Jurnal Impresi Indonesia (JII)
p-ISSN: 2828-1284 e-ISSN: 2810-062x
website: https: //rivierapublishing.id/jii/index.php/
Vol. XX. No. January. 2026

Diagnostic Approaches and Treatment Outcomes in Pediatric Thyroid Malignancies: A Systematic Review

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Keywords
Pediatric thyroid cancer; diagnosis; Treatment outcomes; Ultrasonography; Systematic review.

Abstract
Thyroid cancer in children is rare but often diagnosed at an advanced stage. Although the prognosis is generally good, variations in diagnostic approaches and treatment strategies highlight the need for a comprehensive synthesis of current evidence specifically focused on the pediatric population. This systematic review aims to summarize and evaluate the available evidence regarding diagnostic approaches and treatment outcomes in pediatric thyroid cancer. A literature search was conducted in PubMed/MEDLINE, Scopus, and Embase in accordance with the PRISMA 2020 guidelines. Eligible studies were original clinical trials involving pediatric patients (<18 years) with thyroid cancer that reported diagnostic modalities and/or treatment outcomes. Study selection, data extraction, and risk of bias assessment were performed independently by two reviewers. Due to heterogeneity between studies, a qualitative narrative synthesis was performed. Five retrospective cohort studies met the inclusion criteria. Ultrasonography and fine-needle aspiration biopsy were consistently used as the primary diagnostic tools in all studies. Surgery, primarily total thyroidectomy with or without lymph node dissection, was the primary treatment. Radioactive iodine therapy is generally given to intermediate- and high-risk patients, while some low-risk patients achieve good outcomes without it. Survival and remission rates are high, although recurrence is associated with tumor characteristics such as multifocality, bilaterality, and lymph node involvement. Treatment-related complications are rare. Current evidence supports a staged diagnostic approach and risk-adapted treatment strategies for pediatric thyroid cancer.

INTRODUCTION

Thyroid malignancies represent the most common endocrine cancers in the pediatric population, with an incidence that has steadily increased over the past decades (Qiu & Deng, 2023). Although relatively rare compared to adult thyroid cancer, pediatric thyroid malignancies often present with more advanced disease at diagnosis, including higher rates of lymph node involvement and distant metastasis (Pasqual et al., 2022). Papillary thyroid carcinoma is the predominant histological subtype in children, followed by follicular and less commonly medullary thyroid carcinoma (Spinella et al., 2023). Despite aggressive initial presentations, long-term survival in pediatric patients is generally excellent, emphasizing the importance of appropriate diagnostic evaluation and optimized treatment strategies (Cho et al., 2025). These distinct epidemiological and clinical characteristics differentiate pediatric thyroid malignancies from adult cases and necessitate age-specific approaches. Understanding these

differences is essential to improving outcomes while minimizing treatment-related morbidity in children and adolescents (Tsagli et al., 2024; Moniz et al., 2023).

Accurate diagnosis of thyroid malignancies in pediatric patients remains a clinical challenge due to overlapping features between benign and malignant thyroid nodules (Lebbink et al., 2022). Ultrasonography is widely used as the first-line imaging modality, providing valuable information on nodule characteristics and cervical lymph node involvement (Jie et al., 2023). Fine-needle aspiration biopsy plays a crucial role in cytological evaluation, although its diagnostic accuracy may be limited in children due to indeterminate results and lower prevalence of nodules (Hasannia et al., 2025). Additional diagnostic tools, including molecular testing and cross-sectional imaging, have been increasingly explored to improve diagnostic precision. However, the optimal combination and sequencing of diagnostic modalities in pediatric thyroid malignancies remain debated. This variability underscores the need for a comprehensive synthesis of available evidence regarding diagnostic approaches (Forma et al., 2025; Dagdeviren Cakir, 2023).

The management of pediatric thyroid malignancies primarily involves surgical intervention, with the extent of thyroidectomy and lymph node dissection tailored to disease severity (El Omri et al., 2025). Radioactive iodine therapy and thyroid-stimulating hormone suppression are commonly used as adjuvant treatments, particularly in differentiated thyroid carcinoma. While these strategies have contributed to favorable survival outcomes, they are also associated with potential short- and long-term complications, including hypoparathyroidism, recurrent laryngeal nerve injury, and secondary malignancies (Pasqual et al., 2022; Pasqual et al., 2022). Emerging targeted therapies have shown promise in selected cases, especially for advanced or refractory disease. Evaluating treatment effectiveness in pediatric populations therefore requires careful consideration of both oncologic outcomes and treatment-related morbidity. Balancing disease control with quality of life remains a central challenge in pediatric thyroid cancer management (Pasqual et al., 2022; Forma et al., 2025).

Despite growing literature on pediatric thyroid malignancies, existing studies vary widely in diagnostic criteria, treatment protocols, and reported outcomes (Pasqual et al., 2022; Cho et al., 2025). Previous reviews have often focused on either diagnostic aspects or therapeutic outcomes, limiting a holistic understanding of disease management. A comprehensive synthesis integrating diagnostic approaches with treatment outcomes is needed to guide evidence-based clinical decision-making (Forma et al., 2025; Dagdeviren Cakir, 2023). Systematic evaluation of current evidence may help identify optimal diagnostic strategies and inform treatment planning tailored to pediatric patients. Therefore, this systematic review aims to summarize and analyze available evidence on diagnostic approaches and treatment outcomes in pediatric thyroid malignancies. The findings are expected to support clinicians and researchers in improving care and identifying gaps for future research.

RESEARCH METHOD

This study was conducted as a systematic review designed to synthesize available evidence on diagnostic approaches and treatment outcomes in pediatric thyroid malignancies. The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological rigor and

transparency. A predefined protocol guided the processes of literature search, study selection, data extraction, and synthesis to minimize bias. The review focused on observational and interventional studies reporting diagnostic modalities and clinical outcomes in pediatric populations with thyroid malignancies. Given the anticipated heterogeneity in study designs, diagnostic criteria, and outcome measures, a narrative synthesis approach was planned. This design allowed for comprehensive integration of diverse evidence relevant to pediatric thyroid cancer diagnosis and management.

Eligibility criteria were established using the Population, Intervention, Comparator, and Outcomes (PICO) framework to ensure the inclusion of studies relevant to the objectives of this systematic review. The population of interest comprised pediatric patients, defined as individuals younger than 18 years, with a confirmed diagnosis of thyroid malignancy, including papillary, follicular, medullary, and poorly differentiated thyroid carcinoma. Studies that included both adult and pediatric populations were considered eligible only if data specific to pediatric patients could be clearly extracted and analyzed separately. The interventions of interest included diagnostic approaches such as ultrasonography, fine-needle aspiration biopsy, molecular or genetic testing, and other imaging modalities, as well as treatment strategies encompassing surgical management, radioactive iodine therapy, thyroid-stimulating hormone suppression, and systemic or targeted therapies. When applicable, comparator groups consisted of alternative diagnostic modalities, different treatment strategies, or standard care.

The primary outcomes of interest included diagnostic performance measures, such as accuracy and clinical utility, as well as treatment outcomes including overall survival, recurrence rates, and treatment-related complications. Secondary outcomes included disease progression and long-term follow-up outcomes when reported. Eligible study designs consisted of randomized controlled trials, cohort studies, case–control studies, and cross-sectional studies published in peer-reviewed journals. Reviews, case reports, conference abstracts, editorials, and animal studies were excluded. Only studies published in the English language were included, with no restrictions on publication year to allow comprehensive coverage of the available literature.

A comprehensive literature search was conducted across multiple electronic databases to identify relevant studies on diagnostic approaches and treatment outcomes in pediatric thyroid malignancies. The databases searched included PubMed/MEDLINE, Scopus, and Embase, which were selected to ensure broad coverage of biomedical and clinical research. Each database was searched from inception until the most recent search date, with no initial restrictions on publication year. Reference lists of included studies and relevant review articles were also screened manually to identify additional eligible publications. Only studies published in the English language were considered for inclusion. The final search was conducted on a predefined date to ensure consistency and reproducibility of the search process.

A systematic search strategy was developed to identify studies addressing diagnostic approaches and treatment outcomes in pediatric thyroid malignancies. Search terms were constructed using a combination of Medical Subject Headings (MeSH) and free-text keywords related to pediatric populations, thyroid malignancies, diagnostic modalities, and treatment outcomes. Boolean operators (“AND,” “OR”) were applied to combine relevant concepts, and search strategies were adapted for each database to account for differences in indexing and

syntax. Key terms included variations of “pediatric,” “child,” “thyroid cancer,” “thyroid malignancy,” “diagnosis,” “ultrasonography,” “fine-needle aspiration,” “surgery,” “radioactive iodine,” and “treatment outcomes.” The search strategy was initially developed for PubMed/MEDLINE and subsequently modified for use in Scopus and Embase. Details of the complete search strategy for at least one database were documented to ensure transparency and reproducibility.

All records identified through the database searches were exported into reference management software, and duplicate studies were removed prior to screening. The study selection process was conducted in two sequential stages. In the first stage, titles and abstracts were independently screened by two reviewers to assess potential eligibility based on the predefined inclusion and exclusion criteria. Studies that were clearly irrelevant were excluded at this stage. Full-text articles were then retrieved for studies deemed potentially eligible or when eligibility could not be determined from the title and abstract alone.

In the second stage, full-text articles were independently assessed by the same two reviewers to determine final inclusion in the systematic review. Any disagreements regarding study eligibility were resolved through discussion, and when consensus could not be reached, a third reviewer was consulted. Reasons for exclusion at the full-text screening stage were documented and reported in the PRISMA flow diagram. This rigorous selection process was designed to minimize selection bias and ensure transparency and reproducibility of study inclusion.

Data extraction was performed using a standardized data extraction form developed prior to the review process to ensure consistency and accuracy. Two reviewers independently extracted data from all included studies, and the extracted information was cross-checked to minimize errors. Extracted data included study characteristics such as author, year of publication, country, study design, sample size, and duration of follow-up. Population-specific information, including age range, sex distribution, and histological subtype of thyroid malignancy, was also collected.

In addition, data related to diagnostic approaches and treatment outcomes were systematically extracted. Diagnostic data included the type of diagnostic modality used, diagnostic performance measures, and clinical utility when reported. Treatment-related data comprised details of surgical procedures, adjuvant therapies, and systemic treatments, along with reported outcomes such as survival, recurrence, and treatment-related complications. Any discrepancies in data extraction were resolved through discussion between the reviewers, with consultation of a third reviewer when necessary. This structured approach ensured comprehensive and reliable data collection for subsequent synthesis.

The risk of bias of included studies was independently assessed by two reviewers using appropriate validated tools based on study design. For observational studies, including cohort and case–control studies, the Newcastle–Ottawa Scale (NOS) was used to evaluate methodological quality across three domains: selection of study groups, comparability of groups, and ascertainment of outcomes or exposures. For studies focusing on diagnostic accuracy, the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool was applied to assess potential bias related to patient selection, index tests, reference standards, and

flow and timing. Each study was rated according to the criteria specified in the respective assessment tools.

Disagreements between reviewers regarding risk of bias judgments were resolved through discussion, and a third reviewer was consulted when consensus could not be achieved. The results of the risk of bias assessment were summarized descriptively and presented in tabular or graphical form to provide an overview of study quality. Risk of bias assessments were considered during data synthesis and interpretation of findings to ensure that conclusions were informed by the overall strength and limitations of the available evidence.

Data from the included studies were synthesized using a narrative approach due to anticipated heterogeneity in study designs, patient characteristics, diagnostic methods, treatment strategies, and outcome measures. Findings were grouped and summarized according to key themes, including diagnostic approaches, treatment strategies, and reported clinical outcomes. Diagnostic data were synthesized descriptively to highlight the range of modalities used and their reported diagnostic performance or clinical utility. Treatment outcomes were summarized based on survival, recurrence, and treatment-related complications, allowing comparison across different therapeutic approaches.

Quantitative synthesis or meta-analysis was not performed because of substantial variability in outcome definitions, follow-up durations, and reporting methods among the included studies. Where appropriate, patterns and trends across studies were identified to provide an integrated interpretation of the evidence. The results of the risk of bias assessment were taken into account during data synthesis to contextualize findings based on study quality. This approach enabled a comprehensive and balanced synthesis of current evidence on diagnostic approaches and treatment outcomes in pediatric thyroid malignancies.

RESULTS AND DISCUSSION

Search Results and Study Selection

The systematic search of electronic databases yielded a total of 1,630 records, comprising articles identified from PubMed (n = 480), SagePub (n = 170), SpringerLink (n = 590), and Google Scholar (n = 390). Following the initial identification phase, duplicate records were removed (n = 1,450), and additional articles were excluded prior to screening due to automatic relevance filtering and other predefined reasons (n = 80). After these exclusions, 100 articles remained and were subjected to title and abstract screening. This initial screening resulted in the exclusion of 60 articles that did not meet the predefined eligibility criteria, leaving 40 articles for full-text assessment.

All 40 full-text articles were successfully retrieved and evaluated for eligibility. During the full-text review, 30 articles were excluded due to being outside the specified publication year range (n = 18), incomplete or insufficient outcome data (n = 5), or inappropriate study design relative to the review objectives (n = 7). As a result, five studies fulfilled all inclusion criteria and were included in the final qualitative synthesis of this systematic review (Cho et al., 2025; Puga et al., 2024; Van De Berg et al., 2022; Chen et al., 2022; Bojarsky, 2023). The detailed process of study identification, screening, eligibility assessment, and inclusion is illustrated in the PRISMA flow diagram (Figure 1).

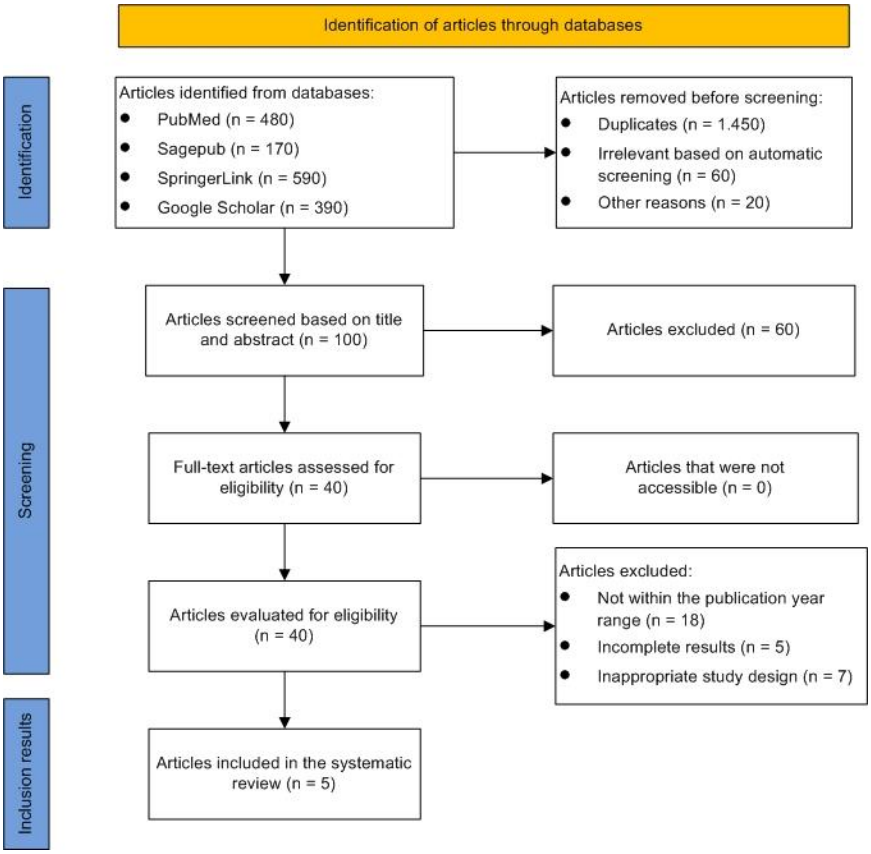

Figure 1. PRISMA Flow Diagram of Article Selection

General Characteristics of the Included Studies

A total of five studies were included in the final qualitative synthesis of this systematic review. The included studies were published across a range of years and originated from different geographic regions, reflecting variability in clinical practice and healthcare settings. Study designs consisted predominantly of observational studies, including retrospective cohort and cross-sectional designs, which are commonly employed in pediatric oncology research due to the rarity of thyroid malignancies in children. Sample sizes varied considerably among studies, ranging from small single-center cohorts to larger institutional series. The study populations consisted exclusively of pediatric patients, with age ranges generally spanning from early childhood to late adolescence. (Table 1).

Regarding disease characteristics, papillary thyroid carcinoma was the most frequently reported histological subtype across all included studies, followed by follicular and medullary thyroid carcinoma. Diagnostic approaches varied, with most studies employing a combination of ultrasonography and fine-needle aspiration biopsy as primary diagnostic tools, while some incorporated additional imaging or molecular testing. Treatment strategies predominantly involved surgical management, with variations in the extent of thyroidectomy and lymph node dissection, followed by adjuvant therapies such as radioactive iodine and thyroid-stimulating hormone suppression in selected cases. Outcome reporting differed among studies, but commonly included measures of survival, recurrence, and treatment-related complications, forming the basis for subsequent qualitative synthesis in this review.

Diagnostic Approaches

Across the included studies, neck ultrasonography was consistently employed as the primary diagnostic modality for the initial evaluation of suspected thyroid malignancies, reflecting its established role as the cornerstone imaging technique in pediatric patients (Kujdowicz et al., 2025). In some cohorts, FNAB results guided the extent of initial surgical management, particularly in cases with suspicious or malignant cytology. Despite variability in reported diagnostic performance, FNAB was regarded as an essential component of the diagnostic pathway in pediatric thyroid cancer across all included studies (Zhu et al., 2021).

Fine-needle aspiration biopsy (FNAB) was commonly employed following ultrasonographic evaluation to establish cytological diagnosis. The included studies reported FNAB as a key diagnostic tool for differentiating malignant from benign thyroid nodules, although indeterminate cytology remained a notable challenge in pediatric populations. In some cohorts, FNAB results guided the extent of initial surgical management, particularly in cases with suspicious or malignant cytology. Despite variability in reported diagnostic performance, FNAB was regarded as an essential component of the diagnostic pathway in pediatric thyroid cancer across all included studies.

Additional diagnostic approaches, including cross-sectional imaging and laboratory evaluation, were selectively utilized to support staging and treatment planning. Imaging modalities such as computed tomography or magnetic resonance imaging were primarily used to evaluate extrathyroidal extension or extensive nodal disease when suspected clinically or on ultrasound (Han et al., 2025; Tsujioka et al., 2025). While molecular or genetic testing was not uniformly reported across studies, some cohorts acknowledged its emerging role in refining diagnostic accuracy and risk stratification (Guleria et al., 2022). Overall, the diagnostic strategies across studies reflected a stepwise approach integrating ultrasonography, FNAB, and adjunctive investigations to optimize diagnostic certainty and guide subsequent treatment decisions (Table 2).

Treatment Strategies

Surgical management was the cornerstone of treatment across all included studies. Total thyroidectomy was the most commonly performed procedure, particularly in patients with confirmed malignancy, multifocal disease, or regional lymph node involvement (Jawadi et al., 2025). Several studies reported the use of central and lateral neck lymph node dissection when nodal metastases were identified preoperatively or intraoperatively. The extent of surgery varied among cohorts and was influenced by tumor size, disease distribution, and risk stratification. Despite differences in surgical approach, operative management aimed to achieve optimal disease control while minimizing perioperative complications (Scholfield et al., 2023; Vouchara et al., 2024).

Radioactive iodine (RAI) therapy was frequently used as an adjuvant treatment, especially in patients with intermediate- to high-risk differentiated thyroid carcinoma. Most studies described RAI administration following total thyroidectomy to ablate residual thyroid tissue and treat microscopic or metastatic disease (Persons et al., 2025). However, treatment strategies differed regarding patient selection and dosing, reflecting evolving clinical practices.

Notably, one included study specifically evaluated outcomes in low-risk pediatric patients managed without RAI, demonstrating the emergence of more conservative treatment approaches in selected cases. These findings highlight increasing attention to risk-adapted use of RAI in pediatric thyroid cancer management (Stanciu et al., 2022).

In addition to surgery and RAI, thyroid-stimulating hormone (TSH) suppression therapy with levothyroxine was routinely implemented as part of postoperative management. TSH suppression was aimed at reducing the risk of tumor recurrence and supporting long-term disease control (Stanciu et al., 2022). Follow-up strategies typically involved periodic clinical evaluation, biochemical monitoring, and imaging surveillance. While systemic or targeted therapies were not widely reported among the included studies, their limited mention reflects their restricted use in pediatric populations. Overall, treatment strategies across studies emphasized individualized, risk-based management to balance effective oncologic control with the reduction of long-term treatment-related morbidity (Table 3).

Treatment Outcomes

Overall, the included studies reported favorable treatment outcomes in pediatric patients with thyroid malignancies, despite frequent presentation with advanced disease. High rates of disease control were observed following primary surgical management, with most patients achieving remission during follow-up (Donner et al., 2024). Long-term survival outcomes were excellent across cohorts, with overall survival approaching near-complete rates in differentiated thyroid carcinoma. These findings reinforce the generally favorable prognosis of pediatric thyroid malignancies when managed with appropriate multimodal treatment strategies (Lee & Lee, 2025).

Disease recurrence and persistence were variably reported among the included studies, with recurrence rates influenced by tumor characteristics and initial risk stratification. Factors such as multifocality, bilaterality, and lymph node involvement at diagnosis were associated with increased risk of recurrence in several cohorts (Hermansyah et al., 2025). However, even in cases of recurrent or persistent disease, subsequent treatments, including additional surgery or adjuvant therapy, were often effective in achieving disease control. Notably, one study demonstrated comparable remission outcomes in selected low-risk patients managed without radioactive iodine, suggesting that de-escalation strategies may be appropriate in carefully selected pediatric populations (Stanciu et al., 2022).

Treatment-related complications were reported but generally occurred at low rates. Surgical complications, including transient hypocalcemia and recurrent laryngeal nerve injury, were the most commonly documented adverse events, while serious long-term complications were infrequent (Scholfield et al., 2023). The risk of complications was influenced by the extent of surgery and adjuvant therapy, underscoring the importance of individualized treatment planning. Collectively, the outcome data highlight the need to balance effective oncologic control with minimization of treatment-related morbidity, particularly given the long life expectancy of pediatric patients (Elgendy et al., 2022).

Risk of Bias Results

The risk of bias assessment indicated that the overall methodological quality of the included studies was moderate to good. Using the Newcastle–Ottawa Scale (NOS) for observational cohort studies, most studies demonstrated adequate quality in the selection domain, with clearly defined pediatric populations and confirmed diagnoses of thyroid malignancy. Comparability between study groups was generally acceptable, although some studies lacked adjustment for potential confounding variables such as tumor stage or extent of lymph node involvement. Outcome assessment was consistently reported across studies, with sufficient follow-up durations to evaluate recurrence and survival outcomes.

For studies evaluating diagnostic components, assessment using the QUADAS-2 tool revealed low to moderate risk of bias across most domains. Patient selection was generally appropriate, although several studies employed retrospective designs, which introduced potential selection bias. Index tests, including ultrasonography and fine-needle aspiration biopsy, were conducted using standard clinical protocols, resulting in low concern regarding applicability. However, variability in reference standards and reporting of diagnostic accuracy metrics contributed to some concerns related to flow and timing. Overall, the risk of bias findings were considered acceptable for qualitative synthesis, and study quality was taken into account during interpretation of the results.

Table 1. General Characteristics of the Included Studies

Author (Year)	Country	Study Design	Sample Size (Pediatric)	Histology	Outcomes Reported
van de Berg DJ et al. (2022)	Netherlands	Nationwide retrospective cohort	133	Papillary & Follicular Thyroid Carcinoma	Recurrence, disease-free survival, overall survival
Cho JW et al. (2024)	South Korea	Retrospective cohort	58	Papillary Thyroid Carcinoma	Recurrence risk, multifocality, bilaterality
Puga FM et al. (2024)	Spain	Single-center retrospective cohort	64	Differentiated Thyroid Carcinoma	Persistent disease, recurrence, treatment response
Chen C et al. (2022)	China	Retrospective cohort	52	Differentiated Thyroid Carcinoma (PTC/FTC)	Tumor characteristics, surgical complications, recurrence
Bojarsky M et al. (2023)	United States	Retrospective cohort	95	Low-risk Differentiated Thyroid Carcinoma	Remission, recurrence, outcomes without radioactive iodine

Table 2. Diagnostic Modalities Used in Pediatric Thyroid Malignancies

Author (Year)	Ultrasonography	FNAB	CT / MRI	Molecular / Genetic Testing	Primary Diagnostic Purpose
Van de Berg et al. (2022)	Yes	Yes	Selective	Not reported	Detection of thyroid nodules, lymph node involvement, preoperative staging
Cho et al. (2024)	Yes	Yes	Not routinely used	Not reported	Evaluation of multifocality, bilaterality, and nodal disease
Puga et al. (2024)	Yes	Yes	Selective	Not reported	Initial diagnosis and risk stratification
Chen et al. (2022)	Yes	Yes	Yes	Not reported	Assessment of tumor extent, extrathyroidal invasion, and nodal involvement
Bojarsky et al. (2023)	Yes	Yes	Not routinely used	Not reported	Confirmation of low-risk disease and postoperative surveillance

Table 1. Treatment Strategies and Therapeutic Approaches in Included Studies

Study	Primary Surgery	Lymph Node Dissection	Radioactive Iodine (RAI)	TSH Suppression	Follow-up Duration
Van de Berg et al. (2022)	Total thyroidectomy (predominant)	Central ± lateral neck dissection when indicated	Yes (risk-adapted)	Yes	Long-term (median >5 years)
Cho et al. (2024)	Total thyroidectomy	Central and/or lateral dissection based on nodal status	Selective	Yes	Median ~6 years
Puga et al. (2024)	Total thyroidectomy; selected lobectomy	Central neck dissection when indicated	Yes (selected cases)	Yes	Up to 12 years
Chen et al. (2022)	Total thyroidectomy (majority)	Central ± lateral dissection	Yes (risk-based)	Yes	Median ~4 years
Bojarsky et al. (2023)	Total thyroidectomy	Selective (based on risk)	No RAI in low-risk cohort	Yes	Median ~5 years

Principal Findings

This systematic review synthesizes current evidence on diagnostic approaches and treatment outcomes in pediatric thyroid malignancies, highlighting several key findings. Across the included studies, a consistent diagnostic pathway was observed, with neck ultrasonography serving as the primary initial modality, followed by fine-needle aspiration biopsy to confirm malignancy (Zhu et al., 2021). Despite variability in diagnostic protocols, this stepwise approach was effective in identifying disease extent and guiding treatment

planning. These findings reinforce the central role of ultrasound-based evaluation and cytological assessment in pediatric thyroid cancer diagnosis (Puga et al., 2024; Gambale et al., 2024).

Regarding treatment, surgical management emerged as the cornerstone of therapy, with total thyroidectomy being the most frequently performed procedure. Adjuvant radioactive iodine therapy was commonly used in intermediate- and high-risk patients, while selected low-risk pediatric patients achieved favorable outcomes without radioactive iodine (Stanciu et al., 2022). This reflects a growing trend toward risk-adapted treatment strategies aimed at minimizing long-term treatment-related morbidity. The evidence suggests that individualized treatment planning, informed by tumor characteristics and risk stratification, is essential in optimizing outcomes for pediatric patients (Hermansyah et al., 2025; Parvathareddy et al., 2023).

In terms of outcomes, the included studies consistently reported excellent survival rates and high rates of disease control, despite frequent presentation with advanced disease at diagnosis. Recurrence was associated with factors such as multifocality, bilaterality, and lymph node involvement, but effective salvage therapies often resulted in sustained remission (Bojarsky, 2023; Elgendy et al., 2022). Importantly, treatment-related complications were generally infrequent, underscoring the effectiveness of current management strategies. Collectively, these findings support the effectiveness of contemporary diagnostic and therapeutic approaches while emphasizing the need for balanced, risk-based management in pediatric thyroid malignancies (Scholfield et al., 2023).

Comparison with Previous Studies

The findings of this systematic review are largely consistent with previous studies and reviews on pediatric thyroid malignancies, which have emphasized the distinct clinical behavior of thyroid cancer in children compared to adults. Earlier literature has consistently reported higher rates of lymph node involvement and distant metastasis at diagnosis in pediatric patients, despite excellent long-term survival (Vanderniet et al., 2025; Martucci, n.d.). The present review confirms these observations, demonstrating that contemporary diagnostic approaches, particularly ultrasonography and fine-needle aspiration biopsy, remain central to identifying disease extent and guiding management. These similarities suggest that current diagnostic practices are aligned with established evidence, although refinements in risk stratification continue to evolve (Zhu et al., 2021).

Compared with earlier systematic reviews that focused predominantly on either diagnostic accuracy or treatment outcomes, this review provides an integrated synthesis of both diagnostic and therapeutic aspects. Previous reviews often highlighted the challenges of indeterminate cytology in pediatric populations and the need for cautious interpretation of fine-needle aspiration results. The included studies in this review similarly reported variability in diagnostic performance, reinforcing concerns raised in earlier literature. However, more recent studies included in this review suggest incremental improvements in diagnostic precision, potentially reflecting advances in imaging techniques and increased clinical experience in managing pediatric thyroid nodules.

In terms of treatment, earlier studies advocated for aggressive surgical and adjuvant therapy due to concerns about advanced disease at presentation. In contrast, recent literature has increasingly supported risk-adapted treatment strategies to reduce long-term morbidity without compromising oncologic outcomes. The findings of this review align with this shift, particularly regarding selective use of radioactive iodine therapy in low-risk pediatric patients. This evolving approach mirrors trends reported in recent guidelines and cohort studies, underscoring a growing emphasis on individualized management and long-term quality of life in children with thyroid malignancies.

Clinical Implications

The findings of this systematic review have important implications for the clinical management of pediatric thyroid malignancies. The consistent use of ultrasonography as the primary diagnostic modality reinforces its role as the cornerstone of initial evaluation in children with suspected thyroid nodules (Jie et al., 2023). Clinicians should prioritize high-quality ultrasound assessment, including careful evaluation of cervical lymph nodes, to optimize preoperative staging and guide subsequent diagnostic steps. Fine-needle aspiration biopsy remains essential for cytological confirmation, although its limitations in pediatric populations highlight the need for multidisciplinary interpretation of results (Zhu et al., 2021).

From a therapeutic perspective, the evidence supports a risk-adapted treatment strategy tailored to individual tumor characteristics. While total thyroidectomy and lymph node dissection remain appropriate for patients with extensive or high-risk disease, selected low-risk pediatric patients may achieve excellent outcomes with less aggressive approaches (Jawadi et al., 2025). The selective use of radioactive iodine therapy, as demonstrated in recent cohorts, underscores the importance of avoiding overtreatment and minimizing long-term adverse effects. These findings align with evolving clinical guidelines that emphasize balancing disease control with preservation of quality of life (Cho et al., 2025).

Long-term follow-up and survivorship care represent additional key clinical considerations. Given the excellent survival rates reported across studies, clinicians must focus not only on oncologic outcomes but also on monitoring and managing treatment-related complications over time (Elgendy et al., 2022). Regular biochemical monitoring, imaging surveillance, and assessment of growth and developmental outcomes are essential components of post-treatment care. The integration of evidence-based diagnostic and therapeutic strategies highlighted in this review may contribute to more standardized, patient-centered care pathways for children with thyroid malignancies (Mitsutake & Saenko, 2021; Guleria et al., 2022).

Strengths and Limitations

This systematic review has several strengths. First, it provides a comprehensive synthesis of recent evidence focusing exclusively on pediatric thyroid malignancies, a population that is often underrepresented in oncologic research (Cinar et al., 2023). By integrating both diagnostic approaches and treatment outcomes, this review offers a holistic perspective on disease management that extends beyond single-domain analyses. The use of predefined eligibility criteria, adherence to PRISMA 2020 guidelines, and structured risk of bias assessment enhance the methodological rigor and transparency of the review.

Additionally, the inclusion of studies from diverse geographic regions increases the generalizability of the findings.

However, several limitations should be acknowledged. The number of included studies was relatively small, reflecting the rarity of pediatric thyroid malignancies and limiting the ability to perform quantitative meta-analysis. Most included studies employed retrospective designs, which are inherently subject to selection bias and incomplete data reporting. Variability in diagnostic criteria, treatment protocols, and outcome definitions across studies also introduced heterogeneity, restricting direct comparison of results. Furthermore, the restriction to English-language publications may have resulted in the exclusion of relevant studies published in other languages. These limitations highlight the need for cautious interpretation of the findings and underscore the importance of further high-quality prospective research in this field.

Future Research Directions

Future research on pediatric thyroid malignancies should prioritize prospective, multicenter studies with standardized diagnostic and treatment protocols. Given the heterogeneity observed in diagnostic criteria and outcome reporting, the development and adoption of uniform definitions for disease staging, recurrence, and treatment response are essential. Further investigation into the diagnostic performance of advanced imaging techniques and molecular or genetic markers may help refine risk stratification and reduce diagnostic uncertainty, particularly in cases with indeterminate cytology. Such efforts could improve early detection and support more precise treatment planning in pediatric populations.

In addition, long-term outcome studies focusing on survivorship and quality of life are critically needed. As survival rates in pediatric thyroid malignancies are high, future research should evaluate the long-term effects of different treatment strategies on growth, development, and psychosocial well-being. Comparative studies examining de-escalation approaches, including selective use of radioactive iodine and less extensive surgical interventions in low-risk patients, may further inform evidence-based guidelines. Collectively, these research directions aim to optimize patient-centered care while minimizing long-term morbidity in children and adolescents with thyroid malignancies.

CONCLUSION

This systematic review demonstrates that pediatric thyroid malignancies, despite often presenting at an advanced stage, yield excellent remission and survival rates through contemporary, risk-adapted strategies centered on neck ultrasonography, fine-needle aspiration biopsy for diagnosis, and surgical management (primarily total thyroidectomy) supplemented by radioactive iodine and thyroid-stimulating hormone suppression in intermediate- and high-risk cases. Recurrence correlates with tumor features like multifocality, bilaterality, and lymph node involvement, while complications remain rare, supporting multidisciplinary approaches that prioritize oncologic control alongside minimizing long-term morbidity in low-risk patients. A recommendation for future research includes conducting prospective, multicenter studies with standardized outcome measures to enhance evidence quality, refine risk

stratification, and optimize long-term survivorship care focused on growth, quality of life, and guidelines for this population.

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