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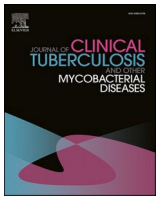

Global research trends in central nervous system tuberculosis — A bibliometric analysis

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ABSTRACT

Background: Central Nervous System Tuberculosis (CNS-TB) is a serious public health concern causing significant morbidity and mortality, especially in high TB burden countries. Despite the expanding research landscape of CNS-TB, there is no comprehensive map of this field. This work aims to (1) obtain a current and comprehensive overview of the CNS-TB research landscape, (2) investigate the intellectual and social structure of CNS-TB publications, and (3) detect geographical discrepancies in scientific production, highlighting regions requiring increased research focus.

Methods: We conducted a bibliometric analysis on CNS-TB literature indexed in Web of Science from 2000 to 2022, evaluating 2130 articles. The dataset was analyzed in R for descriptive statistics. We used R-bibliometrix and VOSViewer for data visualization.

Findings: Publication output grew annually at an average rate of 6·88%, driven primarily by India and China. International collaborations comprised 16·44% of total publications but contributed to 11 of the 15 top-cited papers. Additionally, we identified discrepancies of CNS-TB research in many low- and middleincome countries relative to their TB incidence.

Interpretation: Our findings reveal a growing interest in CNS-TB research from China and India, countries with rapidly developing economies, high TB burdens, and a recent increase in research funding. Furthermore, we found that international collaborations are correlated with high impact and accessibility of CNS-TB research. Finally, we identified disparities in CNS-TB research in specific countries, particularly in many low- and middle-income countries, emphasizing the need for increased research focus in these regions.

1. Introduction

Central Nervous System Tuberculosis (CNS-TB) is a devastating manifestation of Mycobacterium Tuberculosis disease, comprising 1–2 % of Tuberculosis infections [1]. The incidence of CNS-TB is proportional to that of overall TB and it is most common in childhood [1-3]. Currently, global prevalence and mortality rates have only been estimated for Tuberculosis Meningitis (TBM), the most common form of CNS-TB [4]. TBM's prevalence is estimated at 2·11 per 100,000 individuals, with mortality rates ranging from 20 to 50 % [1,4,5].

Even among survivors of CNS-TB, up to a third suffer neurological impairments such as cranial nerve palsies, ophthalmoplegia, seizures, psychiatric disorders, and hemiparesis [1,6]. Moreover, this morbidity of CNS-TB is associated with a country's TB burden, its Human Development Index (HDI), and the prevalence of HIV in the country [4]. The disproportionate morbidity and mortality of CNS infections, especially in low- and middle-income countries (LMICs), underscores the urgency to accelerate research efforts that focus on prevention, diagnostic tools, and effective therapeutics in these settings.

The CNS-TB research landscape has expanded rapidly over the years [1–8]. While analyses of publications related to spinal tuberculosis [9,10,12], infectious meningitis [13], and bacterial CNS infections in south-east asia [11] have been reported, a comprehensive map detailing the current intellectual and social structure of CNS-TB does not currently exist. Such a map would significantly benefit the field by identifying key research constituents, collaboration patterns, and geographical discrepancies. Ultimately, it would allow authors and funding sources to derive novel questions for investigation and position their specific

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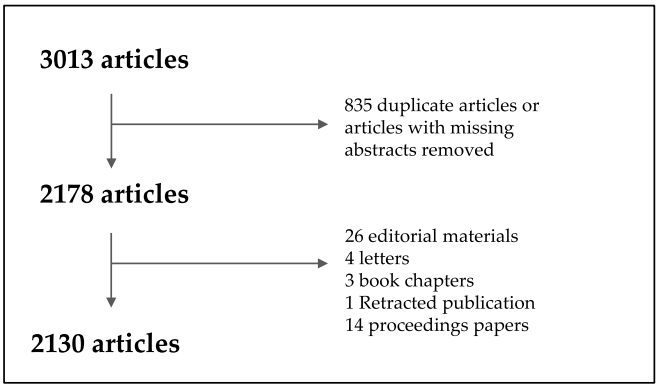

Fig. 1. Study Flow Diagram.

Table 1
Main Information About Data.

OVERVIEW	
Timespan	2000–2022
Sources	659
Documents	2130
Annual Growth Rate %	6.88
Document Average Age	8.9
Average citations per doc	15.62
References	25,602
DOCUMENT CONTENTS	
Keywords Plus (ID)	2037
Author's Keywords (DE)	2843
AUTHORS	
Authors	8194
Authors of single-authored docs	40
AUTHORS COLLABORATION	
Single-authored docs	48
Co-Authors per Doc	6.09
International co-authorships %	16.44

contributions in CNS-TB research [14].

To this end, we performed a bibliometric analysis on all CNS-TB literature indexed in Web of Science. The aim of this work is threefold: (1) to obtain a current and comprehensive overview of scientific research production concerning CNS-TB, (2) to investigate the intellectual and social structure of these publications, and (3) to detect geographical discrepancies in CNS-TB scientific production, highlighting areas that require increased research focus.

2. Methods

2.1. Data extraction

Records were extracted on March 18th, 2023 from Web of Science (WoS) by Clarivate, a standardized and well-established database for scientific research [15]. Only articles in the WoS Core Collection, which contains the full record of fields such as authors, affiliations, citation metrics, and funding information, were analyzed. As other databases either do not contain some of these fields, or are stored in a different format, an attempt to combine databases would have potentially led to a loss of insightful bibliometric information that was specific to our aims.

Title search was used for specificity and to prevent irrelevant results, as recommended by previous bibliometric analyses [16,17]. We aimed to obtain the research trends of CNS-TB from 2000 to 2022. The starting year was set to 2000 because our major interest is in the recent growth of CNS-TB research with a sufficient number of articles for analysis. Hence, the time interval well over two decades would serve this purpose.

We selected search terms to encompass the diverse range of manifestations of CNS-TB, including specific manifestations in the meninges, spine, and optic areas. The search strategy included terms such as "Central Nervous System Tubercul*", "Tubercul* Meningitis", "Tubercul* Brain* Abscess", and "Spinal Tubercul*", among others.

2.2. Filtering

The search yielded 3013 articles. We excluded articles published in books and those classified as letters, meetings, abstracts, editorial materials, and retracted publications. We also removed articles with missing abstracts and any duplicates. This yielded a final count of 2130 articles (Fig. 1). Upon conducting a manual review of each article's title, we determined that all 2130 remaining articles met our inclusion criteria.

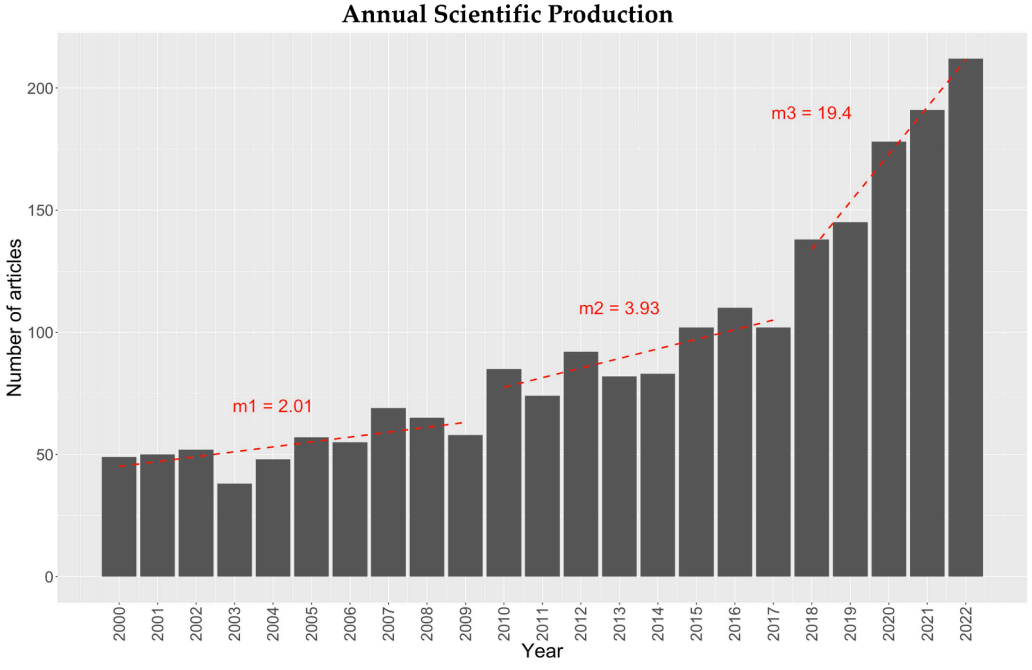

Fig. 2. Annual Scientific Production of CNS-TB literature.

Table 2
Top 15 Cited Documents. TC = Total Citations.

Title	Type	Authors	Journal	Countries	Year	TC
Effect of BCG vaccination on childhood tuberculous meningitis and miliarytuberculosis worldwide	Meta-Analysis	Trunz, BB et al.	LANCET	SWITZERLAND; UK	2006	729
Dexamethasone for the treatment of tuberculous meningitis in adolescents and adults	Randomized Controlled Trial	Thwaites, GE et al.	NEW ENGLAND JOURNAL OF MEDICINE	VIETNAM; UK	2004	622
Tuberculous meningitis: a uniform case definition for use in clinical research	Perspective	Marais, S et al.	LANCET INFECTIOUS DISEASES	AFRICA; UK; INDIA	2010	493
Central nervous system tuberculosis: Pathogenesis and clinical aspects	Non-Systematic Literature Review	Rock, RB et al.	CLINICAL MICROBIOLOGY REVIEWS	USA	2008	349
Spinal tuberculosis: A review	Non-Systematic Literature Review	Garg, RK et al.	JOURNAL OF SPINAL CORD MEDICINE	INDIA	2011	309
Diagnostic accuracy of nucleic acid amplification tests for tuberculous meningitis	Systematic Review; Meta-Analysis	Pai, M et al.	LANCET INFECTIOUS DISEASES	USA	2003	275
Diagnosis of adult tuberculous meningitis by use of clinical and laboratory features	Clinical Research	Thwaites, GE et al.	LANCET	VIETNAM; UK	2002	268
Tuberculous meningitis: more questions, still too few answers	Non-Systematic Literature Review	Thwaites, GE et al.	LANCET NEUROLOGY	UK; SOUTH AFRICA	2013	243
Tuberculous meningitis: many questions, too few answers	Non-Systematic Literature Review	Thwaites, GE et al.	LANCET NEUROLOGY	UK; VIETNAM	2005	238
Corticosteroids for managing tuberculous meningitis	Meta-Analysis	Prasad, K et al.	COCHRANE DATABASE OF SYSTEMATIC REVIEWS	INDIA; UK	2016	225
Intensified regimen containing rifampicin and moxifloxacin for tuberculous meningitis	Randomized Controlled Trial	Ruslami, R et al.	LANCET INFECTIOUS DISEASES	NETHERLANDS; INDONESIA	2013	212
Timing of Initiation of Antiretroviral Therapy in Human Immunodeficiency Virus (HIV)-Associated Tuberculous Meningitis	Randomized Controlled Trial	Torok, ME et al.	CLINICAL INFECTIOUS DISEASES	UK; VIETNAM; NETHERLANDS	2011	206
Tuberculous meningitis	Non-Systematic Literature Review	Wilkinson, RJ et al.	NATURE REVIEWS NEUROLOGY	UK; SOUTH AFRICA; INDIA; NETHERLANDS; VIETNAM; USA	2017	201
Tuberculous meningitis	Non-Systematic Literature Review	Thwaites, GE et al.	JOURNAL OF NEUROLOGY NEUROSURGERY AND PSYCHIATRY	UK; VIETNAM; GAMBIA	2000	193
Spinal tuberculosis (Pott's disease): its clinical presentation, surgical management, and outcome	Clinical Research	Turgut, M	NEUROSURGICAL REVIEW	TURKEY	2001	191

Table 3
Top 15 Active CountriesTC = Total Citations, C/D = Citation to Document Ratio.

Country	Frequency	%	TC	C/D	h-index
INDIA	491	23.05	7830	15.95	42
CHINA	488	22.91	4438	9.09	30
USA	226	10.61	5235	23.16	38
SOUTH AFRICA	176	8.26	4849	27.55	39
UK	172	8.08	8066	46.90	43
TURKEY	108	5.07	2003	18.55	25
NETHERLANDS	73	3.43	2211	30.29	29
VIETNAM	67	3.15	4628	69.07	36
JAPAN	55	2.58	618	11.24	14
FRANCE	52	2.44	452	8.69	13
PAKISTAN	52	2.44	318	6.12	8
KOREA	51	2.39	844	16.55	15
INDONESIA	49	2.30	809	16.51	16
GERMANY	47	2.21	484	10.30	11
SPAIN	37	1.74	404	10.92	11

2.3. Analysis

The records were imported into R Studio for analysis of annual growth, citation analysis, country output and impact, author output and impact, and funding sources [18]. The R-Bibliometrix package was used to obtain a collaboration network for countries [19]. VOS Viewer, a software tool to visualize bibliometric networks, was also used to obtain a collaboration network for authors [20].

To explore global discrepancies in the CNS-TB research output, we calculated a modified ratio of the number of articles from each country to the incidence of overall TB in the respective country.

The article to incidence modified ratio was calculated as:

$$ATI = (\#Articles + 1)/(Incidence\,(per\,100\,k) + 1).$$

The modified ratio, as opposed to a simple ratio, better differentiates countries with zero articles and high TB incidence from countries with zero articles and low TB incidence.

3. Results

3.1. *Research output and growth*

Between 2000 and 2022, 2130 articles on central nervous system tuberculosis (CNS-TB) were published (Table 1). 8194 unique authors published in 659 different journals. International co-authorships produced 16·44 % of articles. The annual growth rate of articles was 6·88 %.

In 2000, 50 publications concerning CNS-TB were indexed in Web of Science (Fig. 2). The annual scientific production experienced a modest growth from 2000 to 2009 (slope = 2·01 articles/year). The rate of increase accelerated between 2010 and 2017 (slope = 3·93 articles/year). Between 2018 and 2022, a rapid surge in the number of publications was observed. (slope = 19·4 articles/year). In 2022, the number of publications in Web of Science exceeded 200, representing a four-fold increase compared to the year 2000.

3.2. Top-cited articles

The top 15 cited documents are listed in Table 2. Out of the 15 documents, 12 pertain to TB meningitis, two focus on spinal tuberculosis, and one provides an overall view of central nervous system tuberculosis. The document types include two *meta*-analyses, one *meta*-analysis with systematic review, six non-systematic literature reviews, two randomized controlled trials, two clinical research articles, and one perspective paper.

Guy E. Thwaites authored five of the 15 top cited articles, all of which focused on Tuberculosis meningitis. Thirteen of the top 15 cited

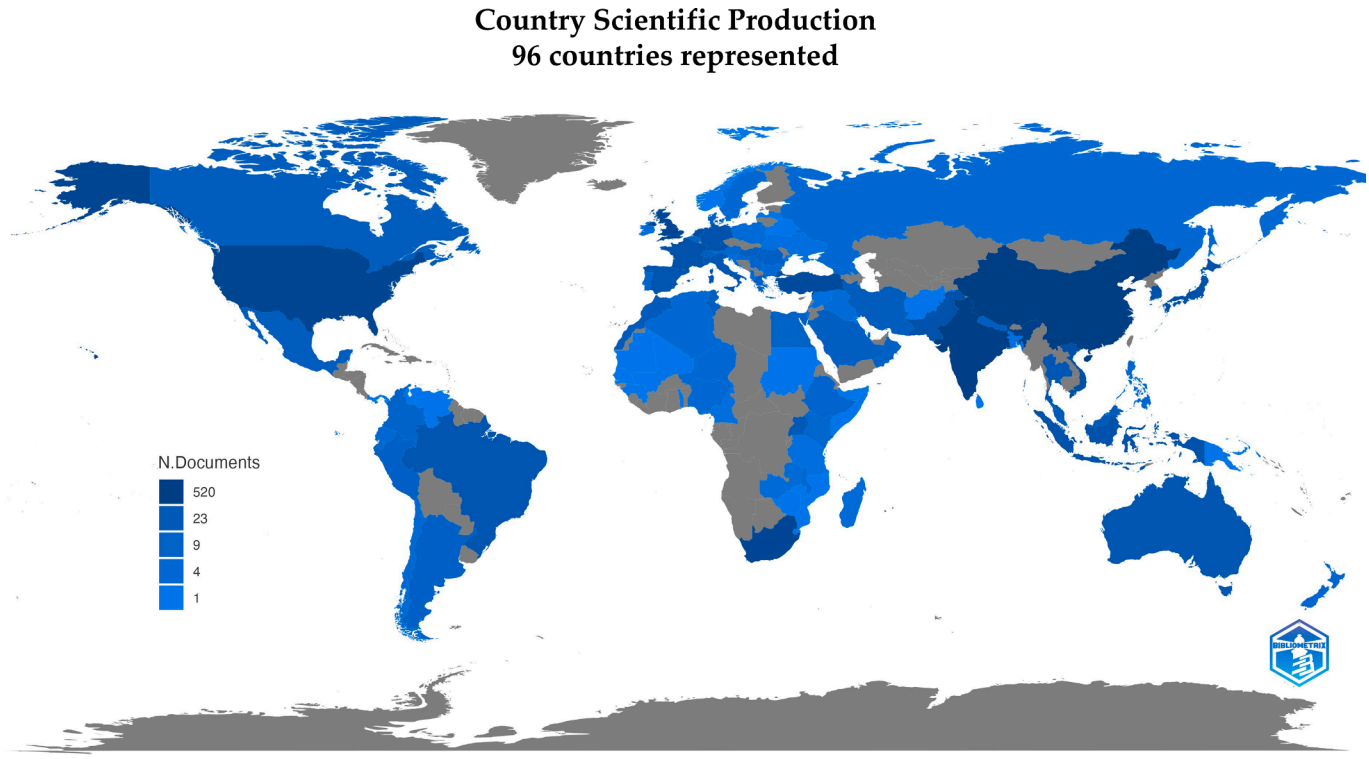

Fig. 3. Country Scientific Production.

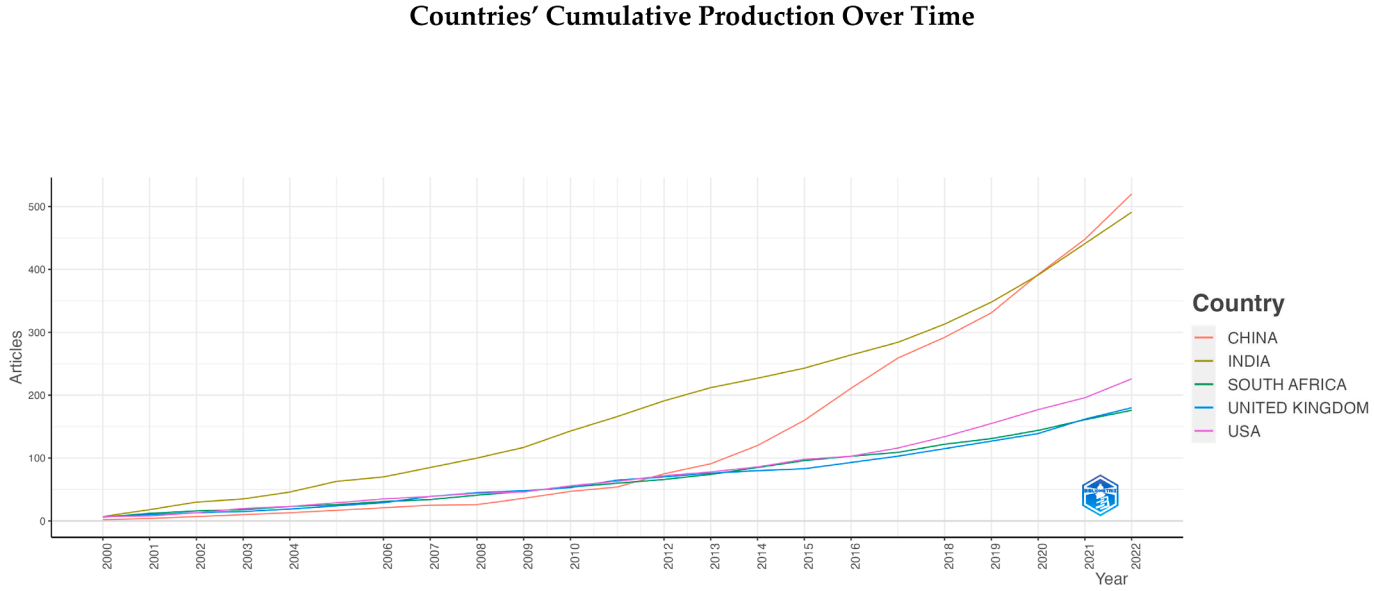

Fig. 4. Top 5 Countries' Cumulative Production Over Time.

articles were published in high impact-factor (>10) journals such as the Lancet Journals, New England Journal of Medicine, and Nature. Country affiliations for the top-cited articles include England, Switzerland, Vietnam, South Africa, India, USA, Netherlands, Indonesia, Gambia, and Turkey. International collaborations contributed to 11 of the 15 highly cited articles.

3.3. Geographical output

Articles about CNS-TB originated from 96 countries. The countries that have produced more than 100 publications include India, China, USA, South Africa, England, and Turkey (Table 3 and Fig. 3).

The quality of publications from each country can be analyzed using citation metrics such as the citation-to-document ratio (C/D) and the h-index. Countries with the greatest C/D are Vietnam (69·07), England (46·9), Netherlands (30·29), Africa (27·55), and USA (23·16). The h-index is a metric that quantifies the cumulative impact of scholarly output and performance. The countries with the highest h-indices for CNS-TB publications are England (43), India (42), Africa (39), USA (38) and Vietnam (36).

The most significant increase in publication output is observed from India and China (Fig. 4). The number of publications in India has grown

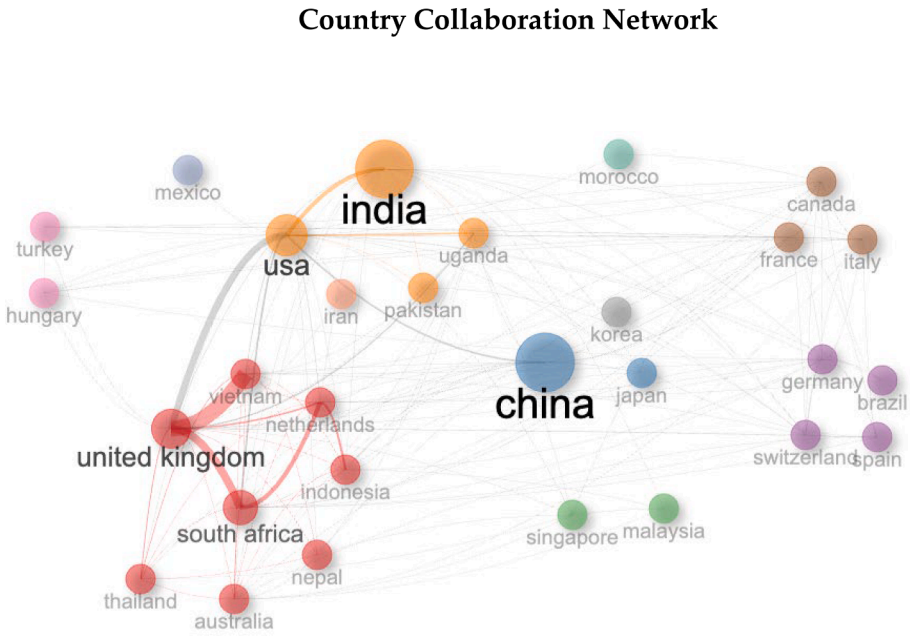

Fig. 5. Country Collaboration Network.

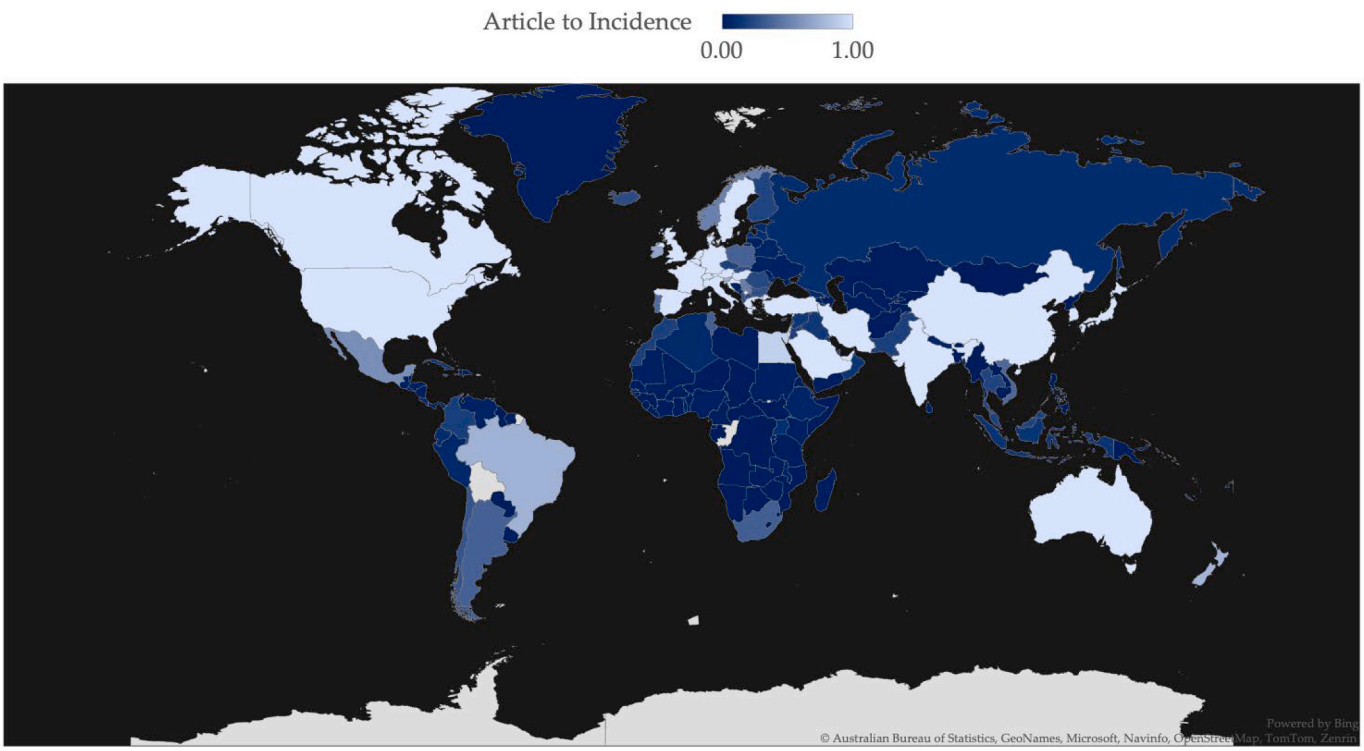

Fig. 6. Modified ratio of Articles to Incidence of overall TB in each country.

at a steady rate from 2000 to 2022. In contrast, China's rapid surge in publication production began after 2012, surpassing India in yearly production by 2022.

3.4. Geographical collaboration

Of the top 30 countries participating in CNS-TB research, all engage in at least one international collaboration (Fig. 5). The collaboration network reveals four major clusters of countries that tend to collaborate: Red Cluster (UK, South Africa, Vietnam, Netherlands, Indonesia, Nepal, Thailand, and Australia), Orange Cluster (India, USA, Uganda, Pakistan, and Iran), Purple Cluster (Germany, Brazil, Switzerland, and Spain), and Brown Cluster (Canada, France, and Italy). The top 5 international collaborations are between UK and Vietnam (59), UK and South Africa (42), USA and UK (39), South Africa and Netherlands (31), and India and USA (30).

3.5. Geographical discrepancies in CNS-TB research

To detect the geographical discrepancies in CNS-TB research, we

Table 4
Top 15 Journals. TC = Total Citations, C/D = Citation to Document Ratio, IF = Impact Factor.

Journal	Frequency	%	TC	C/D	h-index	IF
INTERNATIONAL JOURNAL OF TUBERCULOSIS AND LUNG DISEASE	47	2.21	1151	24.49	21	3.4
PLOS ONE	36	1.69	686	19.06	16	3.752
JOURNAL OF THE NEUROLOGICAL SCIENCES	33	1.55	874	26.48	16	4.553
NEUROLOGY INDIA	31	1.46	426	13.74	11	2.117
CHILDS NERVOUS SYSTEM	29	1.36	468	16.14	14	1.139
CLINICAL INFECTIOUS DISEASES	29	1.36	1019	35.14	18	21
EUROPEAN SPINE JOURNAL	28	1.31	887	31.68	16	2.634
INTERNATIONAL JOURNAL OF CLINICAL AND EXPERIMENTAL MEDICINE	28	1.31	60	2.14	4	1.069
TUBERCULOSIS	28	1.31	361	12.89	12	2.763
MEDICINE	26	1.22	206	7.92	8	1.889
WORLD NEUROSURGERY	25	1.17	215	8.60	9	1.829
INTERNATIONAL ORTHOPAEDICS	24	1.13	749	31.21	18	3.479
INTERNATIONAL JOURNAL OF INFECTIOUS DISEASES	22	1.03	337	15.32	9	12.074
BMC INFECTIOUS DISEASES	21	0.99	390	18.57	12	3.670
JOURNAL OF CLINICAL MICROBIOLOGY	21	0.99	963	45.86	15	11.68

compared the number of CNS-TB articles to incidence rates (ATI) of overall TB [21]. As country-specific incidence rates of CNS-TB have not been reported, we chose to use incidence of overall TB as a general proxy for the incidence of CNS-TB. In Fig. 6, the darker blue regions indicate a lower number of CNS-TB articles relative to the incidence of TB. The comprehensive list of ATIs for each country can be accessed in the Supplemental Table 1.

3.6. Top journals

The journals with the most publications related to CNS-TB are listed in Table 4. Of these top 15 journals, three had an impact factor greater than 10: Clinical Infectious Diseases (1·36 % of publications), International Journal of Infectious Diseases (1·03 % of publications), and Journal of Clinical Microbiology (0·99 % of publications). The International Journal of Tuberculosis and Lung Disease had the most publications, with a frequency of 2·21 %.

3.7. Author output and collaboration

Table 5 lists the authors with the greatest number of publications related to CNS-TB. Six of the top 15 authors are in India, 3 in South Africa, 3 in Vietnam, 2 in China, and 1 in England.

The collaboration network of top authors (Fig. 7) reveals four clusters correlated with institutional affiliation: Red Cluster (Oxford University Clinical Research Unit, Vietnam), Purple Cluster (Universitas Padjadjaran, Pakistan), Yellow Cluster (Stellenbosch University, South Africa), Blue Cluster (Sanjay Gandhi PGIMS or PGIMR Chandigargh, India), and Green Cluster (King George's Medical University, India).

Table 6 lists the top 15 funding sources for research in CNS tuberculosis. The top six funding sources come from the NIH (183 articles, 5·07 %), National Natural Science Foundation of China (145 articles, 3·8%), Wellcome Trust (107 articles, 2·44 %), the Medical Research Council (99 articles, 1·13 %), and the National Research Foundation of South Africa (38 articles, 1·03 %).

4. Discussion

Our bibliometric analysis of CNS-TB research from the past two decades reveals a steady growth from 2000 to 2017 with a more rapid surge between 2018 and 2022. Previous bibliometric analyses of research in overall Tuberculosis report similar growth rates [11,17,22,23].

The rapid growth after 2018 may be connected to the two major strategies against Tuberculosis implemented by the WHO and the UN. In the WHO's post-2015 End TB Strategy, the third pillar focuses on intensified research and innovation, calling for an urgent boost in research investments [24]. Additionally, in the UN's 2018–2022 Global Plan to End TB, countries have committed to increasing funding for TB

Table 5
Top 15 Active Authors. TC = Total Citations, C/D = Citation to Document Ratio.

Author	Affiliation	Country	Frequency	%	TC	C/D	h-index
Thwaites, GE	Oxford University Clinical Research Unit, Centre for Tropical Medicine, Ho Chi Minh City	UK, Vietnam	55	2.58	4793	87.15	34
Misra, UK	Department of Neurology, Sanjay Gandhi PGIMS, Lucknow	India	51	2.39	1764	34.59	18
Kalita, J	Department of Neurology, Sanjay Gandhi PGIMS, Lucknow	India	50	2.35	1018	20.36	16
Garg, RK	Department of Neurology, King George Medical University, Lucknow	India	49	2.30	1181	24.10	19
Solomons, RS	Department of Paediatrics and Child Health, Faculty of Medicine and Health Sciences, Stellenbosch University, Cape Town	South Africa	39	1.83	707	18.13	14
Malhotra, HS	Department of Neurology, King George's Medical University, Lucknow	India	37	1.74	575	15.54	14
Farrar, JJ	Oxford University Clinical Research Unit, Centre for Tropical Medicine, Ho Chi Minh City	UK, Vietnam	34	1.60	3536	104.00	29
van Toorn, R	Department of Pediatrics and Child Health, Stellenbosch University, Cape Town	China	33	1.55	762	23.09	14
Wang, XY	Department of Spine Surgery, Xiangya Hospital of Central South University, Xiangya	China	31	1.46	381	12.29	12
Zhang, HQ	Department of Spine Surgery, Xiangya Hospital of Central South University, Xiangya	South Africa	30	1.41	610	20.33	14
Schoeman, JF	Stellenbosch University, Stellenbosch, South Africa	South Africa	29	1.36	1478	50.97	20
Verma, R	Department of Neurology, King George Medical University, Lucknow	India	29	1.36	475	16.38	12
Chau, TTH	Oxford University Clinical Research Unit, Centre for Tropical Medicine, Ho Chi Minh City	Vietnam	28	1.31	3040	108.57	23
Jain, A	University College of Medical Sciences and GTB Hospital, University of Delhi, Delhi	India	26	1.22	410	15.77	12
Caws, M	Liverpool School of Tropical Medicine, Pembroke Place, Liverpool	UK	24	1.13	1447	60.29	20

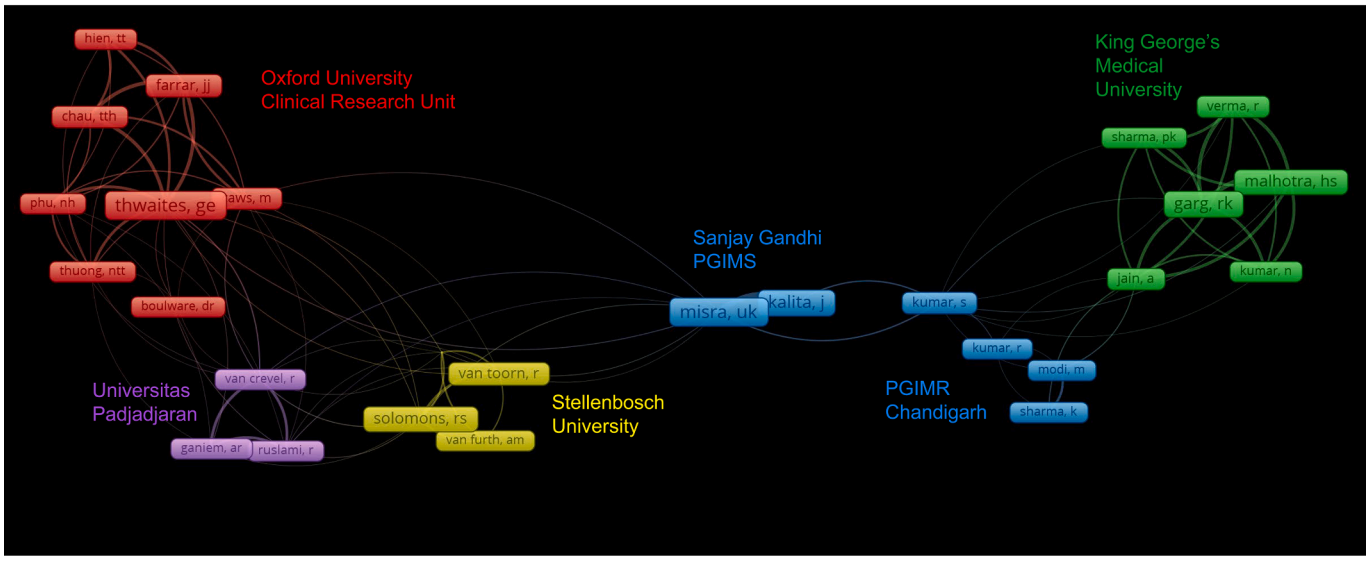

Fig. 7. Collaboration Network of Top Authors. Institutional affiliation of each cluster is noted.

Table 6
Top 10 Funding Sources.

Funding Source	Country/ Region	Frequency	%
NIH	USA	183	5.07
NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA	China	145	3.80
WELLCOME TRUST	UK	107	2.44
MEDICAL RESEARCH COUNCIL	UK	99	1.13
NATIONAL RESEARCH FOUNDATION OF SOUTH AFRICA	South Africa	38	1.03
INDIAN COUNCIL OF MEDICAL RESEARCH	India	19	0.85
EUROPEAN UNION	European Union	15	0.56
BEIJING MUNICIPAL ADMINISTRATION	China	12	0.38
DEPARTMENT OF BIOTECHNOLOGY, GOVT. OF INDIA	India	11	0.33
FUNDAMENTAL RESEARCH FUNDS FOR THE CENTRAL UNIVERSITIES	China	9	0.33

Research and Development to over 2 billion US$ annually [25]. These global efforts and funding expansion continue to pave way for impactful TB research, including in niche topics such as CNS-TB.

The geographical distribution of CNS-TB research is predominantly concentrated in five countries: India, China, USA, South Africa, and the UK. These countries account for 57·14 % of all CNS-TB research in our analysis and all the top 10 funding sources originate from these countries. While the USA and UK have dominated overall TB research [16,23,26], CNS-TB research is primarily led by India and China, two countries with rapidly growing economies. This is consistent with previous reports on spinal tuberculosis research trends [9,10,12].

China's surge in research output occurred after 2012, surpassing India by 2022. This growth can be attributed to China's significant investment in research, accounting for nearly a third of the increase in global research and development growth since 2000 [27,28]. These developments reveal China's increasing prominence and influence in the field of CNS-TB.

Despite the substantial research output from the top five countries, our analysis also revealed that most countries with high TB incidence have extremely low CNS-TB research output. Lack of funding and resources in these regions as well as the considerable manpower, administration, and coordination required for international collaborations are likely barriers in CNS-TB research [26,29]. Nevertheless, this discrepancy highlights the need in these regions for increased research efforts and funding to battle the devastating burden of this disease.

CNS-TB articles were published in journals covering a wide range of specialties, including neurology, infectious disease, orthopedics, and neurosurgery. The International Journal of Tuberculosis and Lung Disease published the largest fraction of CNS-TB articles. This journal has an impact factor of 3.4 and publishes clinical and epidemiological research on TB and various non-TB respiratory diseases [30].

International collaborations are a keystone in scientific research, especially for globally relevant diseases such as Tuberculosis [29]. Collaboration continues to play a prominent role in TB studies, increasing citation impact and accessibility of publications from individual countries [26]. In our analysis, international collaborations produced only 16·44 % of all CNS-TB research, yet 11 of the 15 highest cited articles originated from international collaborations, primarily between HICs and LMICs. Nevertheless, international exchange of knowledge remained strong as all countries formed a dense and highly interconnected citation network. Fostering wider international partnerships could address the geographical discrepancies of CNS-TB publications, enabling better care for Tuberculosis patients worldwide.

While our study provides a comprehensive research landscape of CNS-TB, there are some limitations to this bibliometric analysis. First, our study only included articles from the Web of Science Core Collection, which might exclude relevant publications from other databases, especially those from journals in LMICs and non-English journals [31]. Second, Web of Science does not have adequate mechanisms to distinguish among authors with similar names and often only lists the first initial of an author's first name, which may lead to some bibliographic errors in our analysis [32]. Third, while the use of Title Search is comprehensive and specific, it might have inadvertently excluded some articles that did not contain our search terms in their titles.

5. Conclusion

This bibliometric analysis reveals a growing interest in CNS-TB research, particularly in countries with high TB burden and rapidly

growing economies such as China and India. Furthermore, international collaborations involving HICs continue to play a vital role in enhancing the reach and impact of CNS-TB research. However, there is an urgent need to address research disparities among the majority of LMICs and enhance the impact and visibility of CNS-TB research. Future scholars can use this analysis as a starting point to identify geographical discrepancies and position their specific contributions to the field of CNS Tuberculosis.

6. Data sharing statement

The full set of articles used for the bibliometric analysis and specific search terms will be made available upon request. Data will be available with publication. Anyone who wishes to access the data can send a request to farrokh.farrokhi@vmfh.org.

Ethical statement

This work is an analysis of current literature published in CNS Tuberculosis. There are no human, identifiable information, or animal subjects in this study, thus ethical approval and informed consent is not applicable.

CRediT authorship contribution statement

Aaradhya Pant: . **Farrokh Farrokhi:** Conceptualization, Investigation, Methodology, Writing – review & editing. **Purnima Gyawali:** Investigation, Methodology, Writing – review & editing. **Kalkidan Yekuno:** Investigation, Methodology, Writing – review & editing. **Om Shah:** Investigation, Methodology, Writing – review & editing. **Shreejana Singh:** Investigation, Methodology, Writing – review & editing. **Mohan Raj Sharma:** .

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jctube.2024.100414.

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