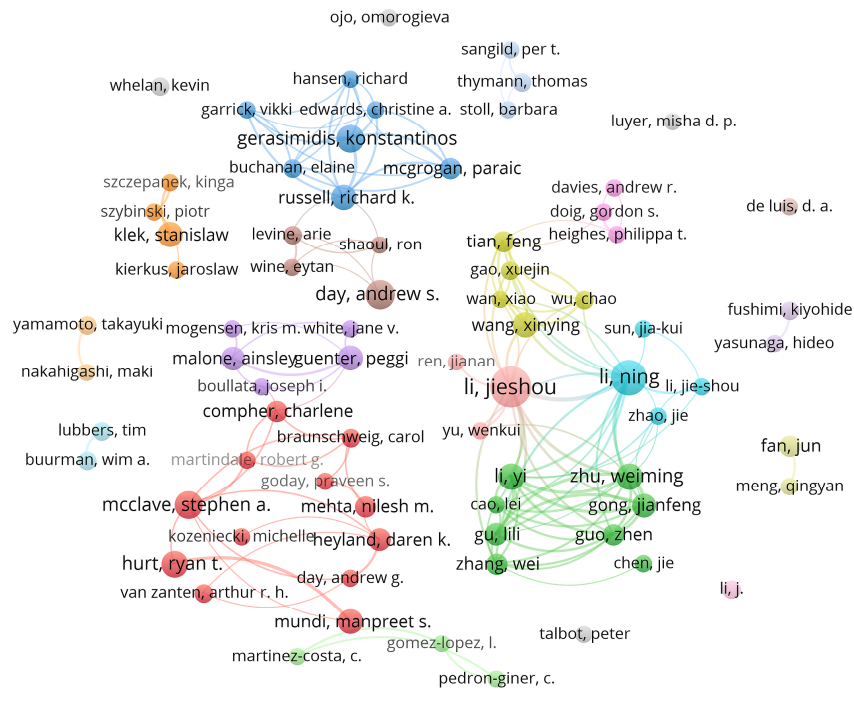


Figure 3. VOSviewer network visualization map of co-authorship.

The 75 coauthors had at fewest four publications and formed 22 clusters. In Figure 3, each dot represents an author, and the dot size indicates the documents. The closer together two dots are, the closer the collaborative relationship between the two authors. Research teams that frequently worked together were noted. A. McClave had the closest collaboration with other authors.

Keywords

A total of 3252 keywords were extracted. A network map of keyword co-occurrence was generated with 106 terms that occurred no fewer than 15 times, and these terms were further divided into five clusters. Enteral nutrition, support, children, malnutrition, and nutrition were the

keywords with the highest frequency in Clusters 1-5 (red, green, blue, yellow, and purple), respectively (Figure 4). Each dot represents a keyword, and the dot size indicates its frequency of occurrence. The shorter the distance between two keywords, the closer their association.

As shown in Figure 5 and Table 4, the top 20 keywords were all from publications between 2014 and 2015. They concerned nutrition (e.g., parenteral nutrition and nutritional support) and conditions such as inflammatory bowel disease, Crohn’s disease, and malnutrition. In descending order, the five most frequently occurring keywords were enteral nutrition, parenteral nutrition, support, guidelines, and children, with 458 (14.1%), 193, 163,

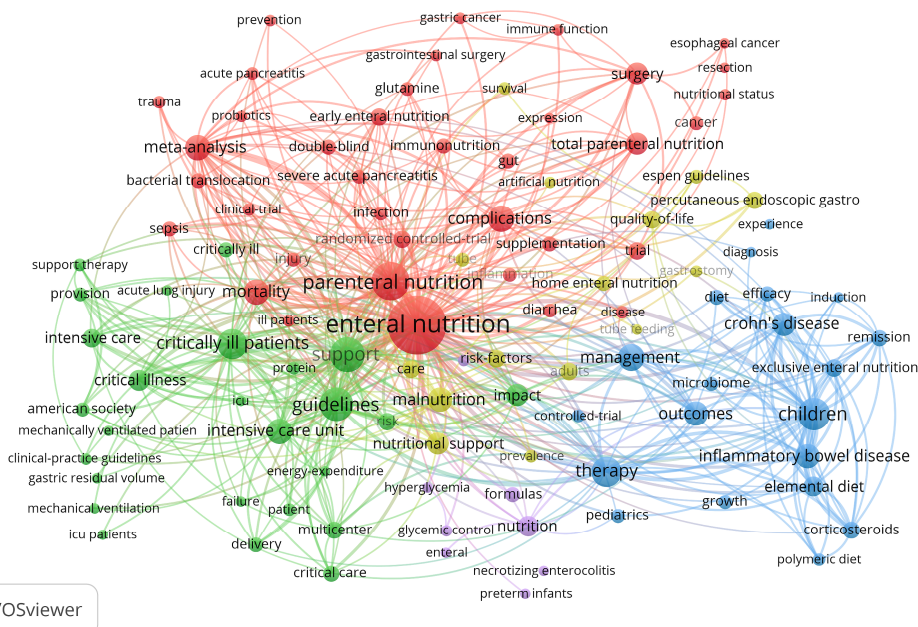


Figure 4. VOSviewer network visualization map of keyword co-occurrence.

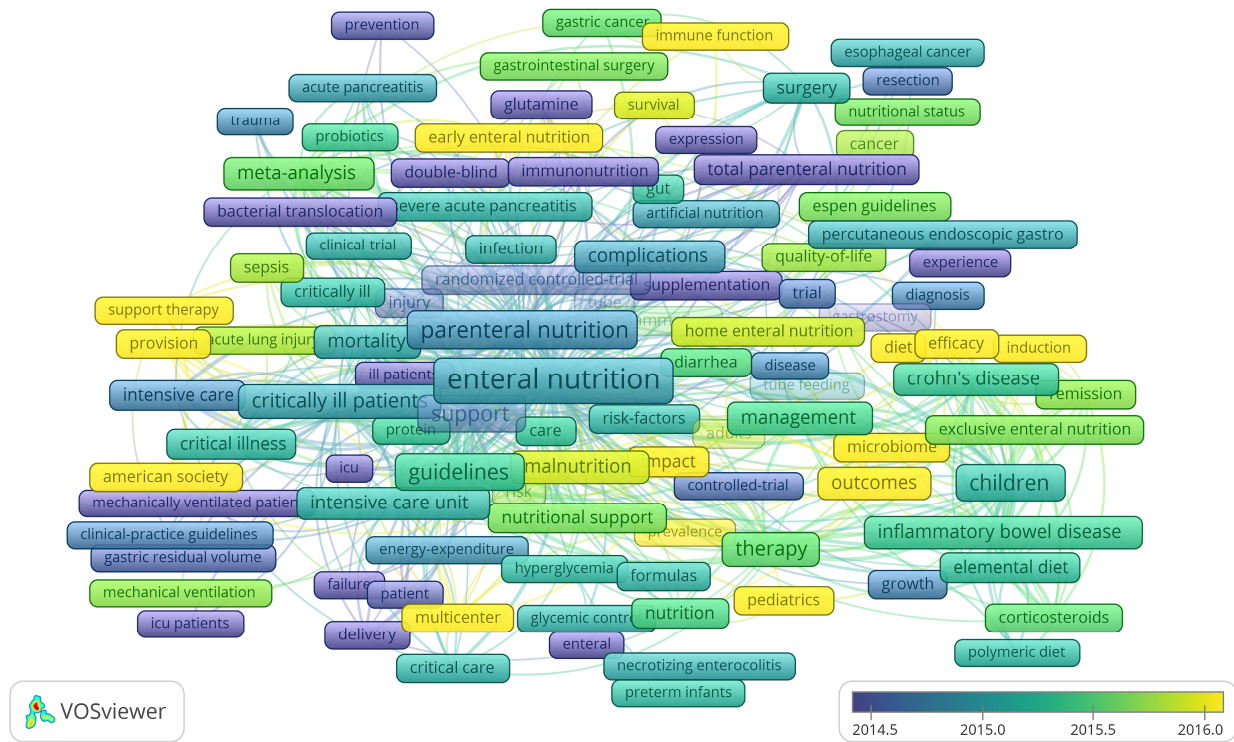


Figure 5. VOSviewer overlay visualization map of keyword co-occurrence over time.

Table 4. The 20 most frequently occurring keywords by average publication year and average citation numbers

Rank	Keyword	Occurrence	Avg. pub. Year	Avg. citation
1	Enteral nutrition	458	2015	12
2	Parenteral nutrition	193	2015	16
3	Support	163	2015	16
4	Guidelines	145	2015	21
5	Children	139	2015	13
6	Therapy	125	2016	15
7	Critically ill patients	117	2015	16
8	Management	97	2015	12
9	Complications	95	2015	16
10	Meta-analysis	90	2016	15
11	Mortality	87	2015	18
12	Intensive care unit	84	2015	27
13	Malnutrition	83	2016	12
14	Inflammatory bowel disease	81	2015	15
15	Outcomes	77	2016	8
16	Crohn's disease	74	2015	15
17	Nutritional support	64	2016	10
18	Surgery	64	2015	13
19	Total parenteral nutrition	64	2014	21
20	Impact	63	2016	10

Avg. pub. Year: average publication year; Avg. citation: average citation.

145, and 139 occurrences, respectively.

Co-cited references

The top 10 co-cited references (i.e., publications cited with others by two or more scholars) were cited more than 635 times (Table 5). The first ranked paper, written by Stephen A. McClave and published in *the Journal of Parenteral and Enteral Nutrition*,¹⁵ had 116 cocitations, of which five and four were co-cited between 50 and 100 times and between 40 and 50 times, respectively.¹⁶⁻²⁴

DISCUSSION

The number of scientific outputs from a field reflects its development.²⁵ Enteral nutrition therapy has existed since it was first developed in ancient Egypt, but the most effective formulas and techniques were developed only in the 20th century.²⁶ The increasing annual publication number between 2010 and 2019 (68 and 139 publications, 7.06% to 14.4%) demonstrates the constant scholarly attention that has been paid to this topic.

Each journal contributed to an average of 2.98 publications. Overall, 24.2% and 14.9% of the journals account-

Table 5. Top 10 co-cited references

Rank	First author	Article	Journal	Year of publication	Number of citations	IF (2018)
1	McClave SA	Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.)	<i>Jpen-Parenter Enter</i>	2009	116	4.11
2	Kreymann KG	ESPEN guidelines on enteral nutrition: Intensive care	<i>Clin Nutr</i>	2006	91	6.40
3	Heyland DK	Canadian clinical practice guidelines for nutrition support in mechanically ventilated, critically ill adult patients	<i>Jpen-Parenter Enter</i>	2003	73	4.11
4	McClave SA	Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (ASPEN)	<i>Jpen-Parenter Enter</i>	2016	58	4.11
5	Marik PE	Early enteral nutrition in acutely ill patients: A systematic review	<i>Crit Care Med</i>	2001	52	6.97
6	Doig GS	Early enteral nutrition, provided within 24 h of injury or intensive care unit admission, significantly reduces mortality in critically ill patients: a meta-analysis of randomised controlled trials	<i>Intens Care Med</i>	2009	51	19.0
7	Heuschkel RB	Enteral nutrition and corticosteroids in the treatment of acute Crohn's disease in children	<i>J Pediatr Gastr Nutr</i>	2000	49	3.02
8	MOORE FA	Early enteral feeding, compared with parenteral, reduces postoperative septic complications - the results of a metaanalysis	<i>Ann Surg</i>	1992	49	9.48
9	Borrelli O	Polymeric diet alone versus corticosteroids in the treatment of active pediatric Crohn's disease: A randomized controlled open-label trial	<i>Clin Gastroenterol H</i>	2006	48	7.96
10	Zachos M	Enteral nutritional therapy for induction of remission in Crohn's disease	<i>Cochrane Db Syst Rev</i>	2007	48	7.76

IF: Impact factor.

ed for three articles or more and two articles, respectively. The remaining 61.0% contributed one publication each. These results demonstrate that most of the journals published relatively few studies on enteral nutrition. With 76 publications, *Nutrition in Clinical Practice* was an exception. Among the top 10 journals and co-cited journals, 40.0% and 80.0% were from the United States, respectively. This indicates that US journals were not only prolific but attract numerous cocitations. Half of the 10 most co-cited journals were also among the top 10 journals, and 6 of the top 10 co-cited journals had impact factors over 5, indicating that high-impact journals were co-cited more frequently and had more influence in this field.

In total, 1653 institutions from 55 countries or regions (the United States, China, and Japan being the top contributors) accounted for the 963 publications analyzed. The United States and China contributed to 24.1% and 22.3% of the publications, respectively. Among the top 10 countries, China and Brazil were the only developing countries. This suggests that developing countries have weaker research capacity in this field; therefore, they should take measures to promote research and learn actively from developed countries. The seven top institutions, which accounted for 124 publications, were from China and the United States, demonstrating their substantial contributions to enteral nutrition research. The network visualization map of co-authorship by country or region revealed positive collaborations between the United States and other countries.

In total, 86.8% of the 5168 authors contributed to one publication. The top 10 authors and Jieshou Li, the most productive author, contributed to 13.0% and 2.70% (26 publications), respectively. The results indicate that few authors were prolific. Andrew S. Day and Stephen A. McClave both ranked among the top 10 authors and co-cited authors. The network visualization map of co-authorship revealed close collaborations between primary authors.

High-frequency keywords can accurately identify major topics in a field. Of the 3252 keywords labeled, 65.7% appeared only once and 4.67% appeared more than 10 times, indicating that relatively few keywords were used frequently. Network graphs of keyword occurrence can reflect research hotspots.²⁷ In the present study, five clusters were identified in the network visualization map of keyword co-occurrence. Most studies on enteral nutrition focus on the fields of nutrition, gastroenterology, hepatology, endocrinology, and nursing.²⁸ The present cluster analysis of the high-frequency keywords identified Crohn's disease, acute pancreatitis, upper gastrointestinal malignancy, and other surgical diseases as research hotspots in this field.²⁹⁻³¹ Furthermore, relevant studies primarily include critically ill patients in intensive care units, patients with malnutrition, and children. To ensure timely administration of nutrition therapy, nursing staff should pay more attention to nutrition risk screening. Enteral nutrition should be delivered as soon as possible for critically ill patients and postoperative patients who cannot consume food orally.³² Furthermore, because childhood is a unique developmental stage, health care practitioners treating children should take additional care regarding nutritional interventions, for which the route,

method, type, and timing differ from those for adult patients.³³ Other research hotspots include comparisons of enteral and parenteral nutrition, early postoperative refeeding, blind insertion, feeding practice approaches, management of intestinal complications, and risk factors. The emergence of feeding practice approaches and blind insertion demonstrates recognition of the clinical importance of thoroughly evaluating patients' conditions and selecting a personalized and appropriate feeding approach. Future research directions include the development of simple, safe, minimally invasive, and effective catheterization technology.³⁴ In addition, safety management for enteral nutrition during infusion and its associated complications are the focus of scholarly attention. Nursing staff administering enteral nutrition therapy should standardize its operations, ensure safe infusion, and identify and treat complications in a timely manner.³⁵

Among the 10 most co-cited references, six publications (four guideline articles and two meta-analyses) concerned the delivery of early enteral nutrition to acutely ill patients.¹⁵⁻²⁰ All of them recommended that early enteral nutrition be administered preference to parenteral nutrition to patients in intensive care if their nutritional needs could not be met orally within 3 days. Early enteral nutrition support is regarded as a proactive therapeutic strategy that may reduce disease severity, the occurrence of infectious complications, the length of intensive care hospitalization, and mortality rates and otherwise favorably affect patient outcomes. One study reported that early enteral nutrition reduced postoperative septic complications more effectively than did parenteral nutrition.²² Three articles concerned using enteral nutrition to treat acute Crohn's disease. Heuschkel noted no differences between enteral nutrition and corticosteroid therapy in treatment efficacy for acute Crohn's disease in children.²¹ Furthermore, because of the adverse effects of steroid therapy, enteral nutrition was the preferred firstline therapy. Borrelli demonstrated that a short-term polymeric diet is more effective than the use of corticosteroids in healing gut inflammatory lesions in patients with active pediatric Crohn's disease.²³

By contrast, Zachos found corticosteroid therapy to be more effective than enteral nutrition in inducing remission of active Crohn's disease.²⁴ This discrepancy may be attributable to differences in study populations. The 10 most co-cited references were discussed from the perspectives of clinical practice guidelines, nutritional support timing, feeding tolerance, and research from relevant fields from the foundational literature.

To the best of our knowledge, this is the first study to involve bibliometric analysis on enteral nutrition research over this time period. The data we analyzed were sourced from the field of enteral nutrition, thus reflecting the current status of research on this subject. This study has some limitations. First, the publications were retrieved from only one database, the Web of Science, and were restricted to reviews and articles. Second, only publications in English were included. Third, data bias may have been introduced because of short names shared by certain authors or variations in keyword phrasing despite standardization.

Nutrition in Clinical Practice, the Journal of Parenteral and Enteral Nutrition, and Nutrients were the three most productive journals, and the three most co-cited journals were *the Journal of Parenteral and Enteral Nutrition, Clinical Nutrition, and Critical Care Medicine*. The United States and China contributed to the highest proportions of the publications (24.1 % and 22.3%, respectively). The top 10 institutions, of which four were from China and three were from the United States, accounted for 124 publications. Positive collaborations among countries were observed. Andrew S. Day and Stephen A. McClave were among the top 10 authors and co-cited authors. Close collaborations were observed among primary authors. Enteral nutrition, parenteral nutrition, and support were the three most frequently co-occurring keywords. The main research hotspots included Crohn's disease, acute pancreatitis, upper gastrointestinal malignancy, and other surgical diseases, and the studies mainly included critically ill patients in intensive care, patients with malnutrition, and children.

AUTHOR DISCLOSURES

The authors declare that there are no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

EDITOR'S NOTE

This report appears to have underestimated the landmark technological innovation of percutaneous endoscopic gastrostomy (PEG) which has led to an extensive and consequential literature on nutrition support and enteral nutrition.^{36,37}

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