



Pediatric Surgical Thyroid Disorders: Comprehensive Review of Congenital, Benign, and Malignant Thyroid Disease with Contemporary Advances in Molecular Diagnostics, Precision Surgery, and Survivorship



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Abstract

Background: Thyroid disorders requiring surgical intervention are uncommon in children but represent a unique spectrum of diseases characterized by higher malignancy rates, distinct molecular profiles, and specific perioperative considerations compared with adults.

Objective: To review the epidemiology, clinical presentation, diagnostic evaluation, surgical indications, operative management, complications, and outcomes of pediatric thyroid disorders.

Methods: Narrative review of contemporary literature, international guidelines, and recent studies addressing pediatric thyroid nodules, thyroid cancer, hyperthyroidism, congenital thyroid abnormalities, and thyroidectomy outcomes.

Results: Although thyroid nodules are relatively rare in children, their risk of malignancy is substantially higher than in adults. Differentiated thyroid carcinoma, particularly papillary thyroid carcinoma, remains the most common pediatric thyroid malignancy. Advances in ultrasonography, molecular diagnostics, risk stratification, and surgical techniques have improved outcomes while minimizing morbidity. High-volume multidisciplinary centers consistently demonstrate lower rates of recurrent laryngeal nerve injury and hypoparathyroidism.

Conclusion: Successful management of pediatric thyroid disorders requires multidisciplinary collaboration involving pediatric endocrinologists, pediatric surgeons, endocrine surgeons, radiologists, pathologists, and nuclear medicine specialists. Contemporary management emphasizes individualized surgical care, precision diagnostics, and risk-adapted follow-up.

Keywords: Pediatric Thyroid Surgery; Thyroid Nodules; Papillary Thyroid Carcinoma; Graves' Disease; Congenital Thyroid Disorders; Thyroidectomy; Molecular Diagnostics; RET Fusion; NTRK Fusion; Precision Oncology; Survivorship; Pediatric Endocrine Surgery

Abbreviations

ATA: American Thyroid Association; DTC: Differentiated Thyroid Carcinoma; PTC: Papillary Thyroid Carcinoma; FTC: Follicular Thyroid Carcinoma; MTC: Medullary Thyroid Carcinoma; FNA: Fine Needle Aspiration; TSH: Thyroid Stimulating Hormone; RAI: Radioactive Iodine; RLN: Recurrent Laryngeal Nerve; QoL: Quality of Life; RET: Rearranged during Transfection Proto-oncogene; NTRK: Neurotrophic Tyrosine Receptor Kinase; MEN: Multiple Endocrine Neoplasia

Introduction

Pediatric thyroid disorders encompass a broad spectrum of congenital, inflammatory, benign, and malignant conditions. Although thyroid disease is less common in children than adults, its clinical significance is substantial because of its effects on growth, development, metabolism, cognition, and long-term health [1].

The incidence of pediatric thyroid nodules has increased steadily over the past two decades, primarily due to increased use of ultrasonography and cross-sectional imaging [2]. Importantly, thyroid nodules in children carry a significantly higher risk of malignancy compared with adults, making accurate risk assessment critical [3].

Differentiated Thyroid Carcinoma (DTC) accounts for the majority of pediatric thyroid malignancies, with Papillary Thyroid Carcinoma (PTC) representing the predominant subtype [4]. Despite presenting more frequently with multifocal disease, lymph node metastases, and pulmonary involvement than adult counterparts, pediatric thyroid cancers exhibit excellent long-term survival exceeding 98% [1].

Recent developments in ultrasound-based risk stratification, molecular testing, precision medicine, targeted therapies, and refinement of surgical approaches have transformed the management landscape [4, 5].

This review summarizes current concepts in pediatric surgical thyroid disorders, emphasizing evidence-based evaluation, operative management, and outcomes.

Materials and Methods

A narrative review methodology was used. Literature sources included: PubMed, Scopus, Web of Science, American Thyroid Association guidelines and Recent pediatric endocrine surgery literature.

The review focused primarily on contemporary publications from 2020-2026 addressing: Thyroid nodules, Pediatric differentiated thyroid carcinoma, Hyperthyroidism, Thyroidectomy outcomes, Molecular diagnostics and Emerging management strategies

Epidemiology

Thyroid nodules are considerably less common in children than adults, with prevalence estimates ranging between 0.05% and 1.8% [6].

Key epidemiological observations include: Female predominance after puberty, increasing incidence during adolescence, Higher malignancy rates than adults, Greater frequency in patients exposed to radiation and Increased risk in familial cancer syndromes.

Recognized risk factors include: Previous head and neck irradiation, Family history of thyroid cancer, Autoimmune thyroiditis, Genetic syndromes and Iodine imbalance [1, 6].

Classification of pediatric surgical thyroid disorders

Benign conditions:

Thyroid Nodules: Most benign nodules include: Colloid nodules, Hyperplastic nodules, and Follicular adenomas

Multinodular Goiter.

May occur due to: Iodine deficiency, Autoimmune thyroid

disease, and Dysmorphogenesis.

Graves' disease: Surgery is occasionally indicated in: Medication failure, Medication intolerance, large goiters, and Patient preference.

Thyroglossal duct and developmental abnormalities: Although not true thyroid diseases, ectopic thyroid tissue and developmental anomalies may mimic thyroid pathology.

Malignant conditions:

Papillary Thyroid Carcinoma (PTC)

Accounts for approximately 90% of pediatric thyroid cancers [4].

Follicular Thyroid Carcinoma (FTC)

Less common than PTC.

Medullary Thyroid Carcinoma (MTC)

Often associated with: MEN2 syndromes, and RET mutations.

Rare Tumors: Poorly differentiated carcinoma, Anaplastic carcinoma, and Primary thyroid lymphoma

Clinical presentation

Most pediatric thyroid nodules present as: Asymptomatic neck masses, Incidental ultrasound findings and Family-discovered swellings.

Features suggesting malignancy include: Rapid growth, Firm consistency, Cervical lymphadenopathy, Vocal cord paralysis, Prior radiation exposure, and Family history of thyroid carcinoma [1].

Diagnostic evaluation

Laboratory assessment:

Recommended investigations include: TSH, Free T4, Thyroid antibodies and Calcitonin (selected cases)

Suppressed TSH may indicate autonomous nodules requiring scintigraphy [7].

Ultrasonography: Ultrasound remains the primary imaging modality [1].

Suspicious features include: Hypoechogenicity, Irregular margins, Microcalcifications, Increased vascularity, Extrathyroidal extension, and Abnormal lymph nodes.

Fine needle aspiration cytology: FNA is recommended for: Nodules ≥ 1 cm with suspicious features, and smaller nodules with high-risk characteristics.

The Bethesda reporting system is widely used [1].

Molecular testing

Recent advances allow assessment of: BRAF mutations, RET fusions, NTRK fusions, and RAS mutations.

Molecular diagnostics increasingly influence surgical planning and risk stratification [1, 4].

Surgical management

Indications for surgery

Surgical intervention is indicated for:

Benign disease: Large symptomatic nodules, Suspicious cytology, Autonomous nodules, and Graves' disease.

Table 1: Classification of pediatric surgical thyroid disorders. The table summarizes the spectrum of pediatric thyroid conditions requiring surgical evaluation or intervention, categorized into congenital, benign, and malignant disorders. Congenital lesions include developmental abnormalities resulting from aberrant thyroid embryogenesis, whereas benign and malignant lesions encompass inflammatory, functional, nodular, and neoplastic diseases. This classification provides a clinically relevant framework for diagnosis, risk stratification, and treatment planning.

Category	Disorder	Clinical Features	Surgical Relevance
Congenital	Ectopic thyroid	Lingual or ectopic thyroid tissue, hypothyroidism, dysphagia	Excision only if symptomatic
	Thyroglossal duct remnant	Midline neck swelling, infection	Sistrunk procedure
	Congenital goiter	Neck mass, airway compromise	Rarely requires surgery
	Thyroid agenesis/hypoplasia	Congenital hypothyroidism	Usually managed medically
Benign	Hashimoto thyroiditis	Goiter, hypothyroidism, nodularity	Surgery for suspicious nodules or compression
	Graves disease	Hyperthyroidism, diffuse goiter	Total thyroidectomy for selected patients
	Solitary thyroid nodule	Neck mass	Requires malignancy evaluation
	Multinodular goiter	Multiple thyroid nodules	Surgery for symptoms or suspicion
	Follicular adenoma	Benign neoplasm	Diagnostic lobectomy often required
Malignant	Papillary thyroid carcinoma	Most common thyroid cancer	Total thyroidectomy ± neck dissection
	Follicular thyroid carcinoma	Hematogenous spread	Thyroidectomy
	Medullary thyroid carcinoma	RET-associated tumor	Early definitive surgery
	Rare thyroid malignancies	Lymphoma, poorly differentiated carcinoma	Individualized management

RET: Rearranged during Transfection proto-oncogene

Table 2: Major molecular alterations identified in pediatric thyroid carcinoma and their clinical significance. RET and NTRK gene fusions are more frequently observed in pediatric thyroid cancer than in adults and are associated with distinct biological behavior and potential therapeutic implications. BRAF and RAS alterations occur less commonly but may assist in risk stratification, prognostication, and selection of targeted therapies. Molecular profiling has become increasingly important in precision medicine and individualized surgical decision-making. Approach to the Pediatric Patient with Thyroid Nodules and Evolving trends in pediatric thyroid nodules and cancer management highlight the growing role of molecular diagnostics in pediatric thyroid oncology.

Molecular Alteration	Frequency in Children	Clinical Significance	Targeted Therapy
RET fusion	High	Multifocal disease, nodal metastasis	Selpercatinib, pralsetinib
NTRK fusion	High	Advanced disease, pulmonary metastasis	Larotrectinib, entrectinib
BRAF V600E	Lower than adults	Classical PTC, possible recurrence risk	BRAF inhibitors
RAS mutation	Occasional	Follicular-pattern lesions	Under investigation
ALK fusion	Rare	Aggressive tumors	ALK-targeted therapy
TERT promoter mutation	Very rare	Poor prognosis	Prognostic marker

PTC: Papillary Thyroid Carcinoma; RET: Rearranged during Transfection; NTRK: Neurotrophic Tyrosine Receptor Kinase; ALK: Anaplastic Lymphoma Kinase

Malignant disease: Proven carcinoma, highly suspicious patients. cytology, and significant growth.

Thyroid lobectomy

Appropriate for: Solitary benign lesions, Selected follicular neoplasms, and Diagnostic purposes.

Advantages include: Lower risk of hypoparathyroidism and Lower recurrent laryngeal nerve injury risk.

Total thyroidectomy

Indicated for: Most pediatric papillary thyroid carcinomas, Bilateral disease, Multifocal disease, and Genetic syndromes.

Because pediatric DTC frequently exhibits multifocality, total thyroidectomy remains common [4].

Lymph node dissection

Central neck dissection: Recommended in selected patients with: Documented nodal disease and High-risk tumors.

Lateral neck dissection: Reserved for proven metastatic disease.

Graves' Disease

Surgical management remains important in selected pediatric

Indications include: Poor medication compliance, Major adverse drug reactions, large goiters, and Ophthalmopathy.

Total thyroidectomy is generally preferred due to lower recurrence rates.

Perioperative considerations

Important strategies include:

Preoperative: Vocal cord assessment, Calcium levels and Vitamin D optimization.

Intraoperative: Recurrent laryngeal nerve monitoring, Identification of parathyroid glands, and Hemostasis optimization.

Postoperative: Calcium monitoring, Vocal cord assessment and Endocrinology follow-up.

Outcomes

Pediatric thyroid surgery generally yields excellent results when performed in experienced centers.

Benefits include: Disease control, Excellent survival and Reduced recurrence.

Table 3: Comparison of clinical characteristics and outcomes between pediatric and adult differentiated thyroid carcinoma. Pediatric patients commonly present with a higher frequency of multifocal disease, cervical lymph node metastases, and pulmonary spread compared with adults. Despite more advanced disease at diagnosis and higher recurrence rates, pediatric patients demonstrate superior disease-specific survival and excellent long-term outcomes. These biological and clinical differences support pediatric-specific diagnostic, surgical, and surveillance strategies. Paediatric thyroid lesions: lessons from recent guidelines; Approach to the Pediatric Patient with Thyroid Nodules.

Variable	Pediatric Patients	Adult Patients
Thyroid nodule prevalence	Lower	Higher
Malignancy risk within nodules	20–30%	5–10%
Multifocal disease	More common	Less common
Bilateral disease	More common	Less common
Cervical lymph node metastasis	Higher frequency	Lower frequency
Pulmonary metastasis	More common	Less common
RET/NTRK fusions	More common	Less common
BRAF mutation prevalence	Lower	Higher
Recurrence rates	Higher	Lower
Disease-specific mortality	Lower	Higher
30-year survival	>98%	Slightly lower
Lifelong surveillance requirement	Essential	Risk-adapted

Long-term survival for pediatric differentiated thyroid carcinoma exceeds 98% [1].

Complications

Hypocalcemia: Most common complication., Temporary: 5-30%, Permanent: <5% in experienced centers.

Recurrent Laryngeal Nerve Injury: Can cause: Hoarseness, Aspiration and Airway compromise. Permanent injury is uncommon.

Hematoma: Rare but potentially life-threatening.

Discussion

Pediatric thyroid surgery has evolved substantially over recent years. Historically, management strategies were largely extrapolated from adult thyroid disease. Contemporary evidence demonstrates important biological, clinical, and molecular distinctions requiring pediatric-specific approaches [4, 6].

One of the most significant observations is the paradox of pediatric

differentiated thyroid carcinoma. Although children frequently present with advanced locoregional disease and distant metastases, overall disease-specific survival remains exceptionally favorable [1, 4]. This finding has stimulated efforts to balance oncologic completeness with minimization of treatment-related morbidity.

Ultrasound risk stratification and FNA remain cornerstones of evaluation [1]. Increasing use of molecular diagnostics, including identification of RET and NTRK fusions, allows more personalized surgical planning and has expanded opportunities for targeted therapies in refractory disease [4].

Recent literature supports individualized surgical decision-making rather than universally aggressive surgery. While total thyroidectomy remains standard for many patients, carefully selected children may benefit from less extensive surgery without compromising outcomes [4].

Another major development involves concentration of care within high-volume centers. Numerous studies demonstrate reduced complication rates, improved preservation of recurrent laryngeal nerve function, lower permanent hypoparathyroidism rates, and improved overall outcomes when procedures are performed by experienced multidisciplinary teams [5].

Emerging concepts include: Precision oncology, Molecular risk stratification, AI-assisted ultrasound interpretation, Targeted kinase inhibitor therapy and Risk-adapted surveillance.

Collectively, these advances are moving pediatric thyroid surgery toward a precision medicine paradigm.

Clinical Significance

This review provides a comprehensive pediatric surgery perspective on thyroid disease, integrating: Congenital thyroid disorders, Benign surgical thyroid disease, Pediatric thyroid malignancies, Molecular diagnostics, Precision medicine, Pediatric versus adult outcome comparisons, TSH suppression strategies, Recurrence patterns, Psychosocial outcomes, and Survivorship and quality-of-life considerations.

The review aims to provide clinicians with a contemporary evidence-based framework for the diagnosis and management of pediatric surgical thyroid disorders.

Table 4: Age-related recurrence patterns, surveillance strategies, and survivorship considerations in pediatric thyroid cancer. Younger children frequently present with more extensive disease and may experience both early and late recurrences, necessitating lifelong surveillance. The table outlines recommended follow-up approaches, including thyroglobulin monitoring, neck ultrasonography, thyroid-stimulating hormone suppression, quality-of-life assessment, and psychosocial support. Particular attention is given to transition-of-care programs and survivorship issues relevant to adolescents and young adults. Evolving trends in pediatric thyroid nodules and cancer management; Approach to the pediatric patient with thyroid nodules.

Variable	Young Children (<10 yr)	Adolescents (10-18 yr)	Adults
Initial disease extent	Highest	Intermediate	Lower
Cervical nodal metastases	Common	Common	Less common
Pulmonary metastases	More common	Less common	Rare
Recurrence timing	Early and late recurrences	Mostly within 5–10 years	Primarily first decade
Lifetime recurrence risk	Highest	High	Lower
Surveillance duration	Lifelong	Lifelong	Risk-adapted
TSH suppression impact	Moderate	Most significant	Variable
Quality-of-life concerns	Family burden	Education, body image, transition care	Work and comorbidities
Long-term survival	Excellent	Excellent	Excellent but comparatively lower

Table 5: Risk-adapted surveillance recommendations following pediatric thyroidectomy for differentiated thyroid carcinoma. The table summarizes a practical follow-up framework based on contemporary pediatric thyroid cancer surveillance principles. Early follow-up emphasizes detection of persistent disease through clinical evaluation, serum thyroglobulin measurement, anti-thyroglobulin antibody assessment, thyroid-stimulating hormone monitoring, and neck ultrasonography. Long-term surveillance is individualized according to initial risk stratification, treatment response, molecular characteristics, and recurrence risk. Because pediatric patients have a longer life expectancy and a higher cumulative lifetime recurrence risk than adults, lifelong follow-up remains an essential component of care. Recent pediatric management approaches increasingly support dynamic risk stratification and response-to-therapy monitoring rather than fixed surveillance schedules.

Time After Surgery	Clinical Assessment	Laboratory Tests	Imaging
0-6 months	Physical examination	TSH, Free T4, Thyroglobulin	Neck ultrasound if indicated
6-24 months	Every 6 months	TSH, Thyroglobulin, Anti-Tg antibodies	Annual neck ultrasound
2-5 years	Annual review	TSH, Thyroglobulin	Risk-adapted ultrasound
5-10 years	Annual review	TSH, Thyroglobulin	Selective imaging
>10 years	Lifelong follow-up	TSH ± Thyroglobulin	Risk-adapted surveillance

TSH: Thyroid-Stimulating Hormone; Tg: Thyroglobulin; Anti-Tg: Anti-Thyroglobulin Antibodies

Table 6: Long-term quality-of-life considerations and survivorship challenges among pediatric thyroid cancer survivors. Although disease-specific survival exceeds 98%, survivors may face lifelong endocrine, psychological, social, and healthcare-transition issues. Potential challenges include long-term levothyroxine therapy, TSH-suppression-related symptoms, anxiety regarding recurrence, educational disruption, body image concerns associated with cervical scars, adherence difficulties during adolescence, and the need for structured transition from pediatric to adult endocrine services. Modern survivorship programs emphasize multidisciplinary care, psychosocial support, quality-of-life assessment, endocrine optimization, and lifelong monitoring to minimize treatment-related burden while maintaining excellent oncologic outcomes. Pediatric thyroid cancer survivorship therefore focuses not only on disease control but also on preserving physical, psychological, social, and educational wellbeing throughout adulthood.

Domain	Potential Issues	Management Strategies
Endocrine	Lifelong thyroxine replacement	Endocrinology follow-up
TSH suppression	Palpitations, insomnia, anxiety	Risk-adapted targets
Education	School absence, concentration issues	School support plans
Psychological	Fear of recurrence, surveillance anxiety	Counseling services
Social	Body image concerns, neck scar visibility	Psychosocial support
Transition care	Loss to follow-up	Structured transition clinics
Long-term survivorship	Lifelong monitoring burden	Survivorship programs
Family impact	Parental anxiety	Family-centered education

QoL: Quality of Life; TSH: Thyroid-Stimulating Hormone

Conclusion

Pediatric thyroid disorders requiring surgery encompass diverse benign and malignant conditions. Although thyroid nodules are uncommon in children, their higher malignant potential necessitates careful evaluation. Advances in imaging, molecular diagnostics, surgical techniques, and multidisciplinary care have significantly improved outcomes.

Future directions include incorporation of molecular profiling, targeted therapies, AI-assisted diagnostics, and personalized surgical approaches. Management within specialized pediatric endocrine and surgical centers remains essential for optimizing outcomes while minimizing treatment-related morbidity.

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