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# One hundred most cited articles related to Endoscopic retrograde cholangiopancreatography: A bibliometric analysis

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**Background:** Endoscopic retrograde cholangiopancreatography (ERCP) has developed over the past few decades into a reliable technology for diagnostic and therapeutic purposes. Through a bibliometric analysis, this research attempted to evaluate the characteristics of the top 100 articles on ERCP that had the most citations.

**Methods:** We extracted pertinent publications from the Web of Science Core Collection (WoSCC) on July 9, 2022. The top 100 ERCP articles with the most citations were identified and analyzed. The following data were extracted: publication year, country/region, organization, total citation times, annual citation times, research type and research field, etc. To implement the network's visual analysis, a bibliographic coupling network based on keywords was built using the VOSviewer 1.6.17 program.

**Results:** The journal with the most publications were *GASTROINTESTINAL ENDOSCOPY*, with 45 articles. Most of the top 100 articles came from the United States ( $n = 47$ ) and Italy ( $n = 14$ ). Indiana University and the University of Amsterdam were among the most important institutions in ERCP research. ML Freeman of the University of Minnesota contributed the highest number ( $n = 9$ ) and the most highly cited paper. The age of the paper and article type is closely related to citation frequency. Of the 100 most-cited articles, clinical application in the field of ERCP has focused on three aspects: diagnosis, treatment, and complications. Clinical use of ERCP has shifted from diagnosis to treatment. Post-ERCP pancreatitis is the focus of attention, and the clinical application of technically complex therapeutic ERCP is the future development trend.

**Conclusion:** This study lists the most influential articles in ERCP by exposing the current state of the field, and showing the evolution of research trends to provide perspective for the future development of ERCP.

## KEYWORDS

ERCP, bibliometric analysis, visualization, post-ERCP pancreatitis, top-cited

## Introduction

Endoscopic retrograde cholangiopancreatography (ERCP), developed in the late 1960s and first described by American researcher McCune et al. in 1968, is a noninvasive or minimally invasive technique for the diagnosis and treatment of hepatobiliary and pancreatic illnesses (1, 2). They performed the world's first intubation of the duodenal papilla using a side-view fiberoptic duodenoscope. Although the intubation success rate was only 25% at the time, it opened a new field of diagnosing and treating biliary and pancreatic diseases (1). ERCP was initially developed as a diagnostic aid, with the operator injecting a contrast agent to understand lesions in the biliopancreatic duct. In the past half-century, with the continuous improvement of operation technology, endoscopy, and its accessory instruments have developed rapidly. ERCP has gradually become an essential interventional therapy for biliary and pancreatic diseases (3, 4). ERCP-related technologies include endoscopic sphincterotomy (EST), endoscopic naso-biliary drainage (ENBD), endoscopic retrograde biliary drainage (ERBD), endoscopic papillary balloon dilation (EPBD), endoscopic naso-pancreatic drainage (ENPD), endoscopic retrograde pancreatic drainage (ERPD), transoral choledochoscopy and treatment, transoral pancreatoscopy, integrable duct ultrasound (IDUS), Spyglass, etc. The development of these techniques has been widely used to treat pancreatic disorders, bile duct strictures, and stones in the bile duct. Even though ERCP has grown to be an effective clinical treatment, complications and adverse events that follow ERCP still exist and may significantly affect patients' morbidity and, very rarely, fatality (5). Pancreatitis, bleeding, cholecystitis, infection, and intestinal perforation are typical post-ERCP complications. The most frequent complication following ERCP is post-ERCP pancreatitis (PEP), whose incidence varies from 3.5% to 9.7%, as reported in meta-analyses and approaches 15% in high-risk patients (6, 7).

Bibliometric analysis is a popular statistical method used to evaluate the characteristics of publications in a specific field. We can quickly obtain information in this field through quantitative and qualitative analysis, evaluate research hotspots, and explore research trends. Since the first bibliometric analysis was published in 1987, many bibliometric analyses have been published recently in various medical fields, such as Endoscopic ultrasound (EUS), liver cancer, and pancreatic neuroendocrine tumors (8–11). Despite increasing research in the ERCP field, nothing is known about the generation of scientific knowledge in this area, and a bibliometric analysis has not yet been published. Therefore, we selected the top 100 most-cited (T100) articles from the Web of Science (WOS) database to provide a bibliometric perspective for the study of ERCP and to reveal the development trend of the discipline.

## Materials and methods

The Science Citation Index (SCI-Expanded) of the Web of Science Core Collection (WoS-CC) database (Clarivate Analytics, United States) is thought to be the most suitable database for bibliometric analysis and was used to conduct a thorough literature search. Ethics Committee approval was not required for this study as it did not involve intervention or data collection in animal or clinical trials. In the SCI-Expanded of WoS-CC, we created search terms based on MESH subject terms and synonyms, as follows with no language, publication type or publication time limit: TS = ("Cholangiopancreatography, Endoscopic Retrograde" OR "Retrograde Cholangiopancreatography, Endoscopic" OR "Cholangiopancreatographies, Endoscopic Retrograde" OR "Endoscopic Retrograde Cholangiopancreatographies" OR "Retrograde Cholangiopancreatographies, Endoscopic" OR "Endoscopic Retrograde Cholangiopancreatography" OR "ERCP"). To prevent changes in the online activity of articles, all data were collected on July 9, 2022.

The retrieved literature is sorted in descending order in the database according to the number of citations. Two researchers (XX and GLL) independently reviewed the abstract or full text to ensure that only studies focusing on ERCP were included in the subsequent analysis. Those that mentioned ERCP only in passing were excluded until the T100 articles were identified. The third researcher (LP) shall settle the differences between the two researchers through negotiation. Relevant information about the T100 articles, including publication date, citation counts, annual citations (total citations/the number of years since publication), author, journal of publication, country of origin, institution, study type, and research field, were extracted to Microsoft Excel 2019. The journal impacts factor 2021 (IF 2021) and quartile were from 2021 Journal Citation Reports (12). In addition, we also downloaded "Full record and cited references" in plain text format and used them in the analysis of bibliometric analysis tools.

VOSviewer 1.6.17 software was used to establish the bibliometric network's author and keyword co-occurrence map. We also detected keyword hotspots and trends by time of appearance. In the network co-occurrence graph, nodes represent elements such as authors or keywords. The size of nodes represents the frequency of element occurrence, the line between nodes indicates the cooperative relationship, and the closer the distance between nodes indicates the closer relationship. Qualitative data were presented as the frequency in percentage. Quantitative data were presented as average or median (first quartile [Q1], third quartile [Q3]) after being tested for normality by the Shapiro-Wilk test. The Pearson and Spearman correlation was used to evaluate bivariate correlation, and  $P < 0.05$  was considered statistically significant. All data were statistically analyzed using IBM SPSS version 26.0 software (IBM Corp., Armonk, NY, United States).

## Results

The main characteristics of the T100 articles are shown in [Supplementary Table S1](#) (3, 5, 7, 9, 13–108). A total of 16,781 publications related to ERCP were initially retrieved, ranked in descending order of citation frequency. After screening, we identified the T100 articles. All 100 articles were published in English. There were 28,129 citations for T100 articles, with a median citation count of 218 (range 159–1,925). Among the T100 articles, Surprisingly, the most cited article was 1,925 times, well ahead of the next most cited paper, 898 times (28, 38). The annual citations of T100 articles varied from 5.82 to 71.3 times, with a median citation count of 11.92.

### Distribution of articles by years of publication

The T100 articles in this field were published in the 32 years from 1988 to 2020. In chronological order, we noticed that 68% of the papers were published after 2000, and 48% were published between 2000 and 2010 ([Figure 1](#)). 2002 had the highest number of publications ( $n=11$ ), followed by 2004 ( $n=10$ ). The oldest article was by Neoptolemos JP et al., published in 1988 (13). The most recent article was published in 2020 by Dumonceau et al. (5). Moreover, there was an inverse correlation between annual citations since publication and article age ( $\rho = -0.638$ ;  $P < 0.001$ ) ([Figure 2A](#)). However,

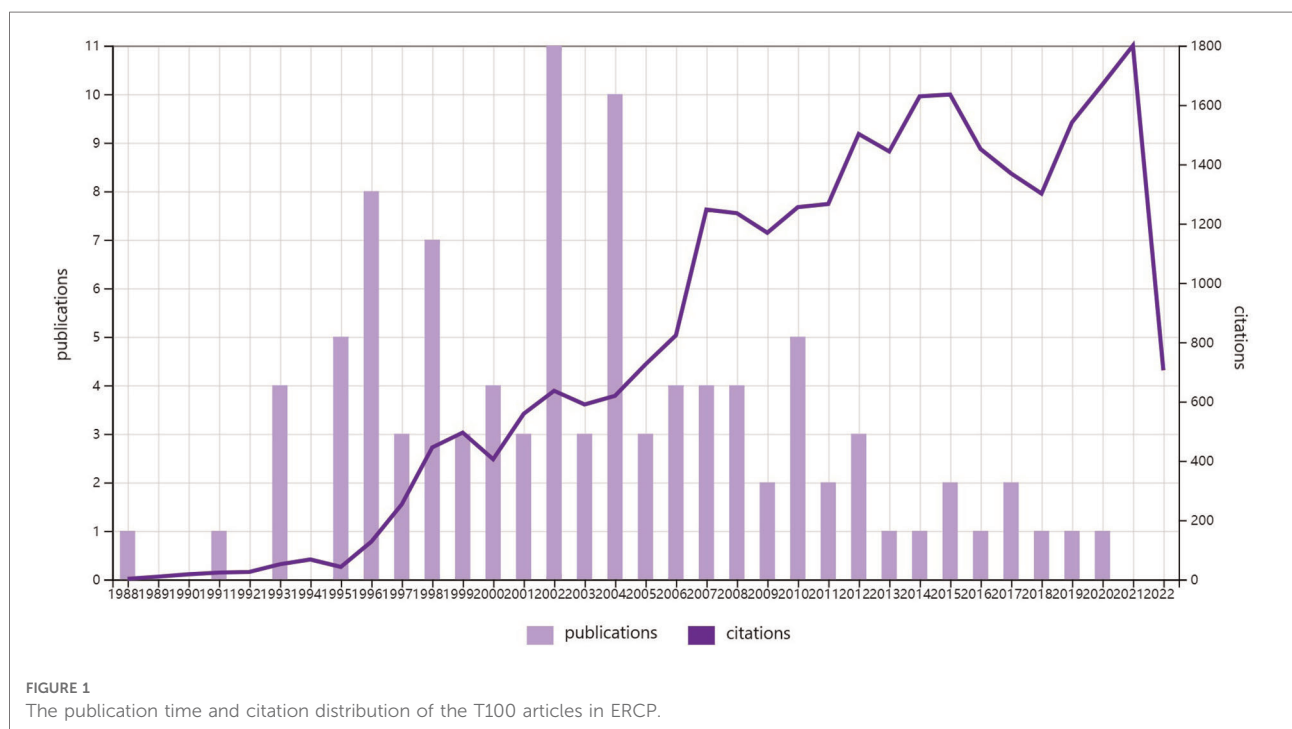
there was no correlation between the age of the paper and total citations (TC) ( $P = 0.174$ ) ([Figure 2B](#)).

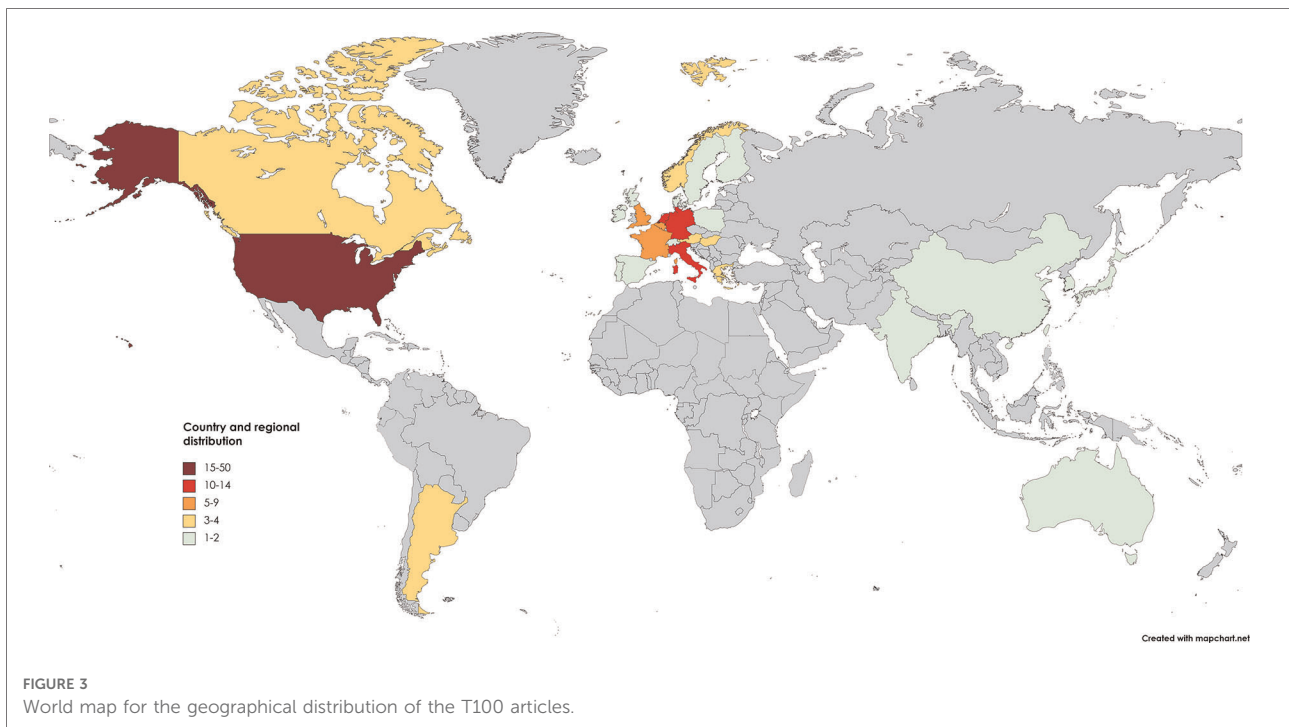
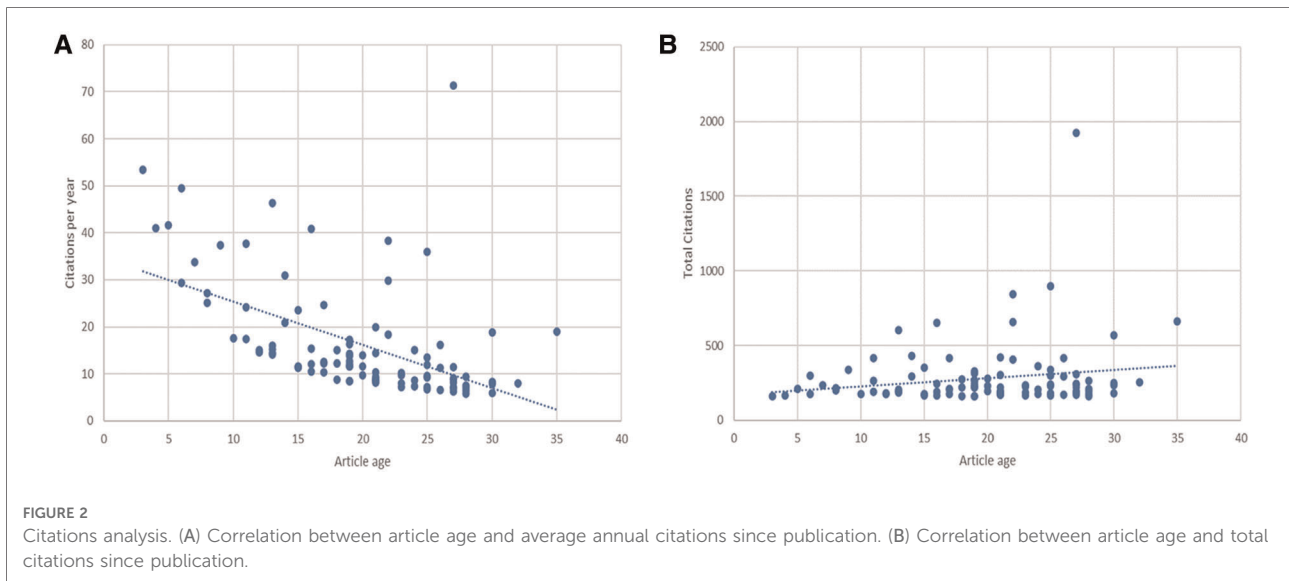
### Distribution of the institution and country

Twenty-nine countries or regions contributed to The T100 articles ([Figure 3](#)). The USA contributed the most publications (47 papers) and the highest total citations (TC), followed by Italy (14 documents) and Germany (12 documents). Thirteen countries contributed three or more articles ([Table 1](#)). In terms of research institutions, Indiana University and the University of Amsterdam contributed the most papers (both eight papers) ([Table 2](#)). Moreover, Indiana University leads in TC ( $n=3870$ ) and mean citations per article ( $n=483.8$ ). The University of Minnesota in the United States and the Università Vita-Salute San Raffaele in Italy tied for third place with six articles each.

### Analysis of authors

A total of 733 authors contributed to the T100 articles, of which nine published at least five ([Table 3](#)). The list was led by Freeman ML and Mariani A, who wrote 9 of the T100 articles each. The nine papers by Freeman ML et al. from the University of Minnesota were cited 4,535 times in the T100 articles. At the same time, he has seven articles as a corresponding author, which is the most. A network was





constructed of the co-authors of the T100 articles (Figure 4). As can be seen from this figure, many groups have formed among the authors, and there seems to be a lack of collaboration between groups. The figure shows that Freeman ML seems to be the most prominent author, but the team with Dumonceau JM as the core has been outstanding in recent years.

### Analysis of journals

A total of 15 journals with an IF between 3.243 and 202.731 published the T100 influential articles (Table 4). The *Lancet*

had the highest IF (IF = 202.731). *Gastrointestinal Endoscopy* not only has the most significant number of T100 articles published ( $n = 45$ ) but also leads the field with 11,305 citations. The *New England Journal of Medicine* had the highest average number of citations per article (TC/publications 705.8), followed by the *Lancet* (TC/publications 364.0) and the *American Journal of Gastroenterology* (TC/publications 360.6). Most of these journals were in the first quartile (Q1) of their corresponding disciplines, except for one journal that was in the second (Q2) and two journals that were in the three (Q3). In the T100 influential articles, there is a positive correlation between the TC/publications and

**TABLE 1** countries or regions published at least three articles. TC = Total citations.

| Country     | Publications | TC     | Mean citations per article |
|-------------|--------------|--------|----------------------------|
| USA         | 47           | 13,400 | 285.11                     |
| ITALY       | 14           | 4681   | 334.36                     |
| GERMANY     | 12           | 2665   | 222.08                     |
| NETHERLANDS | 10           | 2422   | 242.2                      |
| ENGLAND     | 9            | 2519   | 279.89                     |
| FRANCE      | 9            | 1980   | 220                        |
| BELGIUM     | 8            | 1686   | 210.75                     |
| CANADA      | 4            | 2525   | 631.25                     |
| ARGENTINA   | 4            | 945    | 236.25                     |
| GREECE      | 4            | 768    | 192                        |
| HUNGARY     | 4            | 768    | 192                        |
| AUSTRIA     | 3            | 733    | 244.33                     |
| NORWAY      | 3            | 560    | 186.67                     |

**TABLE 2** Institution published at least four articles. TC = Total citations.

| Institution                          | documents | TC   | Mean citations per article | Country     |
|--------------------------------------|-----------|------|----------------------------|-------------|
| Indiana University                   | 8         | 3870 | 483.75                     | USA         |
| University of Amsterdam              | 8         | 1969 | 246.13                     | Netherlands |
| University of Minnesota              | 6         | 1995 | 332.5                      | USA         |
| Università Vita-Salute San Raffaele  | 6         | 1286 | 214.33                     | Italy       |
| Medical University of South Carolina | 5         | 1718 | 343.6                      | USA         |
| University of Michigan               | 5         | 1377 | 275.4                      | USA         |
| Gedyt Endoscopy Center               | 4         | 945  | 236.25                     | Argentina   |
| Universite libre de Bruxelles        | 4         | 945  | 236.25                     | Netherlands |
| Università Cattolica del Sacro Cuore | 4         | 923  | 230.75                     | Italy       |
| Hop edouard herriot                  | 4         | 801  | 200.25                     | France      |

**TABLE 3** First, senior, or corresponding authors who have published at least five T100 articles. TC = Total citations.

| Author       | Number of papers | TC   | Mean citations per article | Author position |                      |        | Affiliation                   | country |
|--------------|------------------|------|----------------------------|-----------------|----------------------|--------|-------------------------------|---------|
|              |                  |      |                            | First-author    | Correspondent author | others |                               |         |
| Freeman ML   | 9                | 4535 | 503.9                      | 0               | 7                    | 2      | Univ Minnesota                | USA     |
| Mariani A    | 9                | 2533 | 281.4                      | 0               | 0                    | 9      | Univ Vita Salute San Raffaele | Italy   |
| Sherman S    | 7                | 3701 | 528.7                      | 0               | 3                    | 4      | Indiana Univ                  | USA     |
| Dumonceau JM | 7                | 1504 | 214.9                      | 0               | 5                    | 2      | Hop Civil Marie Curie         | Belgium |
| Testoni PA   | 6                | 1900 | 316.7                      | 0               | 2                    | 4      | Univ Vita Salute San Raffaele | Italy   |
| Lehman GA    | 6                | 1776 | 296                        | 0               | 0                    | 6      | Indiana Univ                  | USA     |
| Deviere J    | 6                | 1361 | 226.8                      | 0               | 0                    | 6      | Univ Libre Bruxelles          | Belgium |
| Williams EJ  | 5                | 1359 | 271.8                      | 3               | 0                    | 2      | Royal Bournemouth Hosp        | England |
| Tringali A   | 5                | 960  | 192                        | 0               | 0                    | 5      | Catholic Univ                 | Italy   |

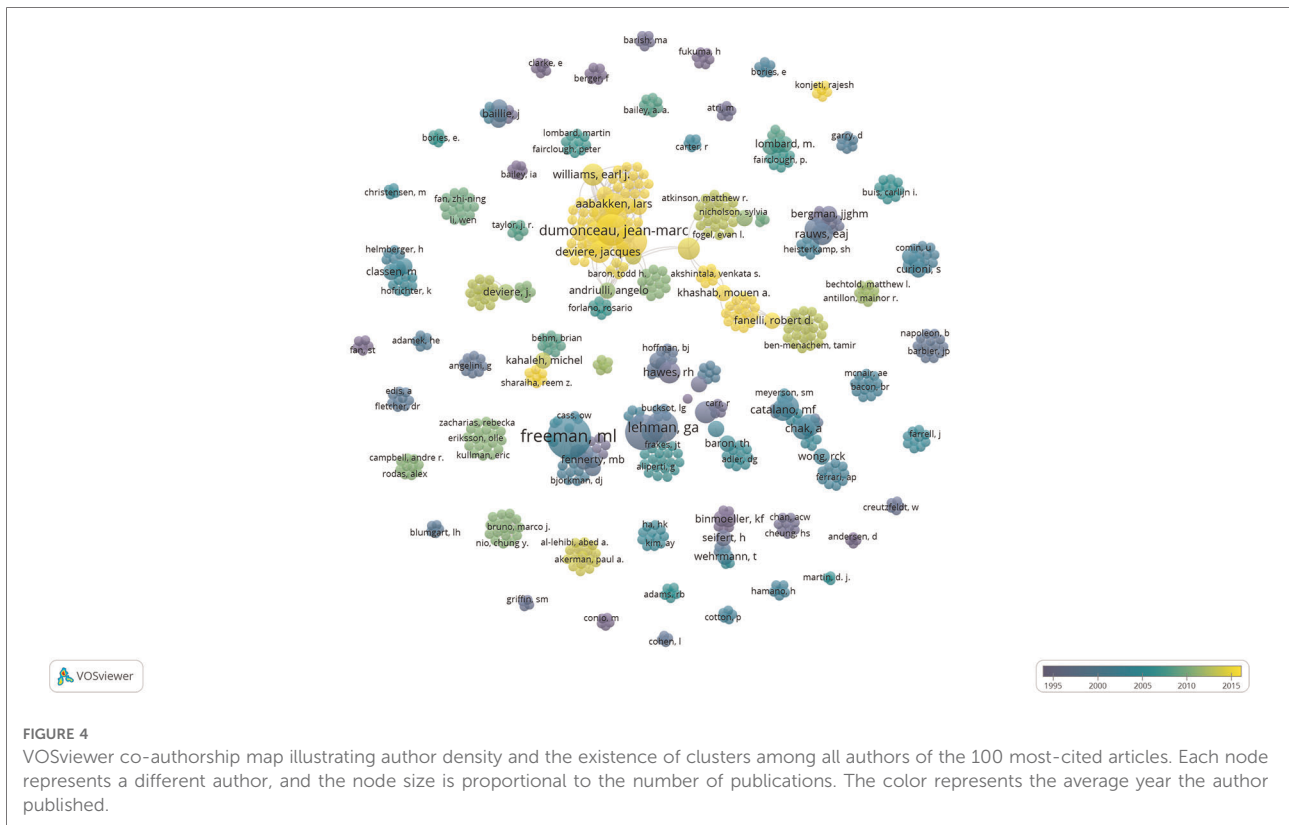
corresponding journal IF ( $\rho = 0.745$ ;  $P = 0.001$ ). However, the corresponding journal IF is unrelated to TC or the number of T100 articles published in each journal ( $P > 0.05$ ).

### Distribution of study types and topics

The most common type of study was prospective study ( $n = 30$ ), followed by retrospective study ( $n = 24$ ), randomized controlled trials (RCT) ( $n = 18$ ), guideline ( $n = 11$ ), systematic reviews ( $n = 10$ ), review ( $n = 4$ ), Case report ( $n = 2$ ) and Conference papers ( $n = 1$ ). Treatment was the most studied subtopic ( $n = 36$ ), followed by Complications ( $n = 32$ ), diagnosis ( $n = 20$ ), EUS-guided interventional therapy when ERCP fails ( $n = 6$ ). Among the 20 articles of diagnostic type,

12 were comparative studies of ERCP and EUS, CT, MRI/MRCP. Therefore, the comparison of ERCP and its competing technologies in diagnosis and treatment is also the focus of researchers. According to the number of citations of various articles, prospective studies have the highest average number of citations per paper. However, the annual citations for guidelines are much higher than those of other publication types, but because this category of articles has mostly been published in recent years, there has been insufficient time to accumulate citations (Table 5).

In VosViewer, we merged synonyms and different variants of the same keyword (Supplementary document) and extracted 301 keywords. VOSViewer heat map detailed the keywords relationships from the T100 articles (Figure 5). Keywords that appear more frequently include “ERCP” 43 times,



**TABLE 4** Journals of top-cited articles. TC = total citations, IF = impact factor. \*In 2013 ARCHIVES OF SURGERY changed to JAMA Surgery.

| Journals                                | Publications | TC     | TC/publications | IF2021  | Quartile (2021) |
|---|--------------|--------|-----------------|---------|-----------------|
| GASTROINTESTINAL ENDOSCOPY              | 45           | 11,305 | 251.2           | 10.396  | Q1              |
| ENDOSCOPY                               | 15           | 3418   | 227.9           | 9.776   | Q1              |
| AMERICAN JOURNAL OF GASTROENTEROLOGY    | 8            | 2885   | 360.6           | 12.045  | Q1              |
| NEW ENGLAND JOURNAL OF MEDICINE         | 6            | 4235   | 705.8           | 176.079 | Q1              |
| GUT                                     | 5            | 1073   | 214.6           | 31.793  | Q1              |
| LANCET                                  | 4            | 1456   | 364.0           | 202.731 | Q1              |
| RADIOLOGY                               | 4            | 842    | 210.5           | 29.146  | Q1              |
| ANNALS OF SURGERY                       | 3            | 774    | 258.0           | 13.787  | Q1              |
| GASTROENTEROLOGY                        | 3            | 734    | 244.7           | 33.883  | Q1              |
| *ARCHIVES OF SURGERY                    | 2            | 365    | 182.5           | 16.689  | Q1              |
| ANNALS OF INTERNAL MEDICINE             | 1            | 238    | 238             | 51.598  | Q1              |
| COCHRANE DATABASE OF SYSTEMATIC REVIEWS | 1            | 175    | 175             | 12.008  | Q1              |
| DIGESTIVE DISEASES AND SCIENCES         | 1            | 163    | 163             | 3.487   | Q3              |
| LIVER TRANSPLANTATION                   | 1            | 212    | 212             | 6.112   | Q2              |
| PANCREAS                                | 1            | 254    | 254             | 3.243   | Q3              |

“complications” 30 times, “management” 25 times, “oddi dysfunction” 17 times, “sphincterotomy” 16 times, “therapeutic ERCP” 16 times, “biliary sphincterotomy” 13 times, “risk-factors” 13 times, “post-ERCP pancreatitis” 11 times and “endoscopic sphincterotomy” 10 times. From the heat map, we could find that the current attention of ERCP mainly focuses on: “diagnosis,” “treatment,” and “complications.” Moreover, 81 keywords with a minimum

number of occurrences of three were analyzed; an overlay visualization map shows how the trends of keywords change over years (Figure 6). For example, “diagnosis,” “computed tomography,” and “cholecystectomy” appeared before 2000 and then “complications,” “therapeutic ERCP,” prospective multicenter “, “controlled trial” and “long-term outcome” began to appear. The top keywords in recent years were “high-risk patients,” “expandable metal stents,” “selective

TABLE 5 Types of documents. \* Expressed in the median (first quartile [Q1], third quartile [Q3]).

| Rank | Study type                   | Publications | TC     | Mean citations per article | annual citations *  |
|------|------------------------------|--------------|--------|----------------------------|---------------------|
| 1    | Prospective study            | 30           | 10,166 | 338.9                      | 9.65 (8.22;15.58)   |
| 2    | Retrospective study          | 24           | 5112   | 213.0                      | 8.88 (7.58;12.15)   |
| 3    | Randomized controlled Trials | 18           | 5821   | 323.4                      | 12.64 (10.83;18.90) |
| 4    | Guideline                    | 11           | 2693   | 244.8                      | 33.71 (17.45;41.60) |
| 5    | Systematic reviews           | 10           | 2512   | 251.2                      | 14.29 (11.60;27.68) |
| 6    | Review                       | 4            | 984    | 246.0                      | 10.42 (8.12;16.03)  |
| 7    | Case report                  | 2            | 668    | 334.0                      | 13.84, 18.41        |
| 8    | Conference papers            | 1            | 173    | 173.0                      | 8.24                |

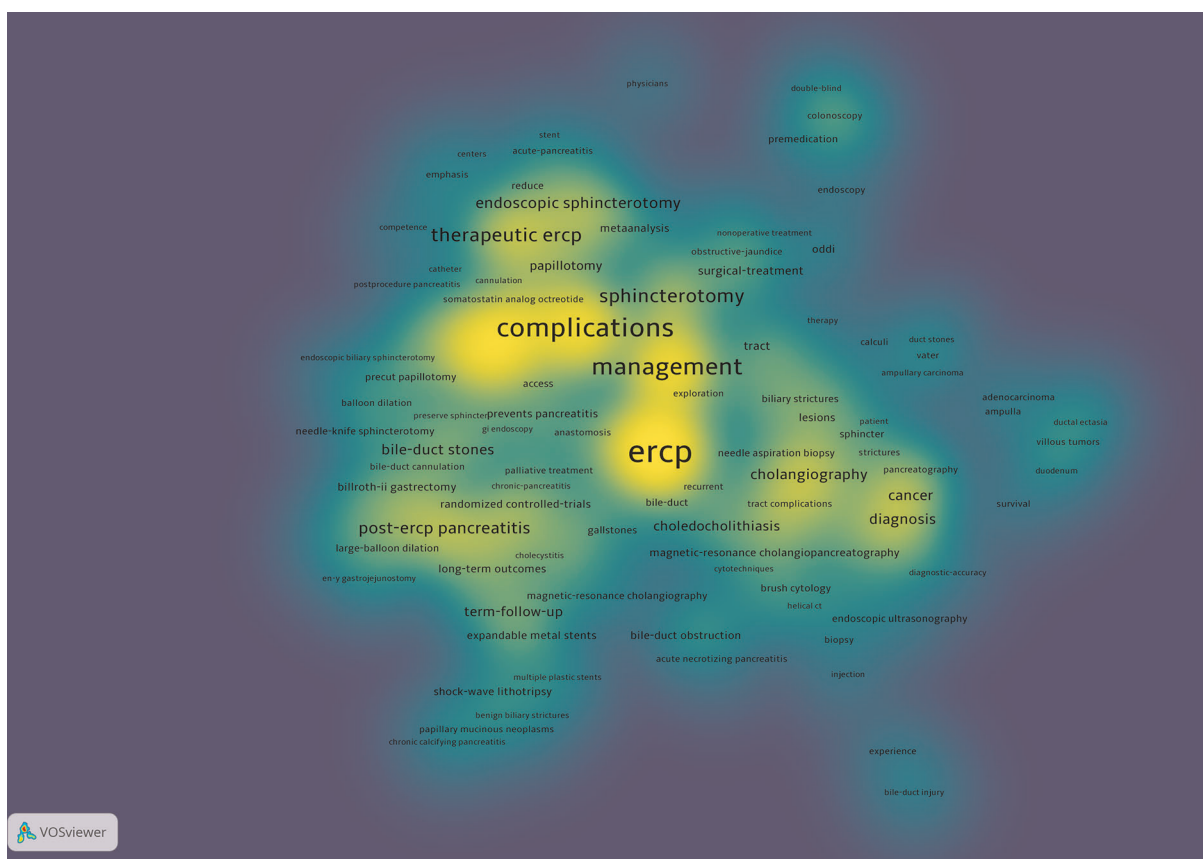


FIGURE 5 Heat map of the 100 most-cited articles in keywords. The darker the color, the more times the keyword appears.

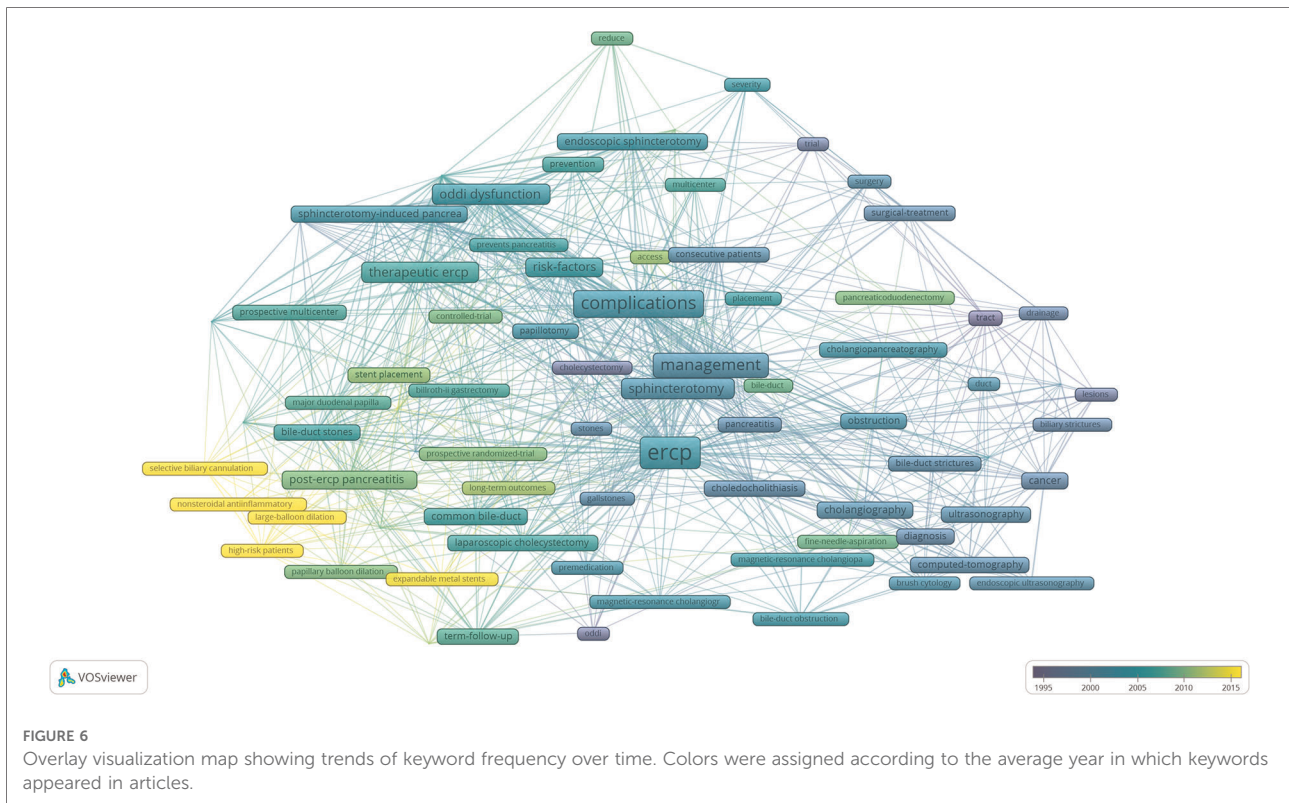
biliary cannulation”, “large-balloon dilation”, and “nonsteroidal antiinflammatory drugs”.

### Discussion

A large number of studies have promoted the field of ERCP. Advances in the Internet have made it easy for researchers to obtain the latest research results, but this has posed a challenge for researchers to get valuable and high-quality research from many resources. Citation analysis can

qualitatively and quantitatively analyze the research status and development history of a specific field, which helps identify classical research and high-impact journals (109). Therefore, this study identified highly cited literature related to ERCP through bibliometrics and evaluated their characteristics to have a deeper understanding of this field.

The number of citations is an important index to evaluate the influence of a paper. In the current research, all top 100 papers have been cited at least 100 times, and the citation frequency of the documents is between 159 and 1925. Although the inclusion criteria were not identical, it was



found that the number of citations of ERCP was higher than that of other endoscopes, such as bronchoscopy ( $n = 196-731$ ) and ankle arthroscopy ( $n = 56-225$ ), indicating that ERCP is a hot topic (110, 111). The top-ranked publication, “Complications of endoscopic biliary sphincterotomy,” had a total of 1925 citations; it was published in the *NEW ENGLAND JOURNAL OF MEDICINE* in 1996 by Freeman et al. (28). Freeman et al. conducted a prospective cohort study of sphincterotomy at 16 institutions in the United States and 1 in Canada. In their paper, 2,347 patients undergoing biliary sphincterotomy were analyzed, and the risk factors of ERCP complications were summarized, providing a reference for future studies (28).

The papers’ geographic distribution was also made clear. Most T100 ERCP research came from nations and organizations in Western Europe and North America. Among the T100 articles, four of the top ten publishing institutions are from the United States. Indiana University from the USA ranked first in the number of articles and TC. This indicates that the USA is in a leading position in ERCP research. As a country with the highest GDP in the world, the United States has top medical research institutions and researchers. According to statistics, the USA led the world in scientific research spending from 1981 to 2020, which might explain why the USA also leads in several other areas of medicine (112–116). In addition, we found that every continent except Africa participated in the T100 articles, indicating that ERCP

is widely used and researched. The most significant scholar on ERCP, Freeman ML, authored 9 of the top 100 articles with the most 4,535 TC. Freeman ML’s studies focused on post-ERCP complications and were published between 1996 and 2006 (28, 49, 55, 62, 69–71, 77, 79). Complications of ERCP are hot topics for endoscopists and are often cited as such. Our analysis revealed that Freeman’s article entitled “Complications of endoscopic biliary sphincterotomy” was the most cited paper ( $n = 1,925$ ) (28). We found that Dumonceau JM is one of the most prolific authors to emerge in recent years, publishing between 2010 and 2020. He has co-authored seven European Society of Gastrointestinal Endoscopy (ESGE) Guidelines, five of which are the corresponding author (3, 5, 92, 100, 103, 105, 108).

We found no significant correlation between IF and the number of T100 articles in the corresponding journals. This could be explained by the diversity of publications’ fields of expertise or subject matter. We note that 60% of the papers were published on *GASTROINTESTINAL ENDOSCOPY* ( $n = 45$ ) and *ENDOSCOPY* ( $n = 15$ ) with IF 10.396 and 9.776, respectively. This indicates that ERCP-related studies are more likely to be published in professional endoscopy journals. Generally, the well-recognized: ESGE consensus guidelines for ERCP are published by *ENDOSCOPY*. In addition to the specific journals on digestive endoscopy, some of the top journals in the medical specialty, such as *The New England Journal of Medicine* and *LANCET*, also played an important



role in this analysis. Ten papers were published in prestigious academic journals with high impact factors in these two medical fields. Although their T100 articles are small in number, they lead in citations per article. The IFs of the 15 journals that published the T100 articles were all >3.0, demonstrating the vitality and significance of ERCP research. The most cited ERCP papers were almost published in US and UK journals, most of them with high IF. These esteemed journals have strong reputations and widespread influence, which draw readers and citations. So high-performing researchers may be more willing to submit high-quality papers to these journals, thus maintaining a high IF (115).

Notably, two case reports received 668 citations (50, 71). They described EUS-guided biliary puncture and drainage (EUS-BD) as an important remedial treatment for the failure of ERCP in benign and malignant biliary ducts. Patients with unresectable malignant distal biliary obstruction were randomized to EUS-BD or ERCP in an RCT. The results showed no statistically significant difference in clinical and technical success between EUS-BD and ERCP. EUS-BD was associated with fewer postoperative complications and higher quality of life (116). However, more research still needs to research whether EUS-BD can replace ERCP as a therapeutic strategy for newly diagnosed patients. In addition, prospective studies and RCTs received the highest average citations per paper (338.9 and 323.4, respectively). Considering the influence of publication time on the number of citations, we calculate the average annual citations. The results showed that guidelines and systematic reviews had the highest average annual citations. Therefore, this embodies the idea of evidence-based medicine, where studies with higher levels of evidence are more likely to be cited.

In terms of research hotspots, besides “ERCP”, “complications” were the most frequent keywords ( $n = 30$ ). The three most cited articles were all prospective studies of ERCP complications (28, 38, 49). The most recent of the T100 articles is the guidelines on complications of ERCP published by ESGE in 2020 (5). Therefore, complications are undoubtedly the most concern for ERCP, with PEP being the most concerned. Given the high incidence of PEP and the health care costs associated with it, many studies have been conducted to prevent PEP. Prophylactic rectal indomethacin dramatically decreased the incidence and severity of PEP in patients at high risk for this complication, according to one RCT trial cited 414 times (101). A recent meta-analysis confirmed these results, but further research is needed on additional prevention methods, including pancreatic stents and intravenous fluids (117).

Regarding research trends, we can clearly see the time evolution of ERCP from diagnosis to treatment (Figure 6). Our overlay visualization map clearly illustrates the rise of “therapeutic ERCP” in the 2000s (Figure 6). ERCP was initially developed in 1968 as a diagnostic tool. In 1974, Drs Meinhard Classen in Germany and Keiichi Kawai in Japan

simultaneously undertook the first biliary sphincterotomy. Since then, ERCP has evolved from a diagnostic to a therapeutic tool (118). With the development of imaging, including the widespread use of noninvasive tests such as computed tomography, magnetic resonance cholangiopancreatography (MRCP), and EUS, diagnostic ERCP has been partially replaced, making its use less and less (119, 120). Although MRCP can identify a range of pancreatic and biliary diseases, including biliary obstruction (121), evaluation of biliary pathologies (122), and choledocholithiasis (123), some studies have pointed out that MRCP cannot completely replace ERCP in the diagnosis of pancreatic and biliary diseases, especially mild bile duct lesions (124, 125). Because of the invasive nature and risk of ERCP, purely diagnostic ERCP has been gradually reduced and is currently mainly used in patients whose etiology cannot be determined by noninvasive tests. Combined with recent keywords, we found that the use of a nonsteroidal anti-inflammatory drug to prevent PEP in high-risk patients, endoscopic large balloon dilation of papillary sphincter for common bile duct calculi, and self-expandable metal stents for benign and malignant biliary obstruction and selective biliary cannulation are recent research hotspots. Thus, the prospect of ERCP lies in the development of new treatment techniques and how to prevent the complications of the procedure. Admittedly, the development of some competing technologies has challenged the clinical application of ERCP, but therapeutic ERCP with increased technical complexity is the way forward in the future.

Although our results provide valuable information, like other bibliometric research, our study has several limitations. First, evaluating the literature only by the number of citations is not comprehensive. For example, the latest important literature does not have enough time to accumulate citations. Second, although we did our best to conduct a comprehensive search, ERCP-related literature may still be missing. Another limitation of this study is that open-access vs. subscription-based journals were not filtered separately during the WOS search. This would seemingly be an impactful factor in how often these articles are being cited. Finally, we only used the WOS database to search literature, and literature from other databases such as Scopus and Google Scholar may be omitted. However, WOS is the most suitable database for bibliometric analysis, which contains the most comprehensive citation information.

## Conclusions

To the best of our knowledge, this is the first bibliometric study of the T100 articles on ERCP. The T100 articles ranged from 159 to 1,925 citations, with publication years ranging from 1988 to 2020. The number of articles published in 2002 was the highest. The USA was the most significant contributor, followed by Italy and Germany. Indiana University was the center of

ERCP research. The paper's age and article type are closely related to citation frequency. Among the T100 articles, clinical application in ERCP has focused on three aspects: diagnosis, treatment, and complications. PEP is the focus of attention, and more technically complex therapeutic ERCP will be further developed. In summary, this study identified the T100 ERCP articles with the highest citation frequency and analyzed their bibliometric characteristics, laying a foundation for further research.

## Data availability statement

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

## Author contributions

XX, LG, and PL contributed to the conception and design of the study. XX and YZ organized the database. XX performed visualization. YW and HK performed the statistical analysis. LG wrote the first draft of the manuscript. YW, HK, and YZ Searched the literature. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsurg.2022.1005771/full#supplementary-material>.

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