



## Systematic Journal Review: Management of Radiofrequency Ablation (RFA) for Thyroid Nodules

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### Abstract

*Benign thyroid nodules are common and may cause compressive symptoms and cosmetic concerns, requiring effective treatment. Radiofrequency ablation (RFA) has emerged as a minimally invasive alternative to surgery; however, variations in technique and outcomes necessitate systematic evaluation. This study synthesizes recent evidence on the effectiveness and safety of RFA for benign thyroid nodules and identifies key technical factors influencing outcomes. A systematic review was conducted following PRISMA guidelines, analyzing studies published between 2020 and 2025 from major scientific databases. Ten eligible articles were included for qualitative synthesis. The results indicate that RFA consistently provides significant short- to mid-term nodule volume reduction, preserves thyroid function, and demonstrates a low complication rate. Most patients achieve optimal outcomes with a single ablation session, and long-term follow-up supports sustained efficacy. Recent international guidelines increasingly endorse RFA as a validated non-surgical treatment, including for large nodules previously managed surgically. The study recommends integrating RFA into national healthcare standards in Indonesia, supported by structured training and competency-based certification, to ensure quality and equitable access. Overall, RFA is confirmed as a safe, effective, and adaptable treatment modality with important implications for clinical practice and health policy.*

**Keywords:** *Diagnosis, Effectiveness, Radiofrequency Ablation, Therapy, Thyroid Nodule Management.*

### INTRODUCTION

Thyroid nodules represent one of the most frequently encountered endocrine conditions in clinical practice, with prevalence rates continuing to increase in parallel with the widespread use of high-resolution imaging modalities, particularly ultrasonography. This technological expansion has led to the detection of a substantial number of previously unrecognized subclinical nodules during routine health screenings or incidental examinations (Grani et al., 2020; Mistry et al., 2020). Epidemiological data indicate that thyroid nodules affect a significant proportion of the adult population globally, with estimates reaching up to 50–60% in ultrasound-based studies. In Indonesia, although nationwide prevalence data remain limited, hospital-based reports and endocrine clinic registries suggest a steadily rising burden of thyroid nodules, particularly among women and individuals in productive age groups. This growing disease burden poses a

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substantial challenge to the national health system, especially within the framework of the National Health Insurance (JKN/BPJS), which must accommodate increasing demand for diagnostic evaluation and long-term management of benign thyroid conditions.

While the majority of thyroid nodules are benign, progressive enlargement may result in compressive symptoms such as dysphagia, dyspnea, and voice changes, as well as cosmetic concerns that negatively affect patients' quality of life and psychosocial well-being (Grani et al., 2020; Rodriguez Escobedo et al., 2022). Even asymptomatic benign nodules often generate anxiety following diagnosis, thereby increasing healthcare utilization through repeated follow-up visits, imaging, and laboratory examinations. These factors underscore the need for evidence-based, efficient, and patient-centered management strategies that not only address clinical outcomes but also consider the broader population-level and economic implications for healthcare systems (Grani et al., 2020; Wang et al., 2025).

Conventional management options, including thyroidectomy and ethanol ablation, remain widely used but present important limitations from both clinical and systemic perspectives. Thyroid surgery, although definitive, is associated with risks of complications such as hypoparathyroidism and recurrent laryngeal nerve injury, prolonged postoperative recovery, and the need for inpatient hospitalization, all of which contribute to increased healthcare costs and resource utilization (Jin & Sugitani, 2021; Papini et al., 2020). In the Indonesian context, access to thyroid surgery is unevenly distributed, with specialist services and adequately equipped surgical facilities largely concentrated in urban tertiary hospitals. Patients in rural and remote regions often face long waiting times, referral delays, and substantial indirect costs related to travel and accommodation, thereby exacerbating inequities in care delivery. Although ethanol ablation offers a less invasive and relatively low-cost alternative for cystic nodules, its applicability is limited, and reported complications necessitate careful patient selection and close monitoring (Baek et al., 2023; Yang et al., 2021).

In response to these challenges, radiofrequency ablation (RFA) has emerged as a minimally invasive therapeutic option with the potential to address not only individual clinical needs but also systemic healthcare constraints. RFA has demonstrated favorable outcomes in reducing nodule volume, alleviating symptoms, and preserving thyroid function, with a low complication rate and minimal need for hospitalization (Podrat et al., 2024). Importantly, RFA is commonly performed as an outpatient procedure, resulting in a markedly shorter length of stay compared to surgery. This characteristic has significant implications for health system efficiency, as reduced hospitalization days translate into lower direct medical costs and decreased financial burden on national insurance schemes such as BPJS/JKN. Several economic evaluations from comparable health systems suggest that RFA may be more cost-effective than surgery for symptomatic benign thyroid nodules, particularly when indirect costs and productivity loss are considered.

Despite its growing adoption, the clinical effectiveness and safety of RFA remain influenced by variability in patient selection, procedural techniques, operator experience, and nodule characteristics across institutions (Issa et al., 2023; Papini et al., 2020). This heterogeneity complicates the formulation of standardized clinical pathways and limits the generalizability of individual study findings. Although recent international guidelines increasingly endorse RFA as an alternative to surgery for benign thyroid nodules, they consistently emphasize the need for standardized protocols, structured training, and robust outcome monitoring to ensure optimal results (Lin et al., 2023).

Previous research has largely addressed thyroid nodule management in a broad manner, while systematic reviews focusing specifically on RFA as a primary therapeutic modality remain limited. Existing studies often prioritize short-term volume reduction

outcomes, with less comprehensive integration of long-term safety, quality of life, cost-effectiveness, and health system impact. Furthermore, substantial methodological heterogeneity persists in terms of ablation techniques, inclusion criteria, and follow-up duration, hindering meaningful cross-study comparisons (Monpeyssen et al., 2021; Noel & Sinclair, 2024). Given the increasing relevance of RFA in resource-constrained health systems, there remains a critical need for an updated and comprehensive synthesis of evidence that incorporates both clinical and systemic perspectives.

A systematic review offers a rigorous methodological approach to synthesizing findings from multiple high-quality studies, thereby enabling a more robust assessment of RFA effectiveness, safety, and determinants of success compared to single studies (Moosapour et al., 2021; Owens, 2021). By integrating diverse outcomes, including complication rates, length of hospital stay, quality of life, and potential cost implications, this approach is particularly well suited to evaluating RFA as an evolving clinical practice with significant policy relevance (Qiao et al., 2022).

Accordingly, this study aims to systematically identify and synthesize current scientific evidence regarding the effectiveness and safety of radiofrequency ablation in the management of thyroid nodules. In addition, this review examines variations in RFA techniques, clinical outcomes, and patient-reported quality of life, while also considering implications for healthcare efficiency and accessibility. Through this comprehensive analysis, the study is expected to provide an evidence-based foundation to inform clinical decision-making, support the rational integration of RFA into national health services, and contribute to strategies that alleviate the burden on Indonesia's healthcare system, particularly within the BPJS/JKN framework.

## **METHOD**

This study employed a Systematic Literature Review (SLR) design to identify, critically appraise, and synthesize scientific evidence related to the use of radiofrequency ablation (RFA) in the management of thyroid nodules. The SLR methodology was selected due to its ability to provide a comprehensive, transparent, and reproducible synthesis of evidence regarding clinical effectiveness, safety, procedural characteristics, and broader health system implications of RFA based on contemporary primary research. All stages of the review process were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological rigor and reporting transparency.

A comprehensive literature search was conducted across five major electronic databases: PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. The search strategy employed combinations of controlled vocabulary and free-text terms using Boolean operators (AND/OR), including: “thyroid nodule” OR “benign thyroid nodule”; “radiofrequency ablation” OR “RFA”; “minimally invasive treatment” OR “nonsurgical therapy”; “treatment outcome” OR “therapeutic effectiveness”; and “quality of life” OR “cost-effectiveness” OR “healthcare cost”. The search was restricted to peer-reviewed articles published between 2020 and 2025 to ensure that the evidence reflected recent technological advancements and current clinical practice.

Eligibility criteria were defined a priori. Studies were included if they:

- (1) involved adult patients with benign thyroid nodules;
- (2) evaluated RFA as a primary or comparative therapeutic modality;
- (3) reported at least one relevant clinical outcome, such as nodule volume reduction, symptom improvement, complication rate, or recurrence; and
- (4) provided data on patient-reported quality of life and/or economic outcomes, including direct medical costs, length of hospital stay, or cost-effectiveness indicators.

Exclusion criteria comprised case reports, editorials, conference abstracts without full text, non-English publications, studies focusing exclusively on malignant thyroid disease, and articles lacking sufficient methodological detail or outcome reporting.

The study selection process was conducted independently by two reviewers. Initial screening was performed based on titles and abstracts, followed by full-text assessment of potentially eligible studies. Any discrepancies between reviewers were resolved through discussion, and when consensus could not be reached, a third reviewer was consulted. Methodological quality and relevance were evaluated to ensure that only studies meeting predefined standards were included in the final synthesis.

Data extraction was systematically performed using a standardized extraction form. The extracted variables included:

- (1) author(s), year of publication, and country of study;
- (2) study design and population characteristics, including sample size and nodule type;
- (3) diagnostic methods applied, such as ultrasonography and fine-needle aspiration cytology;
- (4) RFA procedural parameters, including electrode type, ablation technique, duration, and imaging guidance;
- (5) comparator interventions, such as thyroidectomy, ethanol ablation, laser ablation, or active surveillance;
- (6) clinical outcomes, including volume reduction rate, symptom improvement, complications, and recurrence; and
- (7) health-related outcomes, particularly patient-reported quality of life measures and cost-related indicators.

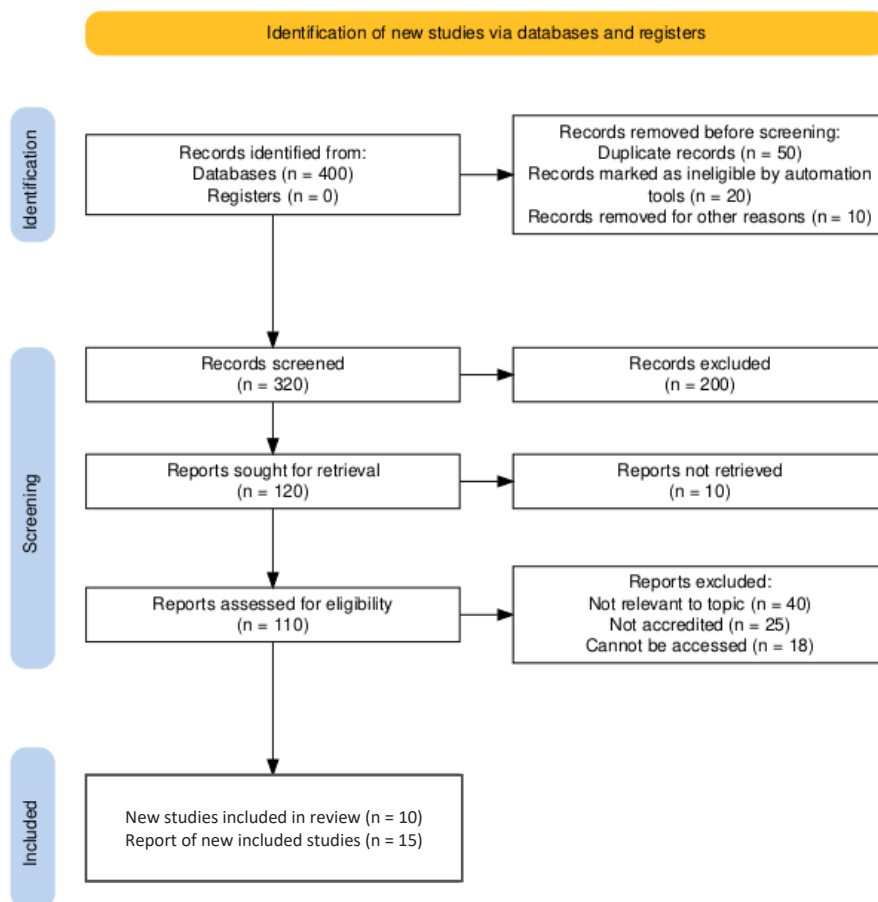


Figure 1. PRISMA Diagram

The literature selection process is summarized in a PRISMA flow diagram (Figure 1), which illustrates the number of records identified, screened, assessed for eligibility, and ultimately included in the review. A total of 400 records were initially identified through database searches. After removal of duplicates and records excluded by automation tools, 320 articles underwent title and abstract screening. Following this stage, 200 records were excluded for not meeting the inclusion criteria. Full-text assessment was conducted on 120 articles, of which 10 were inaccessible and 100 were excluded due to irrelevance, insufficient methodological quality, or absence of key outcome data. Ultimately, 10 studies met all inclusion criteria and were included in the final qualitative synthesis. This multistage process ensured that the review was based exclusively on relevant, valid, and high-quality evidence concerning the diagnosis and therapeutic management of thyroid nodules using RFA.

Data analysis was conducted using narrative synthesis supported by thematic coding. VOSviewer software was utilized to assist in mapping thematic relationships and identifying patterns across studies. Extracted data were categorized into four main analytical themes: (1) pre-procedural diagnostic assessment; (2) indications and technical characteristics of RFA; (3) clinical effectiveness, safety, and quality-of-life outcomes; and (4) comparative and economic implications of RFA relative to alternative treatment modalities. The synthesis aimed to integrate clinical and public health perspectives, resulting in a conceptual framework that reflects current evidence on RFA for thyroid nodules and highlights implications for clinical practice, health system efficiency, and future research directions.

## RESULT

### Article Screening Results

The process of journal searching and screening was conducted using the Publish or Perish software, resulting in 10 journals ranked based on the highest number of citations.

Table 1. Article Screening Results Based on PRISMA Criteria According to the 10 Highest Citation Rankings

No	Article Title	Authors & Year	Study Design	Content (RFA Focus)	Summary
1	<i>Characteristics of Thyroid Nodule Patients Undergoing Radiofrequency Ablation (RFA) at RSUD Dr. Soetomo Surabaya from January 2023 to December 2024</i>	(Afifudin, 2025)	Patient Characteristics Study	Identifies characteristics of patients with thyroid nodules undergoing RFA at RSUD Dr. Soetomo Surabaya, while emphasizing the relevance of RFA use in clinical practice in Indonesia.	
2	<i>Radiofrequency Ablation for Management of Thyroid Nodules: A Case Report</i>	(Yarsa & Bellynda, 2021)	Case Report	Demonstrates that RFA is an effective and safe method for managing benign thyroid nodules in specific cases, reaffirming its role as a viable therapeutic option.	

3	<i>Radiofrequency Ablation of Benign and Malignant Thyroid Nodules</i>	(Navin et al., 2022)	Review Article	Provides a comprehensive review of the role of RFA as a safe and effective minimally invasive therapy for symptomatic benign thyroid nodules and autonomously functioning thyroid nodules (AFTN), and discusses its application in selected thyroid malignancies that remain controversial.
4	<i>Radiofrequency Ablation of Benign Thyroid Nodules: 10-Year Follow-Up Results From a Single Center</i>	(Shin et al., 2025)	Retrospective Study (Long-Term Follow-Up)	Evaluates the long-term efficacy of RFA for up to 10 years. The results show that a single RFA session can provide an adequate volume reduction rate (VRR) and promising long-term outcomes.
5	<i>Efficacy in Size and Symptom Reduction of Radiofrequency Ablation of Benign Non-Functioning Thyroid Nodules</i>	(Rodriguez Escobedo et al., 2022)	Original Article	Assesses the safety and efficacy of RFA for benign non-functioning thyroid nodules. The study shows that RFA is safe, effective in reducing nodule size, and significantly alleviates symptoms.
6	<i>Microwave Ablation in the Treatment of Benign Thyroid Nodules: Case Report</i>	(Malayev et al., 2025)	Review Article & Case Report	Although focusing on microwave ablation (MWA), this article provides context indicating that MWA and RFA are minimally invasive thermal ablation techniques serving as non-surgical alternatives for benign thyroid nodule management.
7	<i>A Novel Strategy for Single-Session Ultrasound-Guided Radiofrequency Ablation of Large</i>	(Yao et al., 2020)	Pilot Cohort Study	Proposes a novel single-session RFA technique for large benign thyroid nodules. The findings show significant volume

	<i>Benign Thyroid Nodules: A Pilot Cohort Study</i>			reduction and symptom improvement within 6 months after the procedure.
8	<i>2020 European Thyroid Association Clinical Practice Guideline for the Use of Image-Guided Ablation in Benign Thyroid Nodules</i>	(Papini et al., 2020)	Clinical Practice Guideline (ETA)	Confirms that RFA is recommended for benign thyroid nodules causing symptoms or cosmetic disturbances, especially for patients refusing surgery. Thermal ablation, including RFA and laser ablation (LA), is regarded as the most thoroughly evaluated technique.
9	<i>Efficacy of Radiofrequency Ablation of Benign Thyroid Nodules</i>	(El Sheikh et al., 2024)	Prospective Study	Evaluates the efficacy and safety of ultrasound-guided RFA for benign thyroid nodules while preserving normal thyroid function. The findings indicate significant volume reduction.
10	<i>The Role of Radiofrequency Ablation as an Alternative Tool in Management of Symptomatic Benign Thyroid Nodules</i>	(Ahmad et al., 2022)	Clinical Study	Assesses the effectiveness of RFA as an alternative management option for symptomatic benign thyroid nodules. The study shows significant volume reduction and symptom improvement after 6 months of follow-up.

The screening results in Table 1 demonstrate that radiofrequency ablation consistently shows effectiveness in reducing thyroid nodule size and alleviating symptoms, as reported by Afifudin (2025), Yarsa & Bellynda (2021), and Escobedo et al. (2022). Long-term studies by Shin et al. (2025) reinforce evidence that RFA offers high durability of outcomes even under monitoring for up to ten years. The review article by Navin et al. (2022) and the ETA guidelines (Papini et al., 2020) emphasize that RFA is a minimally invasive technique gaining increasing recognition in global clinical practice. The findings of Yao et al. (2020) expand the potential use of RFA for large nodules through a single-session strategy. Overall, this table illustrates that RFA is an effective, safe therapeutic modality and serves as an important alternative to surgery for benign thyroid nodules.

Table 2. Data Extraction of Systematic Journal Review Articles on Radiofrequency Ablation (RFA) Management for Thyroid Nodules

No	Title	Authors	Study Design	Subjects / Sample Size	Intervention	Main Outcomes
1	<i>The Role of Radiofrequency Ablation as an Alternative Tool in Management of Symptomatic Benign Thyroid Nodules</i>	(Ahmad et al., 2022)	Prospective study	10 patients with benign non-functioning thyroid nodules	RFA using Cool-Tip RF System; 6-month follow-up	RFA effectively reduces nodule volume, particularly in solid nodules; minor complications occurred in 7.5% of cases (non-permanent voice changes, hematoma, and first-degree burns).
2	<i>Efficacy of Radiofrequency Ablation of Benign Thyroid Nodules</i>	(El Sheikh et al., 2024)	Prospective study	30 patients (5 men, 25 women)	Ultrasound-guided RFA using the moving-shot technique	RFA resulted in significant volume reduction, was safe, and did not impair thyroid function.
3	<i>2020 European Thyroid Association Clinical Practice Guideline for the Use of Image-Guided Ablation in Benign Thyroid Nodules</i>	(Papini et al., 2020)	Clinical practice guideline (ETA Guidelines)	Adult patients with benign nodules	Guidelines for image-guided thermal ablation techniques (RFA, Laser Ablation)	RFA and LTA are the most established techniques for benign nodules; thermal ablation is recommended for symptomatic nodules or cosmetic concerns in patients unwilling to undergo surgery.
4	<i>A Novel Strategy for Single-Session Ultrasound-Guided Radiofrequency Ablation of Large Benign Thyroid Nodules: A Pilot Cohort Study</i>	(Yao et al., 2020)	Pilot cohort study	Not specified	Single-session ultrasound-guided RFA with peripheral ablation strategy	This strategy results in significant volume reduction for large nodules within a 6-month follow-up.

5	<i>Microwave Ablation in the Treatment of Benign Thyroid Nodules. Case Report</i>	(Malayev et al., 2025)	Case report	1 patient	Microwave Ablation (MWA)	MWA is effective and safe, with potential as a non-surgical alternative in benign nodule management.
6	<i>Efficacy in Size and Symptom Reduction of Radiofrequency Ablation of Benign Non-Functioning Thyroid Nodules</i>	(Rodriguez Escobedo et al., 2022)	Original article, retrospective study	Not specified	RFA	RFA is safe, tolerable, and effective in reducing volume and clinical symptoms.
7	<i>Radiofrequency Ablation of Benign Thyroid Nodules: 10-Year Follow-Up Results From a Single Center</i>	(Shin et al., 2025)	Original article, retrospective study (10-year follow-up)	267 nodules from 237 patients	RFA with long-term efficacy evaluation	A single RFA session is adequate in most cases; the study evaluates determinants for additional sessions to achieve optimal Volume Reduction Rate.
8	<i>Radiofrequency Ablation of Benign and Malignant Thyroid Nodules</i>	(Navin et al., 2022)	Review article	No samples	Review of RFA for benign and malignant nodules	RFA is safe, well tolerated, and is an option for symptomatic benign nodules and autonomously functioning thyroid nodules (AFTN).
9	<i>Radiofrequency Ablation for Management of Thyroid Nodules: A Case Report</i>	(Yarsa & Bellynda, 2021)	Case report	1 female patient aged 48 years	RFA	RFA was proven effective and safe in managing large benign thyroid nodules.
10	<i>Characteristics of Thyroid Nodule Patients Undergoing Radiofrequency Ablation (RFA) at RSUD Dr. Soetomo Surabaya from January 2023 to December 2024</i>	(Afifudin, 2025)	Descriptive study of patient characteristics	Patients with thyroid nodules undergoing RFA	RFA	The study aims to identify characteristics of patients receiving RFA; clinical outcome data are not yet available.

Based on the ten analyzed articles, all studies consistently demonstrate that Radiofrequency Ablation (RFA) is a safe, effective procedure capable of significantly reducing thyroid nodule volume (Ahmad et al., 2022; El Sheikh et al., 2024). International clinical guidelines also support the use of RFA as a valid non-surgical alternative for patients with symptomatic benign nodules, particularly for those who refuse or are unable to undergo surgery (Papini et al., 2020). Long-term studies further reinforce evidence that RFA efficacy may persist for more than 5–10 years, with additional sessions required only in selected cases (Shin et al., 2025). Additionally, case reports indicate that RFA can manage large nodules safely, even in patients with certain clinical limitations (Malayev et al., 2025; Yarsa & Bellynda, 2021). Overall, this table confirms that RFA is a minimally invasive therapeutic modality with high effectiveness, low risk, and broad application potential in the management of benign thyroid nodules.

## DISCUSSION

The findings of this systematic review provide robust evidence that radiofrequency ablation (RFA) is not merely an effective minimally invasive intervention for benign thyroid nodules, but also a strategically relevant modality within contemporary health service systems. Across diverse study designs, RFA consistently demonstrates significant volume reduction, symptom alleviation, and preservation of thyroid function, positioning it as an intermediate solution between surgical thyroidectomy and conservative management (Ahmad et al., 2022; El Sheikh et al., 2024). However, the broader significance of these findings extends beyond clinical efficacy and warrants interpretation through health policy, service efficiency, and patient-centered care perspectives.

From a health system efficiency standpoint, the adoption of RFA particularly single-session strategies as proposed by Yao et al., (2020) has substantial implications for improving access to care. Single-session RFA for large benign nodules reduces the need for repeated interventions and postoperative hospitalization, thereby increasing patient turnover in tertiary hospitals. This efficiency gain is especially relevant in healthcare systems with limited surgical capacity and long waiting lists for elective thyroid surgery. By shifting eligible patients from operating rooms to outpatient-based ablation units, RFA can contribute to reducing surgical backlogs and optimizing resource allocation without compromising clinical outcomes. Consequently, RFA aligns well with value-based healthcare principles that emphasize high clinical benefit with lower procedural burden.

Beyond access and efficiency, the psychosocial impact of RFA emerges as an important yet often underemphasized dimension. Multiple studies indicate that minimally invasive ablation is associated with lower procedural anxiety, faster recovery, and improved quality of life compared to open surgery (Ahmad et al., 2022; Yarsa & Bellynda, 2021). The avoidance of general anesthesia, surgical scars, and prolonged recovery periods contributes to better body image perception and psychological well-being, particularly among younger and female patients who constitute the majority of benign thyroid nodule cases. These psychosocial benefits reinforce the argument that treatment success should not be evaluated solely by volumetric outcomes, but also by patient-reported experiences and post-procedural quality of life.

Technological and procedural innovations further strengthen the role of RFA as a standardized therapeutic option. Techniques such as the moving-shot method and peripheral ablation have been shown to enhance procedural precision, reduce complication rates, and improve volume reduction outcomes, especially in nodules with solid components (El Sheikh et al., 2024; Yao et al., 2020). Importantly, these techniques are reproducible and can be integrated into standardized operating procedures (SOPs) within advanced healthcare facilities. The availability of international guidelines, such as

those issued by the European Thyroid Association (Papini et al., 2020), provides a strong framework for harmonizing clinical practice, training requirements, and quality assurance mechanisms, thereby facilitating broader institutional adoption of RFA.

Long-term evidence further consolidates the policy relevance of RFA. The 10-year follow-up study by Shin et al., (2025) demonstrates that durable outcomes can be achieved with a single ablation session in most patients, with additional sessions required only in selected cases based on nodule characteristics. This durability supports the cost-effectiveness of RFA over time and reduces the cumulative burden of repeat interventions. In health economic terms, such sustained efficacy strengthens the justification for including RFA in national treatment guidelines and insurance reimbursement schemes, particularly for benign thyroid disease management.

In summary, this systematic review indicates that radiofrequency ablation represents a clinically effective, psychosocially favorable, and system-efficient therapeutic modality for benign thyroid nodules. Its benefits extend from individual patient outcomes to broader health service delivery improvements, including enhanced access, reduced surgical burden, and standardized minimally invasive care. Supported by long-term evidence and international guidelines, RFA occupies a strategic position as the primary non-surgical intervention for benign thyroid nodules. Integrating RFA into routine endocrine practice and health policy frameworks therefore constitutes a rational and forward-looking step toward improving the overall quality and sustainability of thyroid nodule management.

## CONCLUSION

This study concludes that radiofrequency ablation (RFA) is a minimally invasive therapeutic modality proven to be effective and safe in the management of benign thyroid nodules, based on the synthesis of ten scientific articles analyzed. All studies show consistent findings that RFA can achieve a significant volume reduction rate, improve clinical symptoms, and preserve thyroid function, with a low complication rate. Long-term evidence from a ten-year follow-up study further reinforces the durability of RFA outcomes, while innovations such as the single-session peripheral ablation approach highlight the potential expansion of procedural indications. Additionally, international clinical guidelines support RFA as a viable alternative for patients who refuse or are unable to undergo thyroidectomy. Overall, the systematic review positions RFA as a non-surgical therapy with a strong scientific foundation in terms of effectiveness, safety, and adherence to imaging-based practice standards. Variations in findings across studies primarily related to nodule characteristics and ablation techniques underscore the importance of appropriate patient selection and operator expertise as key determinants of procedural success. Thus, this evidence synthesis provides a comprehensive understanding of the strategic role of RFA in the clinical management of benign thyroid nodules in modern practice.

Future research is recommended to expand the evaluation of long-term RFA outcomes using multi-center prospective designs to produce more generalizable data. Direct comparative studies between RFA and other minimally invasive ablation modalities, such as microwave ablation, should be strengthened to assess differences in clinical efficacy, cost, and safety. Future investigations should also examine the influence of nodule characteristics in greater detail, including internal composition, degree of vascularization, and ablation response to specific techniques. Additionally, the development of standardized operating procedures for ablation techniques, outcome monitoring, and complication management may enhance the consistency of RFA effectiveness across healthcare centers. Integrating systematic patient quality-of-life assessments is also essential to obtain a comprehensive understanding of the clinical benefits of RFA.

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