Original Article

The insight to history and trends of transient elastography for assessing liver fibrosis—a bibliometric analysis

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Background: Transient elastography (TE) has become a prominent technique for the detection of fibrosis, owing to its non-invasive nature, rapid execution, safety, and ease of repetition. This study aims to conduct a bibliometric analysis of the historical development and trends in the application of TE for the assessment of liver fibrosis.

Methods: In the Web of Science (Core Collection database), we selected the Science Citation Index Expanded database to search for relevant literature from 1 January 1983 to 20 November 2023. We performed a search using the following topic words: transient elastography, liver fibrosis. After screening according to the title, abstract and keyword and removing the repetition, the literature included in the study was finally determined, and full records were downloaded. Bibliometric analysis was performed using VOSviewer and CiteSpace.

Results: Through the bibliometric visualization analysis of 577 articles, it was found that since TE was first reported for the measurement of liver fibrosis in 2003, the number of publications in this field has generally shown an upward trend, and the distribution of publications has shown a bimodal distribution, with peaks in 2010 and 2019. France and China have shown a high contribution in this field with a high number of publications. In terms of contributions from individual research centers, Yonsei University stands out prominently. Throughout the history of research in this field, early studies focused on chronic viral hepatitis, by comparing TE and Fibrosis-4, aspartate aminotransferase to platelet ratio index, FibroTest, liver biopsy and other liver fibrosis detection indicators to verify its diagnostic efficacy. Subsequently, the focus of research gradually shifted to non-alcoholic fatty liver disease and other liver diseases, and the scope of research extended to the establishment of prediction models and efficacy evaluation through TE.

Conclusions: The application scope of TE is gradually expanding, and its safety, simplicity, rapidity, high accuracy, quantitative results, repeatability and good tolerance make it popular in clinical practice. Nowadays, the application of TE is not limited to the diagnosis of liver fibrosis, but has been extended to the establishment of prognostic models and efficacy evaluation of various liver diseases. To explore the deeper value of TE through new research methods such as machine learning models, radiate the advantages of TE

to more liver diseases, and combine TE with a variety of non-invasive detection indicators to improve its application value, may be the future development and application prospect of TE in the field of liver fibrosis.

Keywords: Bibliometric; transient elastography (TE); liver fibrosis

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Introduction

Liver fibrosis, a pathophysiological consequence of prolonged hepatic injury, represents the primary cause of mortality associated with chronic liver diseases (CLDs) on a global scale (1). CLDs predominantly encompass chronic infections with hepatitis viruses, non-alcoholic fatty liver disease (NAFLD), alcoholic liver disease (ALD), and autoimmune liver disorders. These conditions may progress to advanced liver fibrosis and ultimately to cirrhosis, which ranks as the 11th leading cause of death worldwide, contributing to approximately 2 million fatalities annually and accounting for 4% of total global mortality (2,3). In most patients with CLD, typical symptoms do not manifest until the development of decompensation after many years (4). The stage of liver fibrosis serves as a critical prognostic determinant for the development of liver-related events in CLDs (5). A comprehensive understanding of liver fibrosis staging facilitates the assessment of key indicators of CLD progression, enables the monitoring of clinical treatment efficacy, and aids in prognostic evaluation (6). As liver fibrosis advances to clinically significant stages, the risk of adverse clinical outcomes markedly increases. Specifically, advanced fibrosis (stage 3, F3) and cirrhosis (stage 4, F4) are strongly correlated with liver-related mortality. Therefore, monitoring the stage of liver fibrosis during treatment is imperative (7-9). Therefore, the early detection, diagnosis, and treatment of liver fibrosis are of paramount importance.

The diagnostic and staging methodologies for liver fibrosis encompass both noninvasive tests (NITs) and liver biopsy (LB). NITs are categorized into two primary types: (I) serum-based markers and predictive models, which include FibroTest, aspartate aminotransferase to alanine aminotransferase ratio (AST/ALT ratio), aspartate aminotransferase to platelet ratio index (APRI), BARD [body mass index (BMI), AST/ALT ratio, Diabetes] score, fibrosis-4 index (FIB-4), nonalcoholic fatty liver disease fibrosis score (NFS), and Forns index; and (II) imaging-based techniques, such as transient elastography (TE), shear wave elastography (SWE), and magnetic resonance elastography (MRE) (10,11). LB has traditionally been the standard diagnostic procedure for assessing intrahepatic inflammation, steatosis, and fibrosis. Nonetheless, this method presents several limitations, including high cost, invasive nature, risk of complications, susceptibility to interpretative errors due to subjective judgment, and sampling error attributable to the limited size of tissue samples (11,12). Consequently, LB is no longer advocated for routine diagnostic use (13). TE has emerged as the preferred technique for fibrosis detection due to its non-invasive nature, rapid execution, safety, and ease of repetition (11,14). TE is an instrument utilized for quantifying liver stiffness (LS) and assessing the extent of fibrosis by analyzing shear wave velocity. It evaluates liver fibrosis by determining LS values (15). Low-frequency elastic waves, generated by the probe, traverse the skin and intercostal spaces, propagating to the liver, where the velocity of the ultrasound emitted and received by the transducer is measured (11). This measured velocity of the elastic wave is converted into LS values based on the elastic modulus, as per Hooke's law, and is expressed in kilopascals (kPa) (16). The stiffness of the tissue is directly proportional to the square of the shear wave's propagation speed; thus, a higher velocity indicates increased LS, suggesting more advanced liver fibrosis. LS values obtained via TE range from 1.5 to 75 kPa, with the upper limit of normal LS approximately between 5 and 5.5 kPa (17). The ultrasound-based Controlled Attenuation Parameter (CAP) technology facilitates the estimation of hepatic fat content during LS measurement (LSM) using TE on FibroScan equipment (18). CAP measurement is a rapid and straightforward procedure that yields a numerical value correlating with the histological degree of steatosis. During the assessment of LS with TE, the CAP algorithm quantifies the attenuation of the ultrasound signal, expressed in decibels per meter (dB/m) (19). A study involving 222 patients with chronic hepatitis B (CHB) demonstrated that employing TE for cirrhosis

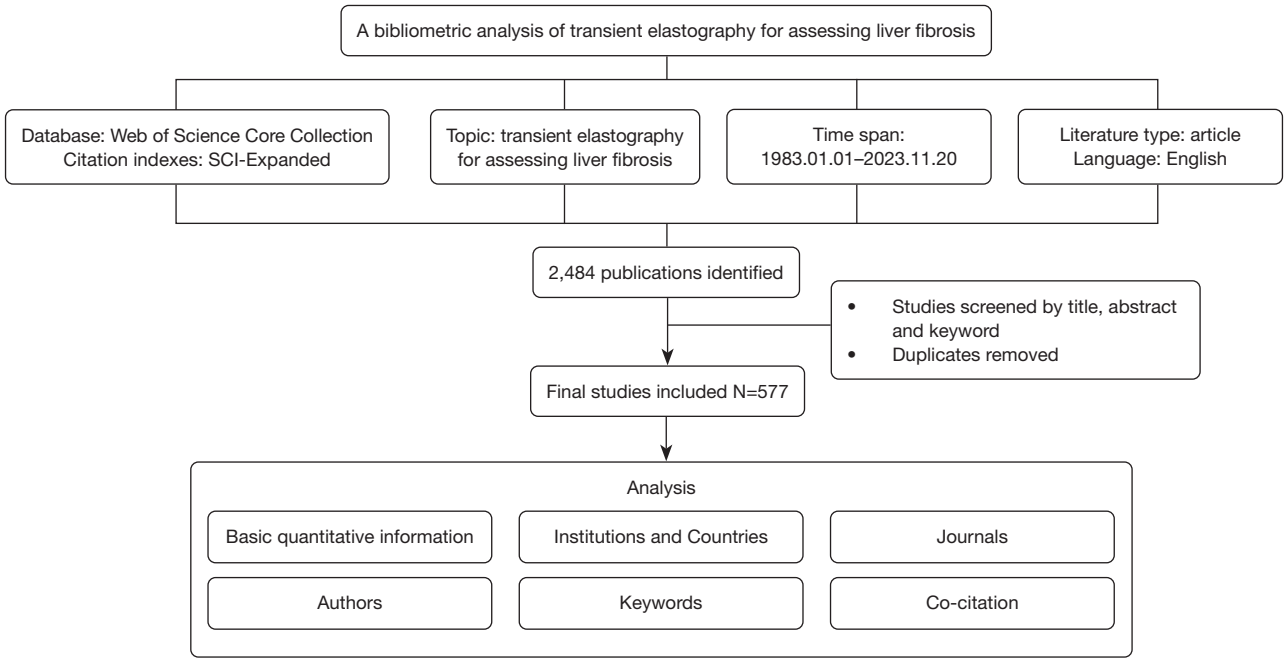

Figure 1 Flowchart of bibliometric analysis. SCI, Science Citation Index.

diagnosis could potentially obviate the need for LB in 61–65% of cases (20). Numerous studies have corroborated the high diagnostic accuracy of TE in identifying significant fibrosis and cirrhosis across various liver diseases, including viral hepatitis (21-23). TE demonstrates high diagnostic accuracy for staging liver fibrosis in patients with CLDs (24). The non-invasive, user-friendly nature of TE, coupled with its ability to deliver immediate results, renders it particularly advantageous for routine clinical practice and for monitoring disease progression or treatment response.

To date, numerous publications have been reported globally on the use of TE in the diagnosis of liver fibrosis. Consequently, there is a need to collate the extensive literature on this subject to elucidate and visualize the intellectual framework of the research field comprehensively and systematically. Since its establishment as an independent discipline in 1969, bibliometrics has been widely employed in literary analysis. Bibliometric analysis offers a quantitative method for reviewing and studying the existing literature within a specific field (25). The analytical process may encompass comprehensive data, including authors, keywords, journals, countries, institutions, and references. Consequently, the progression of a field can be ascertained through bibliometric analysis.

Therefore, we performed a bibliometric analysis on the application of TE in the context of liver fibrosis. This analysis utilized CiteSpace and VOSviewer bibliometric software to offer a thorough examination of the current status and emerging trends within the field, with the aim of fostering its further development.

Methods

Data collection and extraction

The Web of Science Core Collection (WOSCC) Science Citation Index Expanded database was selected as the primary database of our study. We searched articles of TE for assessing liver fibrosis published between 1 January 1983 and 20 November 2023 (Table S1). The entire WOSCC records including the cited references were downloaded in TEXT format within one day of 20 November 2023 to minimize possible deviations caused by database updates. The flowchart of data collection and analysis is illustrated in *Figure 1*.

Data arrangement and analysis

All data were documented and processed using Microsoft Excel 2022. In order to improve the accuracy of the research, synonyms merging of keywords, authors, journals

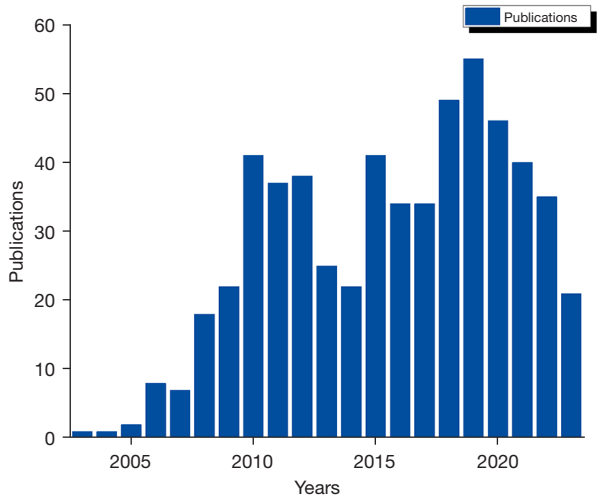

Figure 2 Annual number of published articles.

and countries were identified and documented manually. The processed data from the Web of Science are shown in additional materials (available at https://cdn.amegroups.cn/static/public/qims-24-2117-1.xls).

VOSviewer (version 1.6.20) was used to perform cluster analysis of institutions, journals, authors, and keywords. Some of the cluster diagrams were displayed after processing by Pajek (5.18). CiteSpace (version 6.1.6) was used to analyze the burst words analysis on keywords. WordCloud, author production over time, three field plot, trend topics were drawn using R software (4.3.0). Other diagrams were created using Origin 2021.

Results

Basic quantitative information

A total of 577 articles were incorporated into the present study, authored by 3,496 individuals affiliated with 956 organizations across 57 countries. These articles were published in 185 distinct journals and have collectively garnered 7,513 citations from 1,570 different journals. The earliest study in the field of TE for the assessment of liver fibrosis dates back to 2003 (15). Since the initial report in 2003 that TE was employed for the measurement of liver fibrosis, the number of publications in this field has generally exhibited an upward trend (*Figure 2*). The distribution of publications exhibited a bimodal pattern, with peaks observed in 2010 and 2019, surpassing the publication counts of other recent years. In 2010, the majority of studies concentrated on the application of TE for the diagnosis and efficacy evaluation of chronic viral hepatitis. In 2019, research predominantly focused on the utilization of TE in the context of NAFLD.

Bibliometric analysis of the institutions and countries

To investigate the contributions of various institutions to the field of TE for assessing liver fibrosis, an analysis of the number of publications from different institutions was conducted. Research on TE for liver fibrosis assessment has been carried out at approximately 956 institutions globally. By visualizing the top 10 institutions in this field (*Figure 3A*), it is found that these leading research institutions are located in France, Egypt, Turkey, China, and Malaysia, with Yonsei University in South Korea ranking first, having published 28 articles. Among the top ten research institutes, four are Chinese institutions: Capital Medical University, Fudan University, Shanghai Jiao Tong University, and the Chinese University of Hong Kong.

Through the analysis of countries, it is found that a total of 57 countries are involved in research in this field. An analysis of country contributions revealed that the top five leading countries are France, China, Italy, Japan, and South Korea (*Table 1*). Specifically, France and China have published 96 and 92 papers, respectively, accounting for 16.6% and 15.9% of the total publications, thereby indicating their significant contributions to this field. Furthermore, Italy, Japan, and South Korea have each published 46, 43, and 41 articles, respectively. Germany (29 articles), the United States (25 articles), and Egypt (20 articles) also ranked highly in the volume of national publications. Notably, Spain exhibits the highest number of citations per paper, with 14 papers collectively cited 560 times, resulting in an average of 40 citations per paper (*Table 1*). Only one paper has been published in this field by researchers from thirteen countries, including South Africa, Argentina, Serbia, etc.

Through the analysis of the number of national publications and international partnerships in this field (*Figure 3B-3D*), it is evident that European and Asian countries demonstrate a higher level of research activity. The network of collaborations between these countries is notably extensive. Notably, France, which has the highest number of publications, exhibits strong cooperative relationships with Italy, the United Kingdom, Germany, the United States, Spain, and other countries with substantial publication volumes. The aforementioned studies indicate that TE is predominantly utilized in European and Asian

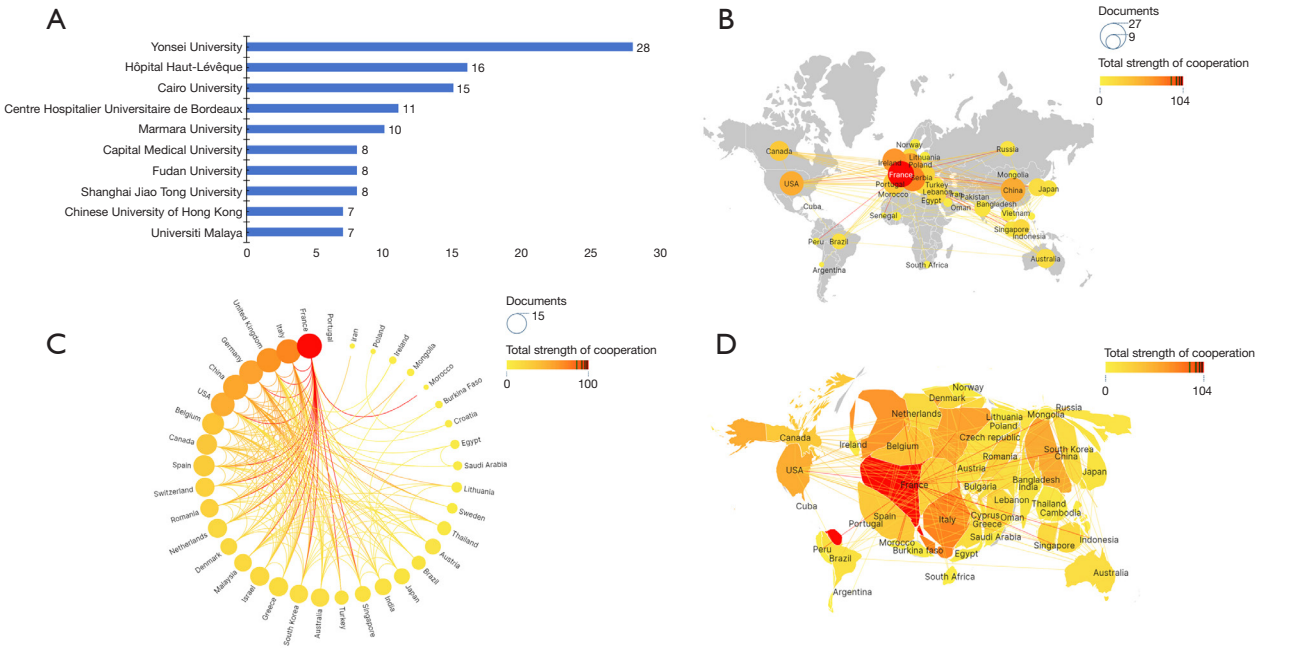

Figure 3 Overview of high-volume countries and research centers. (A) The top 10 research institutions with the largest number of publications; (B-D) the number of national publications and the cooperation between countries. The size of the circle refers to the number of publications, and the color depth of lines represents the strength of the cooperative relationship.

Table 1 Top 15 countries in field contribution

Rank	Country	Documents	Citations	Average citation/ publication
1	France	96	3,209	33.43
2	China	92	2,989	32.85
3	Italy	46	1,477	32.11
4	Japan	43	1,433	33.33
5	South Korea	41	1,332	32.49
6	Germany	29	893	30.79
7	USA	25	817	32.68
8	Egypt	20	664	33.20
9	England	14	549	39.21
10	Romania	14	408	29.14
11	Spain	14	560	40.00
12	Australia	12	383	29.46
13	Canada	12	371	30.92
14	India	12	371	30.92
15	Brazil	11	404	36.73

countries, whereas its application is comparatively limited in African and Oceanian regions. Consequently, there is a need to enhance international collaboration and exchange to collectively advance the development of this field on a global scale.

Bibliometric analysis of the journals

A bibliometric analysis of the journals indicated that the *European Journal of Gastroenterology & Hepatology* is the most prominent journal in the field of TE for assessing liver fibrosis. Visual discovery is carried out for magazines with high publication (*Figure 4A*), the top ten journals also include several high-impact journals listed in the Journal Citation Reports (JCR) Tier 1 category, such as the *Journal of Hepatology*, *Clinical Gastroenterology and Hepatology*, *Hepatology*, *World Journal of Gastroenterology*, and *Hepatology Research*. Based on the analysis of highly cited journals (*Figure 4B*), the top three journals cited were *Hepatology* (3,414 citations), *Journal of Hepatology* (1,836 citations), and *Gastroenterology* (1,086 citations). These journals are all classified as leading publications within the JCR1 category.

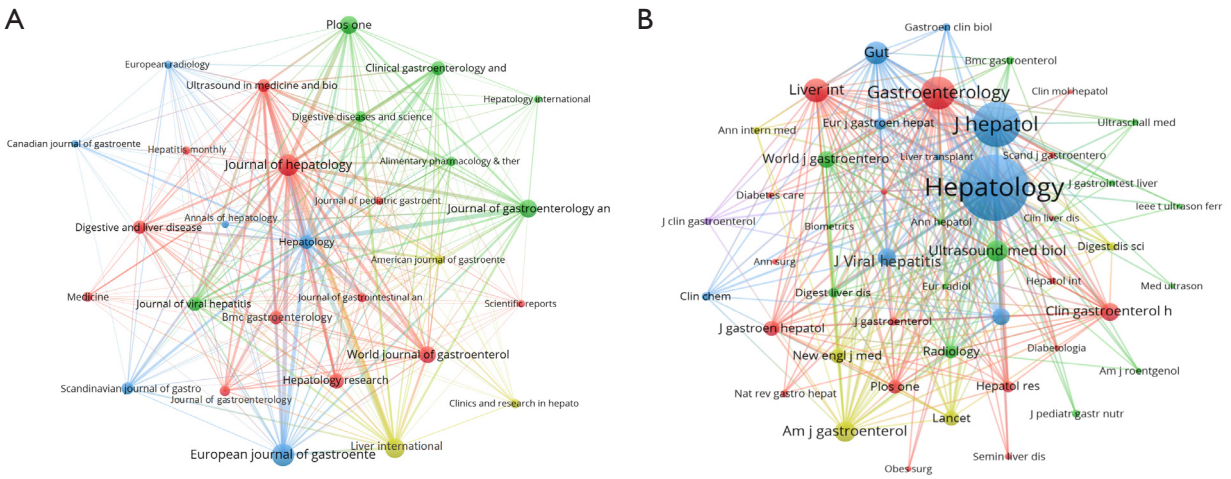

Figure 4 High contribution journals. (A) Journals with high number of articles in this field; (B) journals that publish highly cited articles in this field.

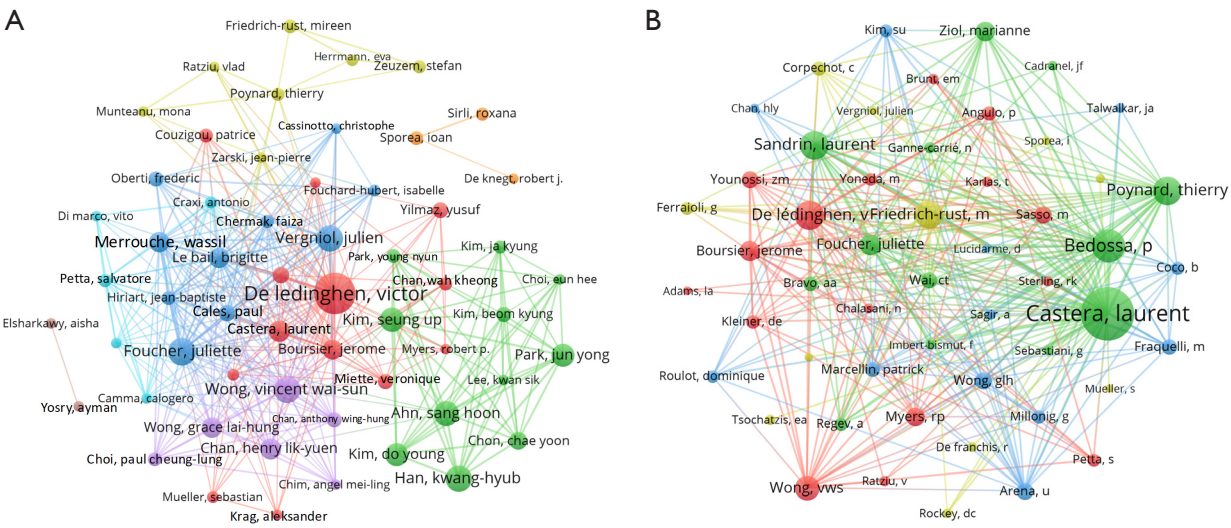

Figure 5 High contribution authors. (A) High-volume authors in this field; (B) highly cited authors in this field.

Furthermore, prominent journals such as the *American Journal of Gastroenterology*, *Ultrasound in Medicine and Biology*, *Clinical Gastroenterology and Hepatology*, *Gut*, *Liver International*, *Journal of Gastroenterology and Hepatology*, among others, are frequently utilized. These journals serve as critical conduits for disseminating research and play a pivotal role in advancing the field.

Bibliometric analysis of the authors

Bibliometric analysis of the authors found that 577 articles included in the study, including a total of 3,469 authors. Visualization and cluster analysis were performed on 57 authors with 7 or more publications (*Figure 5A*) and 52 authors with 50 or more citations (*Figure 5B*), and the top 10 authors were listed (*Table 2*). The results indicate that four authors are ranked within the top ten for both the number of published papers and the number of citations, all of whom are affiliated with institutions in France. Among these authors, three are associated with Haut-Lévêque Hospital: Victor de Lédinghen, Juliette Foucher, and Vincent Wai-Sun Wong. The fourth author, Laurent Castera, is affiliated with Beaujon Hospital. Notably, Victor de Lédinghen has the highest number of publications, with a total of 46

Table 2 Top 10 authors of published articles and cited articles

Rank	Author	Counts	Co-cited author	Citations
1	Victor de Lédinghen	46	Laurent Castera	649
2	Juliette Foucher	26	Pierre Bedossa	340
3	Kwang-Hyub Han	24	Victor de Lédinghen	284
4	Julien Vergniol	24	Laurent Sandrin	278
5	Vincent Wai-Sun Wong	24	Thierry Poynard	273
6	Sang Hoon Ahn	23	Mireen Friedrich-Rust	263
7	Seung Up Kim	22	Vincent Wai-Sun Wong	223
8	Do Young Kim	20	Juliette Foucher	176
9	Jun Yong Park	20	Jérôme Boursier	169
10	Laurent Castera	18	Marianne Ziol	160

articles and a wide range of research topics, including the application of TE in the diagnosis of liver fibrosis (26,27), the comparative study between different ultrasound devices and probes (28), the application of TE in the clinical detection of chronic hepatitis C (CHC) cirrhosis (29), and the comparison of TE with FibroTest, APRI, and LB in the diagnosis of liver fibrosis (30,31), and the error of TE in evaluating LS was analyzed, indicating that BMI greater than 28 was associated with measurement failure (32), Additionally, the therapeutic effect of liver fibrosis has been evaluated using TE (33,34).

Bibliometric analysis of the keywords

A co-occurrence network of author keywords from 577 articles was constructed using VOSviewer. Following the consolidation of synonymous keywords, 75 keywords with a frequency of five or more were selected for visualization (*Figure 6A*). Additionally, high-frequency keywords are illustrated using a WordCloud map (*Figure 6B*). The analysis of keywords, excluding subject words, reveals that high-frequency keywords such as "controlled attenuation parameter", "liver steatosis", "cirrhosis", "chronic hepatitis B", "chronic hepatitis C", "nonalcoholic fatty liver disease", "liver biopsy", "NAFLD", "elasticity imaging techniques", "portal hypertension", "liver stiffness measurement" are representative terms within this domain.

TE is frequently employed for the detection and assessment of liver fibrosis in patients with CHC, CHB, NAFLD, and cirrhosis. With the deepening of research, the application of TE in "biliary atresia", "hepatocellular carcinoma", "metabolic syndrome", and "type 2 diabetes" has gradually increased. The application of TE in pediatric populations is also a primary focus of investigation. In addition, it is also an important research hotspot in this field to evaluate the diagnostic efficacy and accuracy of TE by analyzing TE and FIB-4, APRI, FibroTest, LB and other diagnostic models in different diseases.

Through the analysis of burst words and trend topics, the development relationship of keywords over time is described (*Figure 6C*,*6D*). The findings indicate that, in the initial stages of TE for clinical applications, the primary focus was on evaluating liver fibrosis in viral hepatitis. As research has progressed, the emphasis has gradually shifted towards assessing liver fibrosis in patients with metabolic liver disease and type 2 diabetes.

Bibliometric analysis of the co-citation

Highly cited articles often play a key role in the development of a certain field, which can reflect the key scientific problems and development status of the field in a certain period of time. Co-citation map of articles references was drawn by VOSviewer and results demonstrated in *Figure* 7. In 2003, Sandrin *et al.* published a seminal study titled "Transient elastography: a new noninvasive method for assessment of hepatic fibrosis" in the journal *Ultrasound in Medicine and Biology* (15). This investigation was pioneering in its evaluation of the repeatability of TE and its efficacy in quantifying liver fibrosis in a cohort of 106 patients diagnosed with CHC. The findings indicate that the liver elastography system is

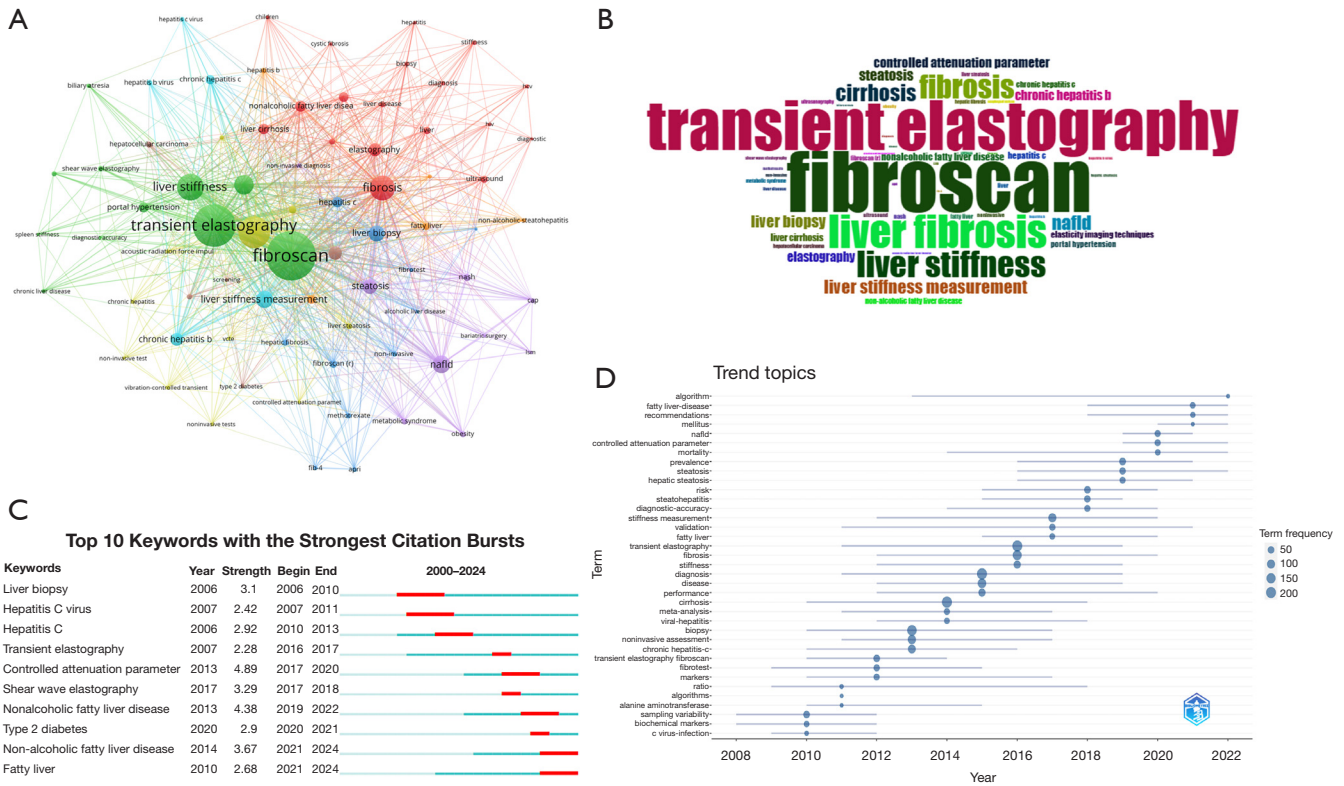

Figure 6 Research focuses and keywords. (A) High-frequency keywords; (B) high frequency keywords WordCloud map; (C) top 10 keywords with the strongest citation bursts; (D) visualize keywords trend topics to describe the development of keywords over time.

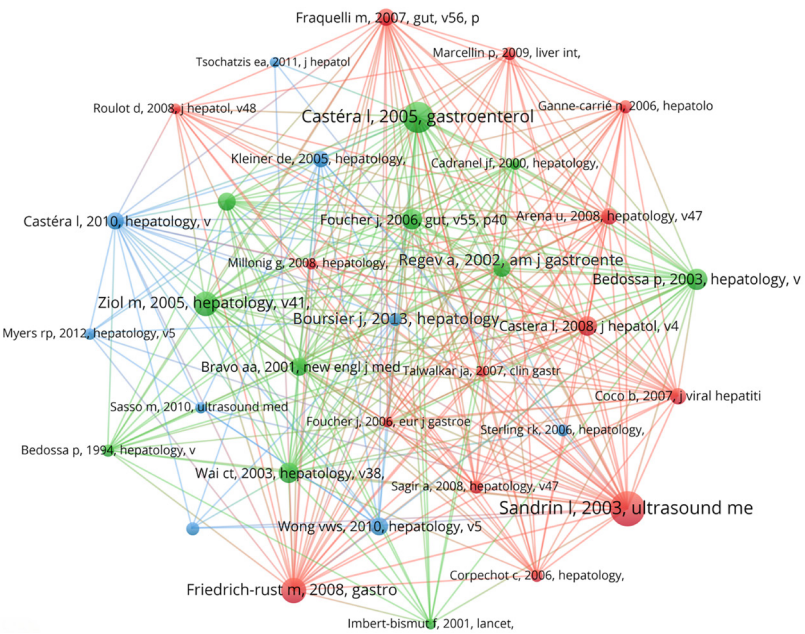

Figure 7 Co-citation chart of articles related.

a non-invasive, painless, rapid, and objective method for quantifying liver fibrosis. This provides a foundation for further clinical trials in subsequent stages and establishes the liver elastography system as a pioneering technique in the quantification of liver fibrosis. In 2003, Bedossa *et al.* published a study titled "Sampling variability of liver fibrosis in chronic hepatitis C" in the journal *Hepatology* (35). This research investigated the heterogeneity of liver fibrosis and its impact on the accuracy of fibrosis assessment through LB. In 2005, Castéra *et al.* published a study titled "Prospective comparison of transient elastography, Fibrotest, APRI, and liver biopsy for the assessment of fibrosis in chronic hepatitis C" in the journal *Gastroenterology* (36). In this study, LB was used as a reference standard to prospectively evaluate the efficacy of TE in patients with CHC, indicating that its performance was comparable to that of FibroTest and APRI. The combination of TE and FibroTest can be used as a reliable method for preliminary evaluation of fibrosis in patients with hepatitis C virus infection before treatment. In 2005, Ziol *et al.* published a study titled "Noninvasive assessment of liver fibrosis by measurement of stiffness in patients with chronic hepatitis C" in the journal *Hepatology* (37). This prospective multicenter study included 327 patients with CHC to investigate the utility of TE in evaluating liver fibrosis in this patient population. The noninvasive evaluation of LS using TE has proven to be a reliable method for detecting significant fibrosis or cirrhosis in patients with CHC. In 2008, Friedrich-Rust *et al.* published a study titled "Performance of transient elastography for the staging of liver fibrosis: a meta-analysis" in the journal *Gastroenterology* (38). The purpose of this meta-analysis was to evaluate the overall efficacy of TE in the diagnosis of liver fibrosis and to determine the factors affecting its diagnostic accuracy, indicating that TE can diagnose cirrhosis with high diagnostic accuracy.

Discussion

To the best of our knowledge, this study represents the first bibliometric analysis delineating the historical development and emerging trends of TE in the assessment of liver fibrosis. We conducted a systematic literature search on the articles related to the application of TE in liver fibrosis in the WOSCC database. Through screening, 577 papers published in 185 journals from 57 countries were finally visualized by bibliometric analysis.

Since the initial publication on TE in 2003 (15), it has progressively emerged as a focal point of research in the study of liver fibrosis, attributed to its non-invasive characteristics, rapid implementation, safety, and ease of repetition. Early studies mainly focused on the comparison of TE with FibroTest, APRI, LB and other non-invasive diagnostic methods in chronic viral hepatitis. In addition, the application of TE in liver fibrosis staging has also been extensively studied. Upon the completion of these studies, the application of TE in liver fibrosis has been widely acknowledged. In recent years, numerous research topics related to TE have emerged, with a significant proportion focusing on NAFLD. These studies encompass various aspects, including the application of TE in screening and diagnosis (39,40), the assessment of its efficacy (41,42), and the comparison of TE with clinical fibrosis markers, LB, and other detection methods in evaluating the stage of liver fibrosis in NAFLD (43,44). While TE cannot yet replace biopsy, it has emerged as a highly valuable tool for the diagnosis and staging, assessment of treatment efficacy, prognosis prediction, and evaluation of liver fibrosis in various CLDs.

In clinical practice, several factors can influence the assessment of liver fibrosis using TE through LSMs. For instance, ALT levels may lead to increased LS values, potentially resulting in erroneous outcomes (45). Additional confounding factors include extrahepatic cholestasis (46), hepatic congestion (47), excessive alcohol consumption (48), and a high BMI (>28 kg/m^2) (49,50). The research conducted by Alqahtani *et al.* demonstrated that FIB-4 and APRI are effective tools for assessing advanced liver fibrosis in obese patients with NAFLD, particularly in cases where TE is limited (51). Furthermore, diagnosing liver fibrosis via TE is challenging in patients with ascites or a narrow intercostal space (15). During pregnancy, TE is not recommended due to alterations in liver position (11). SWE evaluates liver fibrosis by quantifying the velocity of shear waves in conjunction with imaging data during an abdominal ultrasound examination (52). SWE is an objective and reproducible method that offers the advantage of obtaining quantitative measurements without the application of manual pressure, while directly assessing tissue elasticity. Unlike TE, SWE allows for examination while simultaneously confirming the anatomical structure of the liver. However, similar to TE, SWE results may be overestimated in the presence of intrahepatic inflammation, cholestasis, right heart failure leading to hepatic congestion, amyloidosis, or recent food intake, necessitating careful interpretation of the findings (14,53). The optimal cutoff value for accurately diagnosing the stages of liver fibrosis

by SWE has not yet been established (54). MRE utilizes a technique grounded in phase-contrast magnetic resonance imaging to quantitatively evaluate the extent of liver fibrosis. Among various NITs for assessing liver fibrosis, MRE demonstrates superior diagnostic performance (55). The test's repeatability has also been substantiated (56,57). In contrast to TE, MRE can be conducted in the presence of ascites (58). Nevertheless, MRE is subject to several limitations, including issues related to claustrophobia, body size exceeding the scanner's capacity, the presence of metal implants, as well as its high cost and limited accessibility. Furthermore, in cases where patients exhibit intrahepatic inflammation or cholestasis, LSMs obtained via MRE may be falsely elevated (59).

In recent years, as research in the field has advanced, numerous predictive models have been developed that integrate TE with emerging cutting-edge technologies, including artificial intelligence (AI) and machine learning algorithms (MLAs). These models aim to enhance screening and diagnosis, risk assessment, treatment evaluation, and prognosis of liver fibrosis. In 2022, Noureddin *et al.* developed a diagnostic model for NAFLD utilizing MLAs applied to data from the National Health and Nutrition Examination Survey (NHANES). This study investigated the use of machine learning to predict NAFLD as identified by TE, thereby affirming the diagnostic efficacy of TE in the definitive diagnosis of NAFLD (60). TE has developed a range of diagnostic, prognostic, and efficacy evaluation models for CLDs by integrating MLAs with AI systems (61). Sarvestany *et al.* developed a model utilizing MLAs to identify patients with all-cause advanced liver fibrosis. Their MLA demonstrated superior performance compared to all traditionally used biomarkers. Although the area under the receiver operating characteristic curve (AUROC) for their MLA {0.773 [95% confidence interval (CI): 0.699–0.834]} was marginally lower than that of TE [0.826 (95% CI: 0.758–0.889)], it still showed significant promise (62). In 2023, Lin *et al.* conducted a study involving data from 5,155 patients with CLDs to develop and validate an MLA (63). This algorithm utilizes LS as a primary clinical feature for the prediction and risk stratification of hepatocellular carcinoma in individuals with CLDs. Otero Sanchez *et al.* conducted an examination of a novel machine-learning approach's capability to identify diabetes subtypes at risk for liver-related complications, thereby confirming the significance of TE in the assessment of clinically significant fibrosis (64). Azhie *et al.* developed a long short-term memory (LSTM) model utilizing an MLA to predict the risk of fibrosis following liver transplantation, based on longitudinal data from 1,893 adults who underwent the procedure over a span of more than 30 years (65). The findings indicated that, within a subgroup of patients with available TE results, the application of a weighted LSTM model for detecting fibrosis [≥ F2; 0.705 (0.687 to 0.724)] did not demonstrate a statistically significant improvement over TE alone [0.685 (0.66 to 0.704)]. This underscores the critical role of TE in the early detection of graft fibrosis post-liver transplantation, thereby potentially preventing disease progression and reducing the necessity for retransplantation. The utilization of TE-based AI and MLAs has the potential to enhance the identification of patients with cirrhosis who are at risk of variceal bleeding in the future (66). In 2024, Zhang *et al.* utilized TE outcomes to stage liver steatosis and developed an innovative and cost-effective MLA (67). This integration of TE and ML significantly enhanced the diagnostic accuracy and efficiency in the assessment of NAFLD. AI and MLAs are expected to use a variety of NITs to establish a more accurate diagnostic model.

At present, TE is endorsed by the American Association for the Study of Liver Diseases (AASLD), the European Association for the Study of the Liver (EASL), and the Chinese Guidelines for the Prevention and Treatment of CHB as a significant method for the clinical evaluation of liver fibrosis associated with hepatitis B and hepatitis C viruses (68,69). In the clinical practice guidelines of South Korea for evaluating liver fibrosis in CLDs using NITs, TE is strongly recommended for diagnosing significant fibrosis and cirrhosis in patients with CHB, CHC, NAFLD, primary biliary cholangitis (PBC), autoimmune hepatitis, and primary sclerosing cholangitis due to its high sensitivity and specificity. Additionally, TE is suitable for screening or excluding advanced fibrosis in patients with ALD (11). The clinical practice guideline issued by the American Gastroenterological Association (AGA) indicates that TE may serve as an alternative approach to LB for the staging of fibrosis. Additionally, it can be utilized for the ongoing monitoring of patients, with the frequency of repetition ranging from every 6 months to 2 years, contingent upon the fibrosis stage and the patient's response to therapeutic interventions (70). Kjaergaard *et al.* utilized TE as a reference index for fibrosis screening and conducted a clinical trial with 3,378 participants to identify biomarkers capable of accurately screening for fibrosis in patients with ALD and NAFLD (71). In a clinical trial involving 966 patients diagnosed with nonalcoholic steatohepatitis

and clinically significant fibrosis, Vali *et al.* assessed the diagnostic accuracy of TE in comparison to the gold standard LB. The findings indicated that TE demonstrated acceptable accuracy in detecting advanced fibrosis [area under the curve =0.83 (95% CI: 0.80–0.86)] (72).

In evaluating contributions to the field, it is essential to conduct a comprehensive assessment of the bibliometric data pertaining to countries, institutions, and authors. Analysis indicates that researchers from France and China have the highest total number of publications in this domain, with a particularly notable prominence. TE originated in France (15), which could potentially explain the higher volume of academic publications and the extensive international collaboration with various countries. China exhibits a high prevalence of hepatitis B within its population. Consequently, the mortality burden associated with liver diseases, including hepatitis B, is increasing (73). In response, Chinese researchers have concentrated on the utilization of TE to evaluate liver fibrosis in patients afflicted with hepatitis B. France exhibits significant collaborative efforts with high-output countries such as Italy, the United Kingdom, Germany, the United States, and Spain, resulting in the completion of numerous high-quality studies. For instance, an international, multicenter, retrospective follow-up study involving 3,985 patients with PBC across 23 centers in 12 countries, conducted by Corpechot *et al.*, demonstrated that LSM validated by TE serves as the primary, independent, and effective predictor of PBC outcomes (74). The study suggests that LSM should be considered a viable alternative endpoint for assessing clinical benefits in PBC management. In 2023, Lemoine *et al.* conducted a European multicenter study to prospectively evaluate the prevalence and associated factors of hepatic steatosis and progressive fibrosis among human immunodeficiency virus (HIV)-infected individuals at risk for NAFLD at research centers in France, Germany, and other countries (39). The study demonstrated the accuracy of CAP technology in screening for steatosis within this population.

Core journals frequently publish essential research within their respective fields. Researchers can identify potential journals for manuscript submission by analyzing publication metrics. Journal analysis has demonstrated that publications such as the *European Journal of Gastroenterology & Hepatology*, *Journal of Hepatology*, *Clinical Gastroenterology and Hepatology*, *Hepatology*, *World Journal of Gastroenterology* and *Hepatology Research* played a key role in the development of the field.

Our study is subject to several limitations that warrant consideration. Firstly, the WOSCC was the sole database utilized for the literature search, which may have introduced publication bias. Consequently, the articles included in our study may not encompass the entirety of relevant literature in the field. Nonetheless, WOSCC is recognized as a leading repository for significant topics within the current field, and this study represents the only available analysis of its kind. Second, the publication metrics of various countries were analyzed from a global perspective, with the location of the corresponding author serving as the basis for statistical categorization. This methodology may introduce a degree of publication bias; however, it remains the most viable approach currently available. Third, conclusions derived solely from bibliometric research may not fully align with real-world conditions. Nonetheless, throughout the bibliometric analysis process, we have adopted a meticulous and cautious approach to enhance the accuracy and reliability of the research findings.

Conclusions

Liver fibrosis represents a crucial intermediary stage in the progression of various CLDs, which have the potential to advance to cirrhosis. Therefore, the early and accurate diagnosis of liver fibrosis is of utmost importance. TE is a technology that indirectly assesses LS by measuring the speed of ultrasonic wave propagation, thereby determining the extent of liver fibrosis. This method demonstrates superior diagnostic performance in staging liver fibrosis among patients with chronic viral hepatitis, NAFLD, autoimmune liver disease, and other related conditions. In addition to its diagnostic utility, TE assessment of liver fibrosis serves as a valuable index for evaluating diagnostic efficacy. Fibroscan-related prognostic models for various diseases have garnered significant attention and understanding. Exploring the value of TE through a variety of research methods such as MLAs, radiating the advantages of TE to more liver diseases, and combining TE with a variety of non-invasive detection indicators to improve its application value may be the application prospects of TE in the field of liver fibrosis.

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Footnote

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