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Research on Ultrasound Diagnosis of Thyroid Nodules: A Bibliometric Analysis

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Abstract: *Objective:* To evaluate global research trends and outputs on the ultrasound diagnosis of thyroid nodules using bibliometric analysis. *Methods:* The study searched the Web of Science Core Collection for publications on thyroid nodule ultrasound diagnosis (2000–2025). Relevant literature data (publication year, countries, institutions, authors, journals, keywords, and citations) were extracted. Bibliometric analyses were performed using VOSviewer to map collaboration networks, research hotspots, and co-citation patterns. *Results:* A total of over 8,000 publications were included. Annual output rose from 25 in 2000 to 390 in 2022. The United States and China together contributed more than one-third, with the U.S. leading by citations and China showing rapid growth. Leading institutions were concentrated in East Asia and North America, especially Korea and China. Author networks revealed strong collaboration among Korean radiologists. The thyroid was the most productive and most-cited journal. Keyword co-occurrence clustered around ultrasound risk stratification, FNA cytology and molecular testing, and management strategies. Co-citation analysis highlighted guidelines, particularly the 2015 ATA statement, as central to the knowledge network. *Conclusion:* Research on ultrasound diagnosis of thyroid nodules has expanded rapidly over the past two decades, with Asia and North America at the forefront. Collaboration networks reveal regional clusters and prolific contributor groups. The literature emphasizes differentiating benign from malignant nodules via standardized ultrasound risk stratification and adjunct FNA, while emerging trends include the integration of advanced imaging techniques, artificial intelligence, and nonsurgical therapies. These bibliometric insights map the evolution of this field and can guide future research and international collaboration.

Keywords: Thyroid nodules; Ultrasound diagnosis; Bibliometric analysis; Risk stratification; Artificial intelligence

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1. Introduction

Thyroid nodules are common, with ultrasound detecting them in up to 60% of adults, though only a small fraction is malignant. The widespread adoption of high-resolution ultrasound has markedly increased detection over the

past two decades. Ultrasound remains pivotal for characterizing nodules, guiding fine-needle aspiration (FNA), and stratifying malignancy risk. Standardized reporting systems such as ACR TI-RADS and its international variants have enhanced diagnostic consistency and reduced unnecessary biopsies [1]. Research has expanded worldwide, shifting from risk assessment toward management approaches like active surveillance and minimally invasive ablation [2]. Meanwhile, artificial intelligence (AI)–assisted interpretation has emerged as a tool to improve diagnostic accuracy [3]. Despite this progress, a bibliometric analysis is needed to comprehensively map research trends, collaboration, and emerging hotspots, providing insights into the evolution and future directions of ultrasound-based thyroid nodule diagnosis.

2. Methods

2.1. Data source and search strategy

To capture publications on ultrasound diagnosis of thyroid nodules and used the following Topic Search (TS) query: TS = ((“thyroid nodule” OR “thyroid lesion” OR “thyroid tumor” OR “thyroid carcinoma”) AND(“ultrasound” OR “ultrasonography” OR “sonography”) AND (“diagnosis” OR “differential diagnosis” OR “malignan” OR “benign”) AND (“clinical study” OR “clinical trial” OR “patients”)) This query combined terms related to thyroid nodules and carcinoma, ultrasound/sonography techniques, diagnostic evaluation of benign and malignant nodules, and clinical research settings. The truncation operator was used to include multiple word variations. The search was limited to peer-reviewed articles and reviews published in English from January 2000 to June 2025. Non-article records such as conference abstracts, letters, and editorials were excluded. The search was finalized on June 30, 2025, and all retrieved records were exported with complete bibliographic and citation information for subsequent bibliometric analysis.

2.2. Data analysis tools

Data were analyzed using VOSviewer version 1.6.20 for performance metrics and collaboration maps (authors, institutions, countries, keywords). Standard network algorithms were applied to identify clusters of related items. Key indicators included annual publications, citations, author and institutional productivity, journal output, and keyword frequencies. Visualizations and summary tables were generated to present research patterns and hotspots.

3. Results

3.1. Annual publication trends

Figure 1 illustrates the publication trends from 2000 to 2025, showing an exponential growth pattern ($R^2 = 0.9461$). In the early phase (2000–2009), annual output remained low, but research activity rose sharply after 2010, driven by advances in imaging and increasing thyroid disease incidence. The surge continued, peaking after 2018, with more than 350 publications annually from 2020 to 2022. From 2023 to 2025, cumulative output still increased, but yearly publications fluctuated, with a decline in 2025 likely due to incomplete data or shifting research priorities. Overall, the field demonstrates strong momentum, with growth expected to continue as new technologies drive further innovation.

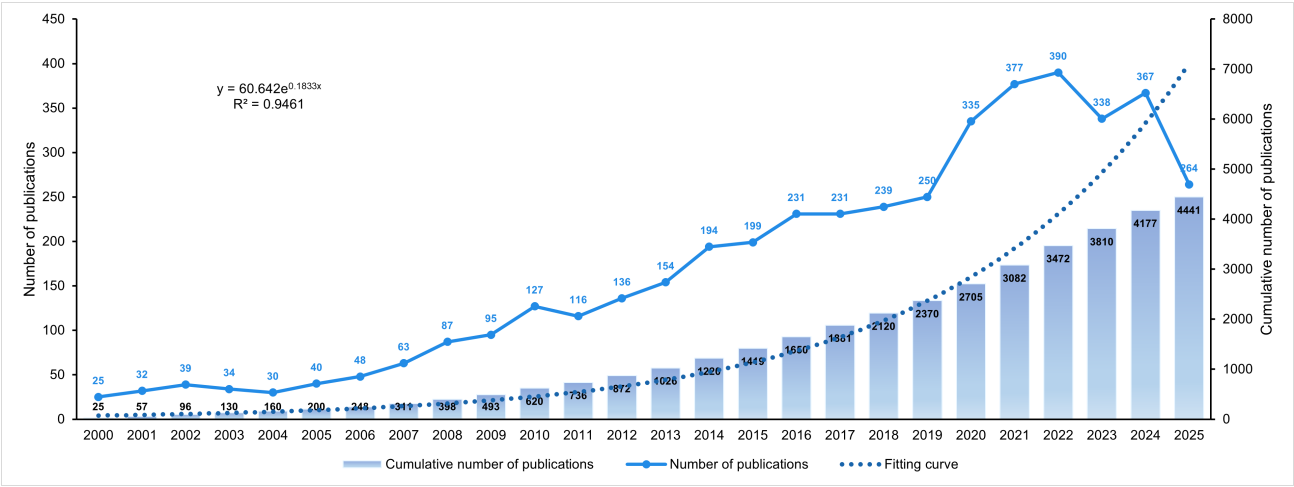

Figure 1. Annual number of publications and citations on ultrasound diagnosis of thyroid nodules, 2000–2025.

3.2. Country and institutional analysis

Global research on thyroid nodule ultrasound is concentrated in a few key regions, with the United States, China, and South Korea occupying central positions in the international collaboration network (**Figure 2**). The U.S. maintains broad partnerships with European countries such as Italy, Germany, and the UK, while China collaborates closely with East Asian neighbors including Japan and South Korea. South Korea, despite its smaller size, plays a pivotal role in advancing thyroid ultrasound, supported by its national screening practices and radiology expertise. European nations contribute actively and often serve as bridges for multinational studies, while countries from the Middle East and South America are gradually entering the global network, indicating the geographic expansion of this field.

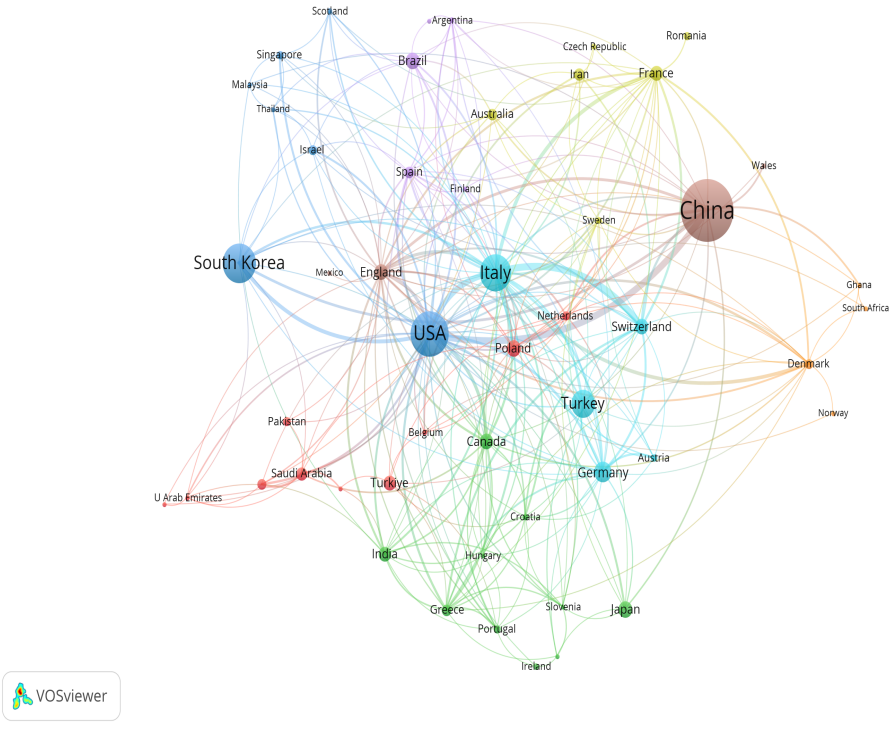

Figure 2. Global collaboration map of countries engaged in ultrasound diagnosis of thyroid nodules research.

At the institutional level (**Figure 3**; **Table 1**), East Asian universities dominate output. The University of Ulsan (147 publications, 8,436 citations) and Yonsei University (142 publications, 8,264 citations) rank highest, reflecting the strength of Korean radiology groups. Shanghai Jiao Tong University follows with 120 publications, alongside other Chinese centers such as Zhejiang and Tongji University. Sungkyunkwan and Seoul National University further reinforce Korea's leadership. In North America, Mayo Clinic stands out with comparatively fewer papers (58) but exceptionally high citation impact (17,934 citations; around 309 per article), underlining its role in guideline development and influential clinical studies. Overall, collaboration at the institutional level remains regionally clustered, with strong intra-national cooperation but fewer cross-regional ties, suggesting that while global engagement is evident, much research activity remains centered within regional academic hubs.

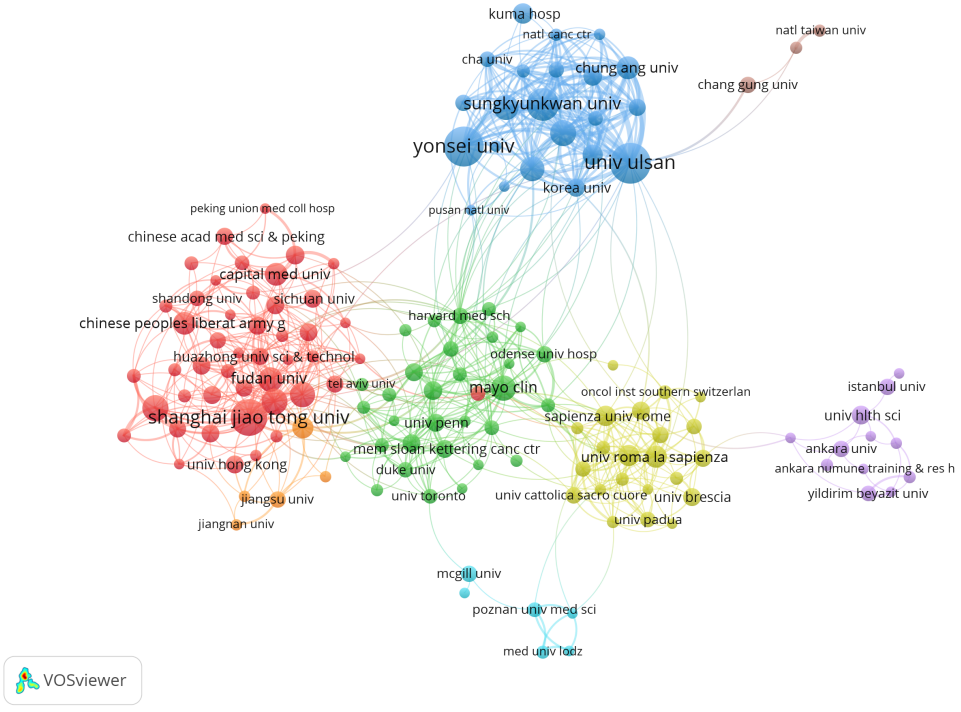

Figure 3. Institutional collaboration network in research on ultrasound diagnosis of thyroid nodules.

Table 1. Top 10 institutions by publication output

Institution name	Total number of articles	Total citations	Average citations
Univ Ulsan	147	8436	57.3878
Yonsei Univ	142	8264	58.1972
Shanghai Jiao Tong Univ	120	1484	12.3667
Sungkyunkwan Univ	93	5580	60
Zhejiang Univ	62	696	11.2258
Tongji Univ	62	1249	20.1452
Seoul Natl Univ	59	4585	77.7119
Sun Yat Sen Univ	58	867	14.9483
Mayo Clin	58	17934	309.2069
Inje Univ	57	2262	39.6842

3.3. Author and co-authorship network

The field of thyroid nodule ultrasound research is dominated by several highly productive author groups, often concentrated within specific countries or institutions. As shown in **Table 2**, the top 10 most prolific authors are overwhelmingly from South Korea. Jung Hwan Baek and Jin Young Kwak rank first with 104 publications each, followed closely by Eun-Kyung Kim with 96 papers. All three are radiologists affiliated with leading Korean medical centers and have made substantial contributions to ultrasound-guided interventions and the development of risk stratification systems. Other Korean radiologists, including Hee Jung Moon, Jeong Hyun Lee, Jung Hyun Yoon, and Jung Hee Shin, also appear in the top 10, each with dozens of publications. This pattern underscores South Korea's leading role in advancing thyroid ultrasound techniques, exemplified by the establishment of the K-TIRADS classification system and pioneering studies on ultrasound-guided ablation.

Table 2. Top 10 authors by publication output

Author name	Total number of articles	Total citations	Average citations
Baek, Jung Hwan	104	5616	54
Kwak, Jin Young	104	5220	50.1923
Kim, Eun-Kyung	96	5308	55.2917
Moon, Hee Jung	76	3328	43.7895
Lee, Jeong Hyun	73	4741	64.9452
Yoon, Jung Hyun	62	2457	39.629
Shin, Jung Hee	53	2171	40.9623
Trimboli, Pierpaolo	46	1437	31.2391
Kim, Dong Wook	42	1574	37.4762
Choi, Young Jun	42	1534	36.5238

The co-authorship network further illustrates the collaborative structure of this field (**Figure 4**). Korean scholars such as Kwak Jin Young, Baek Jung Hwan, and Lee Jeong Hyun form a densely connected cluster, reflecting frequent collaboration and a highly cohesive academic network. In contrast, European researchers such as Pierpaolo Trimboli, Giovanna Luca, and Enrico Papini constitute another cluster, primarily focused on clinical guidelines and follow-up management. Cross-national authors like Cosimo Durante and Erik K. Alexander function as bridging nodes, linking research outcomes from different regions. Overall, the author network exhibits regional clustering: Korean scholars dominate clinical and imaging research, whereas European and North American researchers contribute substantially to guideline development and evidence-based practice. International collaborations, though less frequent, play a crucial role in integrating diverse expertise and ensuring cross-regional knowledge exchange.

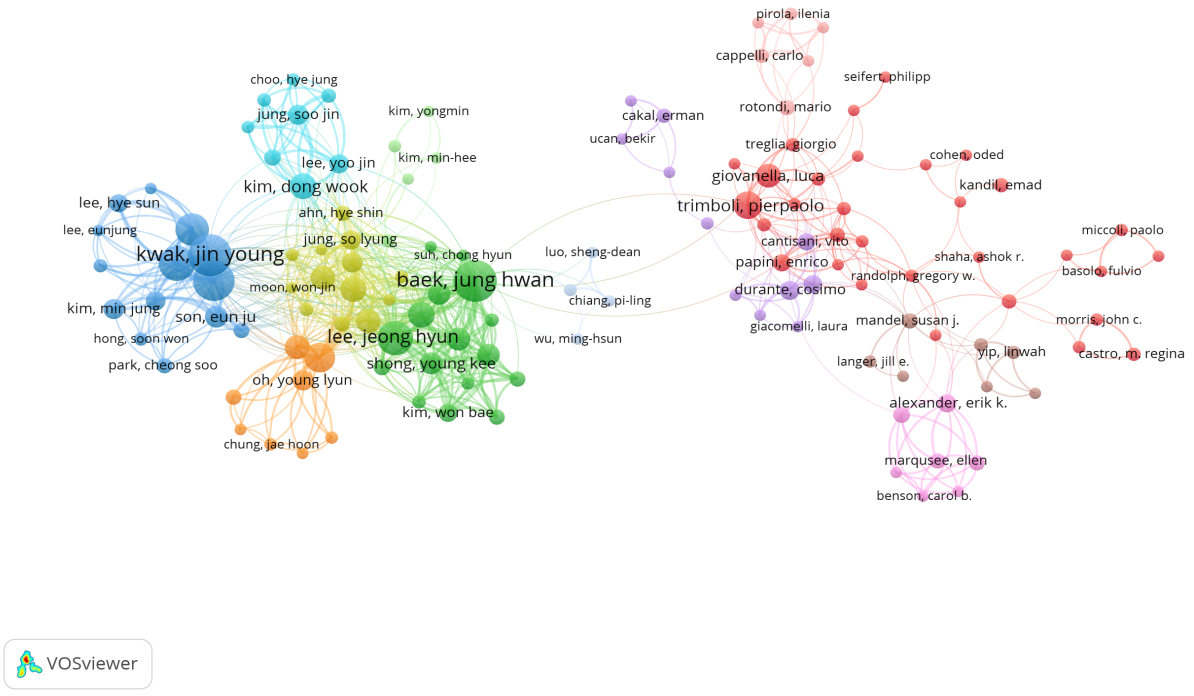

Figure 4. Co-authorship network of leading authors in research on ultrasound diagnosis of thyroid nodules.

3.4. Journal distribution

Publications on thyroid nodule ultrasound were concentrated in a few core journals but spanned across radiology, endocrinology, and multidisciplinary outlets (**Table 3**). Thyroid ranked first, publishing 207 articles with over 26,000 citations, reflecting its role as the leading forum for guidelines and consensus statements. Frontiers in Endocrinology contributed the second-highest number of articles (133), but with relatively low citation averages, likely due to recent publications. Other endocrine journals, such as Endocrine and JCEM, were also major contributors, with JCEM showing particularly high average citations (around 89 per paper). Radiology journals, including European Radiology, Journal of Ultrasound in Medicine, and Korean Journal of Radiology, provided substantial outputs, while Radiology, with only 25 papers, achieved the highest average impact (around 143 citations each). Overall, a few high-impact journals dominate influence, while specialized journals host most of the technical research.

Table 3. Top 10 journals by publication output

Journal name	Total number of articles	Total citations	Average citations
Thyroid	207	26084	126.0097
Frontiers In Endocrinology	133	1205	9.0602
Endocrine	122	2198	18.0164
Journal Of Ultrasound In Medicine	92	2835	30.8152
Journal Of Clinical Endocrinology & Metabolism	91	8130	89.3407
European Radiology	79	3311	41.9114
Clinical Endocrinology	78	2541	32.5769
American Journal Of Roentgenology	63	3441	54.619
Korean Journal Of Radiology	44	2962	67.3182
Radiology	25	3578	143.12

3.5. Keyword co-occurrence and thematic evolution

The author keyword analysis highlights the main research focus in thyroid nodule ultrasound. The most frequent terms were cancer, management, ultrasound, diagnosis, malignancy, and fine-needle aspiration (FNA), which align closely with the central clinical task of distinguishing malignant from benign nodules (**Table 4**).

Table 4. Top 10 keywords by co-occurrence frequency

Rank	Frequency	Centrality	Time	Keyword
1	1681	0	2000	cancer
2	1616	0	2000	management
3	989	0	2000	ultrasound
4	942	0	2000	diagnosis
5	878	0	2000	nodules
6	873	0	2000	carcinoma
7	854	0	2000	thyroid nodule
8	775	0	2000	fine needle aspiration
9	736	0	2002	malignancy
10	694	0	2000	thyroid nodules

The co-occurrence network (**Figure 5**) reveals three thematic clusters. One cluster is centered on imaging and risk stratification, represented by keywords such as ultrasound, TI-RADS, calcifications, and elastography. Another cluster focuses on cytology and molecular diagnosis, with terms including FNA, cytology, the Bethesda system, and BRAF mutation. A third cluster highlights treatment and management, encompassing management, surgery, radiofrequency ablation, and thyroidectomy. Bridging these clusters are recurring terms such as thyroid cancer, malignant, and diagnosis, which appear across contexts and underscore their central role in the literature. Burst keyword analysis further indicates that recent hotspots include guidelines, classification systems (TI-RADS), and radiofrequency ablation, with artificial intelligence emerging as a growing focus in the last five years.

3.6. Reference co-citation analysis

Figure 6 illustrates the co-citation relationships and academic influence among core references. Node size indicates citation frequency, with Haugen (2016) and Cooper (2009) as dominant nodes, underscoring their central role in guideline development for thyroid nodule diagnosis and management. Early foundational works such as Papini (2002) and Moon (2008) laid the groundwork, while Russ (2017) and Durante (2015) reflect more recent advances in diagnostic standards and risk stratification. The network's color-coded clusters capture the thematic evolution of the field: one centered on fine-needle aspiration and cytopathology, another on ultrasound features and malignancy prediction, and a third on guidelines and clinical management. Together, these clusters reveal a developmental trajectory from classic studies to guideline-driven practice and imaging-based approaches, establishing a stable knowledge framework that continues to integrate emerging research findings.

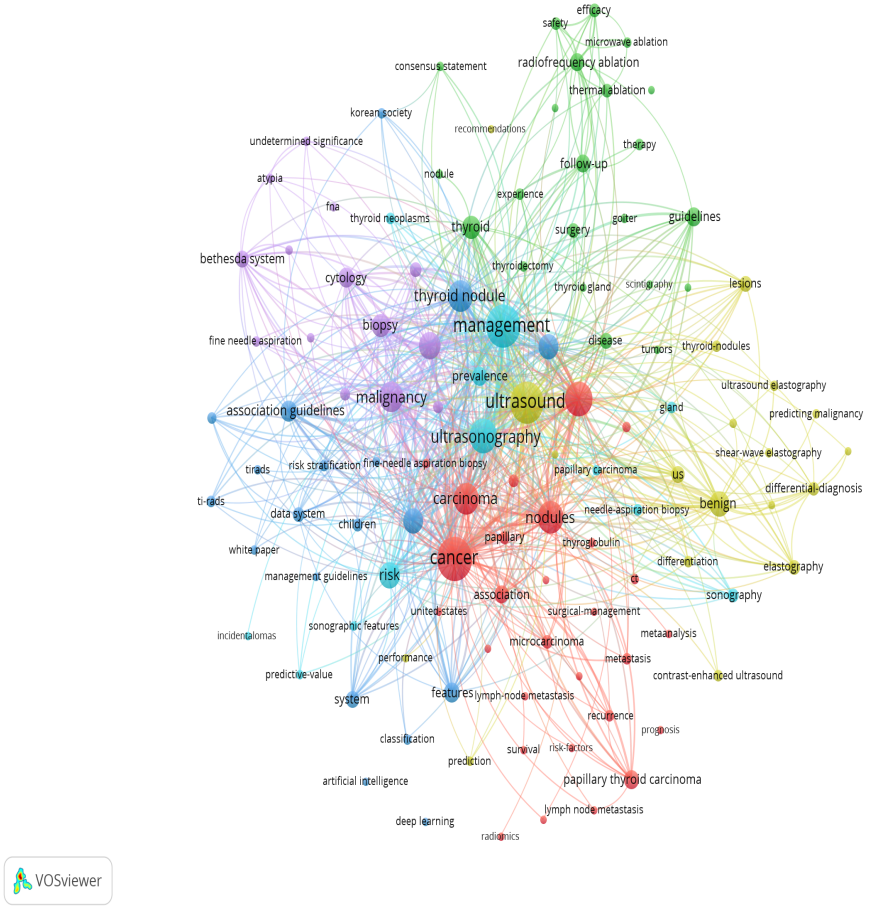

Figure 5. Keyword co-occurrence network in research on ultrasound diagnosis of thyroid nodules**.**

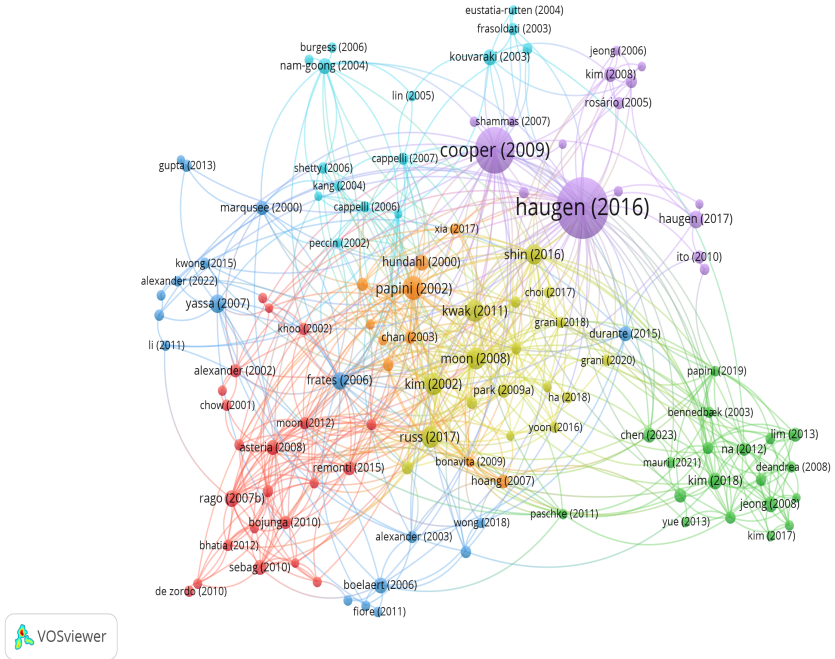

Figure 6. Co-citation network of core references in the field of thyroid nodule ultrasound diagnosis.

4. Discussion

This bibliometric analysis provides a comprehensive overview of research on ultrasound diagnosis of thyroid nodules, highlighting how the field has evolved in response to clinical needs, guideline development, and technological innovation. The trajectory of publications and citation patterns shows not only growing academic interest but also a gradual convergence toward standardized diagnostic pathways. Interpreting these patterns offers insights into strengths, unresolved challenges, and future directions.

The dominance of guidelines and structured classification systems in the co-citation network underscores their pivotal role in shaping the intellectual foundation of the field. Landmark documents such as the 2015 American Thyroid Association (ATA) guidelines remain central, unifying practice standards across diverse clinical environments. More recently, the updated Bethesda System has refined indeterminate categories and malignancy risk estimates, directly influencing how cytology guides management [4]. Comparative validation of major TIRADS frameworks (ACR, EU, K-TIRADS) demonstrates broad agreement but systematic differences in risk allocation [5]. This lack of harmonization complicates multinational research and clinical adoption, pointing to the need for global efforts to reconcile thresholds for malignancy prediction and align diagnostic lexicons.

Publication trends also reflect a paradigm shift from diagnosis to management. Earlier studies concentrated on distinguishing benign from malignant nodules, whereas more recent research emphasizes therapeutic strategies. Radiofrequency ablation (RFA) for benign nodules exemplifies this transition. Consensus statements now provide clear recommendations on patient selection, technique, and follow-up, consolidating RFA as a safe and effective alternative to surgery [6]. By reducing morbidity compared to thyroidectomy, minimally invasive ablation improves quality of life, recovery time, and cosmetic outcomes. In parallel, active surveillance for low-risk papillary thyroid carcinoma has matured into a validated management pathway. Large cohorts confirm that carefully monitored surveillance can safely avoid overtreatment while maintaining excellent prognosis [6]. Together, these strategies represent a shift in oncology toward risk-adapted approaches that balance oncologic safety with patient-centered outcomes.

Artificial intelligence (AI) has rapidly emerged as another defining theme. Deep learning models show promise in augmenting human interpretation, particularly in detecting subtle features such as gross extrathyroidal extension that may be missed by radiologists [3]. These technologies could expand access to expert-level interpretation in regions with limited subspecialty expertise. Yet integration into practice faces barriers: variability in image acquisition protocols, equipment, and operator expertise introduces heterogeneity that may limit model generalizability. Moreover, AI must evolve in step with pathology classifications. The 2024 WHO classification and 2023 Bethesda updates have refined diagnostic categories and clarified indeterminate zones [3]. Models trained on outdated frameworks risk misalignment with current standards, emphasizing the need for synergy between technological development and evolving diagnostic criteria.

Global collaboration patterns highlight both strengths and limitations. Korean researchers dominate output, especially in radiology-driven studies such as ultrasound-guided interventions and K-TIRADS development. European and North American scholars, though less prolific, have shaped guidelines, cytopathology frameworks, and influential meta-analyses. While this regional specialization has been productive, limited cross-continental collaboration means that findings are often validated locally rather than globally. Building shared image repositories and multinational datasets linking ultrasound features, cytology, and outcomes would enhance reproducibility and generalizability.

The distribution of research across journals reflects the field's dual structure. Specialty outlets such as

the Korean Journal of Radiology and European Radiology publish much of the methodological innovation, while high-impact endocrine journals like Thyroid and JCEM concentrate the most influential guidelines and practice-changing studies. This two-tiered dissemination suggests that technical advances circulate within specialty readerships, whereas general guidelines reach broader audiences through mainstream journals. For future dissemination, bridging these outlets may ensure that methodological innovations achieve wider clinical translation.

From a clinical perspective, the findings underscore the need to integrate standardized risk stratification with individualized management. Consistent use of ultrasound lexicons and cytology frameworks enhances diagnostic uniformity, while strategies such as RFA and active surveillance expand the therapeutic repertoire beyond surgery. AI holds promise but requires careful validation and interpretability to avoid premature clinical adoption. From a research standpoint, priorities include multinational trials comparing TIRADS frameworks, integration of AI with updated cytology systems, and pragmatic studies evaluating real-world management strategies with attention to patient-reported outcomes and health economics.

This study has limitations. Restriction to the Web of Science Core Collection and English-language publications may underrepresent non-English literature and regional practices. Challenges in author name disambiguation and institutional affiliations could bias productivity metrics. Furthermore, citation-based analyses are limited by time lag, with newer studies not yet accruing influence. Nonetheless, consistent patterns across multiple indicators, such as the centrality of guidelines, dominance of regional clusters, and emergence of AI and minimally invasive management, support the robustness of the findings.

5. Conclusion

In conclusion, the landscape of thyroid nodule ultrasound research reflects both consolidation and innovation. Core guidelines and classification systems provide a stable framework, while minimally invasive therapies, surveillance strategies, and AI are reshaping practice. Recent advances in cytopathology [4], comparative validation of risk stratification [5], consensus on ablation therapy [7], evidence supporting surveillance [8], AI-driven imaging interpretation [3], and updated pathology frameworks [9] together illustrate a field moving toward standardized yet personalized care. Global collaboration and harmonization of diagnostic criteria will be essential to optimize patient outcomes and ensure equitable dissemination of best practices.

Disclosure statement

The authors declare no conflict of interest.

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