

Bibliometric Study of fMRI in Epilepsy Research based on Citespace in China

Pinqin Wang^{1,2}, Min Xiao¹, Xin Peng^{1,*}

¹ Research Center of Humanities and Medicine, Zunyi Medical University, Zunyi, China

² Department of Radiology, the First People's Hospital of Zunyi (Third Affiliated Hospital of Zunyi Medical University), Zunyi 563000, China

* Corresponding author

Abstract: Objective: To conduct a visualized analysis of Chinese literature on applying functional magnetic resonance imaging (fMRI) in epilepsy research from 2010 to 2024 using CiteSpace software, revealing its research status, trends, and hotspots. Materials and Methods: Relevant literature published between 2010 and 2024 was retrieved from the China National Knowledge Infrastructure (CNKI) database. Bibliometric analysis and visualization were performed using Excel and CiteSpace. Results: A total of 255 articles were included. There were numerous author collaborations but limited inter-team cooperation. Institutional collaborations were also scarce. Prominent keywords included "epilepsy," "magnetic resonance imaging," "functional magnetic resonance imaging," and "temporal lobe epilepsy." Nine keyword clusters were identified, including "independent component analysis," "graph theory," "low-frequency amplitude," "magnetic resonance imaging," "working memory," "tuberous sclerosis," "resting-state fMRI," "brain dysfunction," and "focal epilepsy." Conclusion: The main research hotspots in the application of fMRI in epilepsy include "independent component analysis," "graph theory," "low-frequency amplitude," "magnetic resonance imaging," "working memory," "tuberous sclerosis," "resting-state fMRI," "brain dysfunction," and "focal epilepsy." Enhanced collaboration and integration of current research hotspots and frontiers are necessary to advance the field of fMRI application in epilepsy.

Keywords: Functional Magnetic Resonance Imaging, Epilepsy, Bibliometrics, Visualization.

1. Introduction

Epilepsy is a common neurological disorder, often referred to as "seizures" or "convulsions." Abnormal neuronal discharges in the brain cause it. According to surveys, there are approximately 10 million people with epilepsy in China¹. Clinically, epilepsy primarily manifests as epileptic seizures that last for more than 30 minutes. Epilepsy is often accompanied by various comorbidities, such as fractures and headaches, and has a high disability and mortality rate. It severely affects patients' quality of life and burdens society and families with a heavy economic burden. 2. Traditional diagnostic methods for epilepsy include electroencephalography (EEG) and imaging techniques. However, these methods have certain limitations in localizing epileptic foci and defining functional areas of the brain. Functional magnetic resonance imaging (fMRI), a non-invasive brain imaging technique, has become an essential tool for diagnosing and treating neurological diseases in recent years³, and its application in epilepsy research has gradually gained attention. CiteSpace is a literature analysis and visualization software developed by Dr. Chen Chaomei from Drexel University, and it is widely used to detect emergent keywords and analyze centrality⁴. CiteSpace can reveal publication trends, cooperation patterns between authors, institutional collaborations, and emerging research hotspots through co-authorship network analysis, keyword co-occurrence and clustering, and keyword burst detection. This study aims to retrieve relevant literature on fMRI and epilepsy from the China National Knowledge Infrastructure (CNKI) database, using CiteSpace for visual analysis, to explore the current state of research on fMRI and epilepsy in China. The goal is to investigate the trends and hotspots in

fMRI research on epilepsy.

2. Materials and Methods

2.1. Data Source

CNKI (China National Knowledge Infrastructure) is one of the largest academic databases in China. It is widely recognized as an essential platform for Chinese academic resources. Therefore, conducting bibliometric analysis using CNKI is highly representative. This study retrieved all relevant literature on the application of fMRI in epilepsy research from CNKI. The search strategy involved the use of two sets of keywords: Topic 1 ("functional magnetic resonance imaging" OR "functional MRI" OR "fMRI") AND Topic 2 ("epilepsy" OR "epileptic disorder" OR "seizure disorder"). The retrieval period was limited to January 1, 2010, to March 10, 2024, to ensure relevance. The search focused on Chinese journal articles and theses, yielding 569 articles. After reading the abstracts or full texts of the retrieved papers, the researchers excluded invalid literature. The selected articles were exported and saved in RefWorks format. After deduplication using CiteSpace, 255 articles were included in the final analysis.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria: All relevant literature on the application of fMRI in epilepsy research. Exclusion criteria: Case reports, scientific and technological achievement reports, conference papers, and other invalid documents; literature unrelated to the topic; duplicate publications.

2.3. Visualization Tool Parameters

CiteSpace parameters were set as follows: Time Slicing:

From 2010 To 2024; Years Per Slice:1; Term Source: Title & Abstract & Author Keywords(DE)&Keywords Plus (ID); Visualization: Cluster View-Static & Show Merged Network; Other software parameters were set to default. Three nodes were selected: institutions, keywords, and corresponding visual maps were generated and enhanced.

3. Graph Analysis Method

Cluster visualization analysis of keywords was performed. Generally, a cluster's modularity value (Q value) falls within the range of [0, 1). A $Q > 0.3$ indicates that the partitioned community structure is significant. The clustering is generally considered reasonable when the average silhouette value (S value) is more significant than 0.5. If the S value is more significant than 0.7, the clustering is highly convincing 5.

4. Results Analysis

4.1. Publication Trends

The selected literature was imported into Excel to plot a

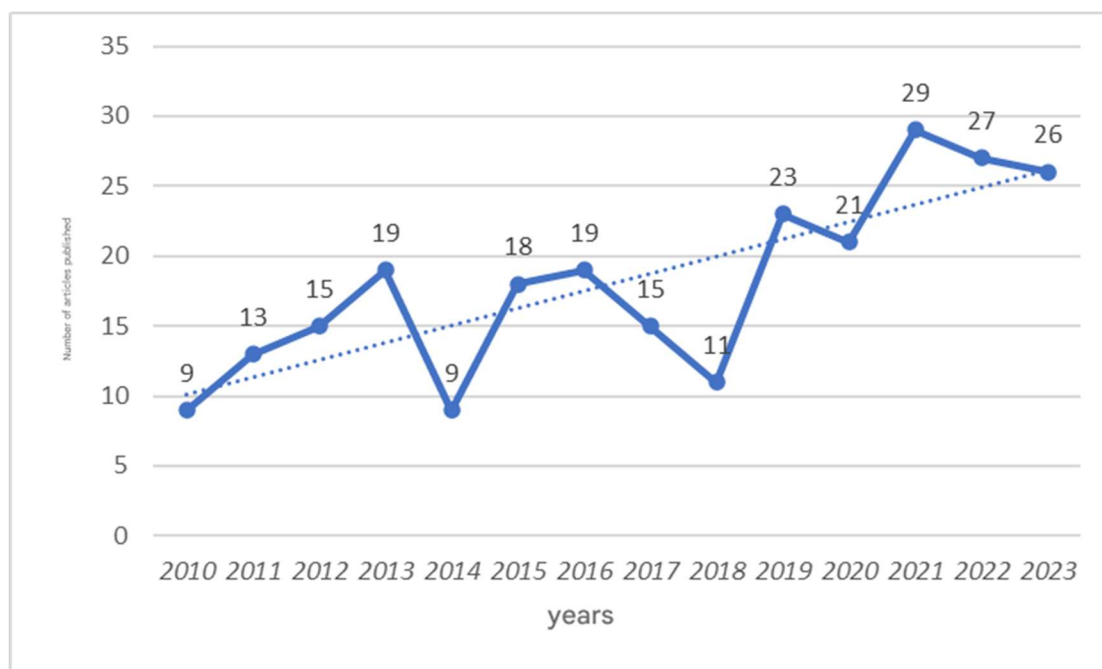


Figure 1. Annual publication volume of fMRI in epilepsy research in the CNKI database from 2010 to 2023

4.2. Author Information

Table 1 lists the top five authors in terms of publication volume. As shown in the table, Zhang Zhiqiang has the

highest number of publications, with 27 papers (centrality 0.10), followed closely by Lu Guangming, with 21 papers (centrality 0.03). The third-ranked author is Xu Qiang, with nine publications (centrality 0.00).

Table 1. Publication volume of authors on fMRI in epilepsy research in the CNKI database from 2010 to 2024

Rank	Author	Frequency	Centrality
1	Zhang Zhiqiang	27	0.10
2	Lu Guangming	21	0.03
3	Xu Qiang	9	0.00
4	Zheng Jinou	8	0.00
5	Liu Heng	7	0.00

4.3. Institutional Information

A table of the top five institutions in terms of publication volume in this field was created based on publication volume by institution (see Table 2). The Department of Medical

Imaging at Nanjing General Hospital of Nanjing Military Region has the highest publication volume, with 14 papers, followed by the University of Electronic Science and Technology of China, with 13 papers.

Table 2. Publication volume of institutions on fMRI in epilepsy research in the CNKI database from 2010 to 2024

Rank	Frequency	Institution
1	14	Department of Medical Imaging, Nanjing General Hospital, Nanjing Military Region
2	13	The University of Electronic Science and Technology of China
3	10	Department of Neurology, First Affiliated Hospital, Guangxi Medical University
4	5	Lanzhou University of Technology
5	4	Department of Neurology, General Hospital of Tianjin Medical University

4.4. Keyword Co-occurrence Analysis Results

A co-occurrence analysis of the “Keywords” node was conducted using CiteSpace to analyze the relationships between keywords, and a keyword co-occurrence network diagram was drawn (see Figure 2). The map contains 77 nodes

and 154 links, with a network density of 0.0526. The most common keywords related to fMRI in epilepsy research include “epilepsy,” “magnetic resonance imaging,” “functional magnetic resonance imaging,” and “temporal lobe epilepsy.” A statistical table of the top 5 most Frequent keywords is shown in Table 3.

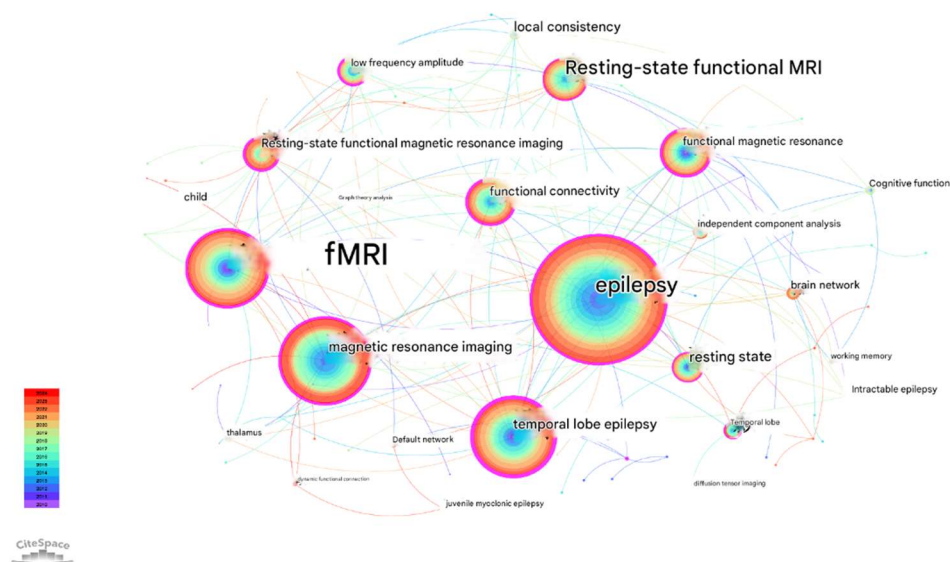


Figure 2. Keyword Network Diagram of fMRI in Epilepsy Research from 2010 to 2024 in the CNKI Database

Table 3. Top 5 Keywords of fMRI in Epilepsy Research from 2010 to 2024 in the CNKI Database

Rank	Frequency	Centrality	Keyword
1	99	0.28	Epilepsy
2	66	0.4	MRI
3	59	0.29	fMRI
4	59	0.43	Temporal Lobe Epilepsy
5	35	0.32	Functional MRI

4.5. Keyword Clustering Analysis Results

After the keyword co-occurrence visualization analysis, keyword clustering can be performed. CiteSpace uses two standard algorithms for keyword clustering: LSI (Latent Semantic Indexing) and LLR (Likelihood ratio). This study adopts the LLR algorithm, resulting in 9 clusters, as shown in Figure 3. The clusters are as follows: #0 Independent Component Analysis, #1 Graph Theory, #2 Low-Frequency

Amplitude, #3 Magnetic Resonance Imaging (MRI), #4 Working Memory, #5 Tuberos Sclerosis, #6 Resting-State Functional MRI (rs-fMRI), #7 Brain Functional Abnormalities, #8 Focal Epilepsy. Moreover, the clustering quality is indicated by $Q = 0.6587 (> 0.3)$, showing that the clustering is effective, and $S = 0.766 (> 0.7)$, indicating that the clustering results are reliable.

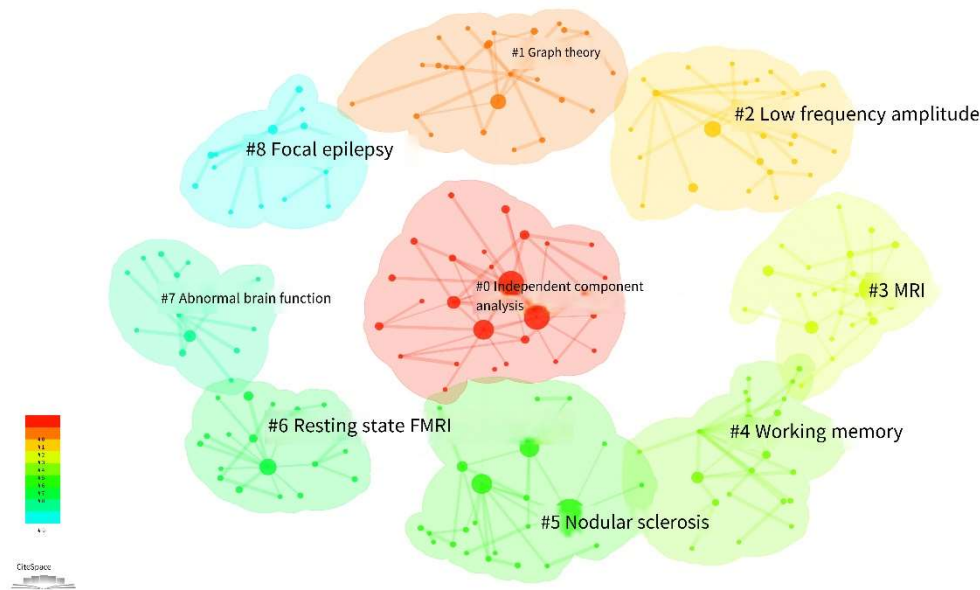


Figure 3. Keyword Clustering Diagram of fMRI in Epilepsy Research from 2010 to 2024 in the CNKI Database

5. Discussion

5.1. The Application Value and Significance of fMRI in Epilepsy Research

The annual increase in published papers further supports this trend, highlighting the widespread impact and growing research interest in this field. fMRI not only helps researchers identify brain regions involved in epileptic seizures but also monitors brain functional changes before and after treatment and their connections to other related diseases, providing strong imaging evidence for clinical diagnosis and treatment.

5.2. Analysis of the Author and Institutional Information

The Author and Institutional Information section shows some core authors and institutions.

Zhang Zhiqiang from the Affiliated Jinling Hospital of Nanjing Medical University has a high volume of publications, demonstrating his central role in fMRI research in epilepsy.

The Department of Medical Imaging at Nanjing General Hospital dominates fMRI research in epilepsy, with the highest publication volume. However, it is worth noting that the connections between the institutions with the highest publication volumes are relatively sparse, indicating limited collaboration between these institutions. Thus, related institutions should strengthen their partnerships in future research to expand the collaborative network between authors and institutions. Through collaboration, researchers can share resources and exchange ideas, promoting fMRI's broader and deeper application in epilepsy research.

5.3. Implications of Keyword Co-occurrence and Cluster Analysis

Keyword co-occurrence and cluster analysis provide us with a macro perspective, which helps us to deeply understand the core concepts and main research topics of epilepsy research. Through these analyses, we can find out which keywords appear frequently and infer the focus and trend of research. In the keyword co-occurrence analysis,

"epilepsy" and "magnetic resonance imaging" are the most frequently occurring keywords, indicating MRI's central position in epilepsy research. Since its birth, MRI has played an unparalleled role in the diagnosis of neurological diseases, especially in the diagnosis and treatment of epilepsy patients 6. Various functional imaging methods have emerged with the continuous advancement of MR imaging technology. For example, diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI), susceptibility-weighted imaging (SWI), fMRI, and other technical methods can evaluate many pathophysiological changes related to epilepsy 7, 8. In particular, resting-state functional magnetic resonance imaging (rs-fMRI) can visualize the areas of cognitive dysfunction associated with epilepsy and has become a hot topic in epilepsy-related research⁹. Among the top 15 keywords, the one with the highest centrality is "temporal lobe epilepsy" (0.43). Temporal lobe epilepsy (TLE) is a type of focal epilepsy named because the lesions are primarily located in the temporal neocortex and the medial temporal lobe structure. It is the most common focal epilepsy in clinical practice. Most TLE cannot be treated with drugs and are often accompanied by functional impairment¹⁰. However, due to the unclear pathogenesis of TLE and the complex and diverse clinical symptoms, current diagnostic technology makes it challenging to accurately diagnose TLE in the early stages and assess the precise epileptogenic area before surgery. As a relatively advanced neuroimaging technology, resting-state functional magnetic resonance imaging can detect activities between different brain regions and has been widely used in TLE-related research 11.

The cluster analysis results showed that there were 9 clusters in total. The clustering results can be roughly divided into three aspects: (1) Research methods of fMRI in the field of epilepsy research, including rs-fMRI, independent component analysis (ICA), graph theory, and amplitude of low-frequency frequency (ALFF). The latter three are specific analysis methods based on rs-fMRI. 12; (2) Using fMRI to study epilepsy symptoms, including working memory and brain function abnormalities; (3) Using fMRI to study epilepsy lesions, including tuberous sclerosis and focal epilepsy. The clustering results show that fMRI in epilepsy

research mainly focuses on data analysis methods, epilepsy symptoms, and epilepsy lesions. The smaller the clustering result order number, the more keywords the cluster contains. Therefore, "#0 Independent Component Analysis, #1 Graph Theory, and #2 Low-Frequency Amplitude" are the top three clusters containing the most keywords. Therefore, the current research hotspot in this field is mainly on data analysis methods. ICA has been shown to isolate low-frequency resting-state patterns from data acquired at various spatiotemporal resolutions and can detect and classify brain activity underlying epileptic discharges¹³. Graph analysis is a safe and widely used brain activity assessment technology. This method quantitatively analyzes the nodes and connections of functional brain networks, reveals changes in brain networks, profoundly understands the anatomical basis of brain dysfunction, and provides a reference for disease diagnosis and treatment¹⁴. The researchers found that ALFF, an essential analytical tool for rs-fMRI, can quantify the intensity of brain activity¹⁵. These analysis results are significant in guiding the selection of future research directions and designs.

5.4. Study Limitations

First, the data source of this article is limited to the China National Knowledge Infrastructure (CNKI) database, and relevant literature in other databases is omitted so that the analysis results may be omitted. Second, this article only collected articles published in Chinese from 2010 to 2024, and the collection of literature is not extensive enough. In addition, it takes some time from literature retrieval to paper completion, so the relevant literature included in CNKI was not selected after the literature retrieval. Future research can consider expanding the data source, increasing the time range of literature retrieval, and conducting a more comprehensive visual analysis of keywords to provide more information for applying fMRI in epilepsy.

6. Summary

This paper visualizes the literature on functional magnetic resonance imaging (fMRI) in epilepsy research from 2010 to 2024, revealing the main trends and research hotspots in this field. During this period, the application of fMRI in epilepsy research has continued to increase, especially in 2021, reaching the highest number of publications, showing the importance of fMRI in epilepsy research. Through the analysis of the institutional cooperation network, it was found that multidisciplinary and multi-institutional collaboration played an essential role in improving the quality of research. In the author cooperation network, Zhang Zhiqiang and Lu Guangming from the Jinling Hospital, Affiliated with Nanjing University Medical School, are in a core position, forming a large research cluster. Institutional cooperation analysis shows that the Department of Imaging of Nanjing General Hospital of Nanjing Military Region, the University of Electronic Science and Technology of China, and the Department of Neurology of the First Affiliated Hospital of Guangxi Medical University have the highest number of publications in this field. However, cooperation between different institutions still needs to be strengthened. Keyword cluster analysis found that independent component analysis (ICA), graph analysis, and low-frequency amplitude (ALFF) are the main hotspots of current research. These methods have essential applications in detecting brain activity during epileptic seizures, evaluating changes in brain functional

networks, and quantifying the intensity of brain activity. In-depth research on these hotspots will help to understand and treat epilepsy more accurately. Keyword emergence analysis shows that future research trends may focus on the study of gene expression, effective connectivity, and epilepsy-related depression. In-depth research in these directions is expected to provide new ideas for personalized treatment of epilepsy and have a positive impact on improving patient prognosis.

In summary, this study provides a comprehensive overview of the application of

fMRI in epilepsy research through systematic visual analysis reveals significant research trends and hotspots and provides a reference for future research directions.

References

- [1] Ding D, Zhou D, Sander JW, et al. Epilepsy in China: major progress in the past two decades. *Lancet Neurology*. 2021;20(4):316-326.
- [2] Sun Huiliang, Zhang Hong Research progress on the pathogenesis and diagnosis of cognitive impairment in epilepsy comorbidity *Chinese Journal of Practical Internal Medicine* 2024; 44(01):75-79.
- [3] Edited by Jia Wenxiao and Chen Min *Clinical Application of Magnetic Resonance Functional Imaging*: Beijing: People's Military Medical Press, 2012
- [4] Chen Yue, Chen Chaomei, Liu Zeyuan, The methodological function of CiteSpace knowledge graph *Scientific research* 2015; 33(02):242-253.
- [5] Zheng Xiaodong, Gao Shan, Han Wenjin, Visual analysis of treatment for adolescent idiopathic scoliosis *Chinese Organizational Engineering Research* 2025; 29(03):645-653.
- [6] Mesraoua B, Koepf M, Schuknecht B, et al. Unexpected brain imaging findings in patients with seizures. *Epilepsy & Behavior*. 2020;111.
- [7] Hung SC, Chen Y, Yap PT, et al. Magnetic Resonance Fingerprinting of the Pediatric Brain. *Magnetic resonance imaging clinics of North America*. 2021;29(4):605-616.
- [8] Verma G, Delman BN, Balchandani P. UltraHigh Field MR Imaging in Epilepsy. *Magnetic resonance imaging clinics of North America*. 2021;29(1):41-52.
- [9] Frontiers Prod O. Alterations Functional Connectivity in Temporal Lobe Epilepsy and Their Relationships With Cognitive Function: A Longitudinal Resting-State fMRI Study (vol 11, 625, 2020). *Frontiers in Neurology*. 2020;11.
- [10] Meng Zhaomin, Huang Ling Progress in MRI research on cognitive dysfunction in temporal lobe epilepsy *Chinese Medical Innovation* 2023; 20(05):171-175.
- [11] Sun YM, Peng YX, Wen Q, et al. Resting-state fMRI in temporal lobe epilepsy patients with cognitive impairment A protocol for systematic review and meta-analysis. *Medicine*. 2021;100(41).
- [12] Xiong X, Dai LL, Chen W, et al. Dynamics and concordance alterations of regional brain function indices in vestibular migraine: a resting-state fMRI study. *Journal of Headache and Pain*. 2024;25(1).
- [13] Ren Xingyu, Zhou Zhibin, Gao Yujun New progress in the application of resting state functional magnetic resonance imaging in temporal lobe epilepsy *Journal of Molecular Imaging* 2021; 44(01):198-201.
- [14] Guo RW, Wu J, Zheng YM, et al. Graph Theory Further Revealed Visual Spatial Working Memory Impairment in Patients with Inflammatory Bowel Disease. *Journal of Inflammation Research*. 2024;17:2811-2823.

[15] Tan Yanlin, Gao Xue Application of rs fMRI based on ALFF in the evaluation of brain activity status in the computer area of benign epilepsy with central temporal spike waves in children

Chinese Journal of Eugenics and Genetics 2021; 29(08):1155-1158.