Imaging of Pediatric Thyroid Tumors: A COG Diagnostic Imaging Committee/SPR Oncology Committee White Paper

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August 12, 2022

Abstract

Pediatric thyroid cancer is rare in children, however incidence is increasing. Papillary thyroid cancer and follicular thyroid cancer are the most common subtypes, comprising about 90% and 10% of cases respectively. This manuscript provides consensus imaging recommendations for evaluation of pediatric patients with thyroid cancer at diagnosis and during follow-up.

Introduction

Thyroid cancer is relatively rare in children and adolescents, accounting for only 1.8% of the total thyroid cancers diagnosed in the United States annually, but the incidence is increasing.[1-4] Female predominance of thyroid cancer increases with age, approximating a 6:1 female to male ratio by age 15 to 19 years, making thyroid cancer the second most common malignancy in this age/gender group.[1,5] In children, thyroid cancer may be asymptomatic and discovered incidentally at imaging for another purpose, or may present as a painless palpable thyroid mass, neck mass related to cervical lymphadenopathy, difficulty breathing, and/or hoarseness[6]

Thyroid cancer in children is classified into differentiated, poorly differentiated, and medullary subtypes. Subtypes of differentiated thyroid cancer include papillary thyroid cancer (PTC) and follicular thyroid cancer

(FTC) subtypes. PTC is most common, accounting for up to 90%, and is further subdivided into classical, follicular, solid, and diffuse sclerosing variants.[1,2] FTC accounts for up to 10% of thyroid cancer.[2]

Risk factors for developing PTC and FTC include autoimmune thyroid disease (i.e. Hashimoto's thyroiditis and Graves' disease), iodine deficiency, and prior therapeutic radiation exposure.[6,7] Genetic predisposition syndromes including APC-associated polyposis, *DICER1* syndrome, Carney Complex, PTEN hamartoma syndrome, and Werner syndrome may account for up to 5% of differentiated thyroid cancers.[6,7]Additionally, Li-Fraumeni, Peutz-Jeghers, familial paraganglioma, McCune-Albright, and Beckwith-Wiedemann syndromes are also associated with an increased risk of differentiated thyroid cancer.[7] Genetic mutations of the *BRAF, RET/PTC, ALK* , *RAS,* and *ΠΑΞ8/ΠΠΑΡγ* genes play a role in thyroid cancer pathogenesis.[4,8] The*RET/PTC* genetic rearrangement is relatively more common in children compared to adult thyroid cancers, while *BRAF* mutations are less commonly encountered in children than adults with PTC.[6,9] Finally, thyroid cancer is one of the most common secondary malignancies in childhood cancer survivors.[7,10]

Poorly differentiated and medullary thyroid cancers are rare in the pediatric population.[7] Most medullary thyroid carcinomas are hereditary, related to germline *RET* mutations causing multiple endocrine neoplasia (MEN) type 2A, MEN 2B, or familial medullary thyroid carcinoma (FMTC) and incidence is highest in the 0 to 4 year age group.[1,2,7]

In children, thyroid nodules occur in 0.5-5% of the population, however, there is a 19-25% rate of malignancy, highlighting the importance of nodule identification.[11-13] Compared to adults, children with thyroid cancer are more likely to present with larger tumor size and extrathyroidal extension.[9,14]Children also have increased rates of regional lymph node and pulmonary metastasis compared to adults, at 60-80% and 10-25% respectively.[9,14] However, despite more extensive disease at presentation, the mortality rate from thyroid cancer is lower in children than adults, with overall survival of 95% at 20 years in children.[9,14]

Imaging in Tumor Staging

The American Joint Committee on Cancer (AJCC) and Union International Contre le Cancer (UICC) Tumor-Node-Metastasis (TNM) staging system is recommended for pediatric thyroid carcinoma (GRADE: A; SOR: 1.21, very strong recommendation). Use of this post-operative staging system is recommended by the American Thyroid Association (ATA).[9] The AJCC/UICC-TNM staging system incorporates size of tumor and extrathyroidal extension, regional lymph node status, and distant metastasis, and its main purpose is to define an anatomic-based classification of the extent of disease, to guide further management (Table 1).

Based on the AJCC/UICC-TNM classification system, ATA guidelines classify children with thyroid carcinoma into risk groups (Table 2).**Stratification of patients into ATA risk groups is recommended as this allows estimation of disease-free survival (Table 2), identifies patients at risk for residual/persistent cervical lymphadenopathy, and guides further management by identifying patients that may require further imaging to define distant metastasis and that may require^{131}I therapy.** (GRADE: B; SOR 1.36, very strong recommendation)

Imaging Modalities

Ultrasound is the cornerstone of imaging thyroid cancer, and plays a role in diagnosis, staging, operative planning, and disease monitoring in pediatric patients.[15] The advantages of ultrasound are that it is portable, can be performed quickly, is cost-effective, and requires no patient preparation and no sedation or anesthesia.[16] The high spatial resolution and ability to detect microcalcifications as a finding of tumor are additional advantages, and ultrasound is superior to other imaging modalities at characterizing thyroid nodules.[17] The primary disadvantage of ultrasound is that it is operator-dependent, and screening for cervical nodal metastatic disease requires experience and meticulous technique.

Computed tomography (CT) may play a role in imaging locoregional metastatic disease as well as pulmonary metastases. However, use of iodinated IV contrast material is discouraged because it interferes with radioactive iodine (RAI) uptake, and if RAI therapy is deemed necessary, treatment must be delayed for weeks to

3 months. CT scanning parameters should be optimized for patient size to minimize radiation exposure. Additionally, sedation or anesthesia may be required to achieve breath-holds necessary to detect miliary pulmonary metastases in patients unable to comply with breath holding instructions.

Magnetic resonance imaging (MRI) in patients with thyroid cancer is primarily used in the evaluation of bulky cervical metastatic disease and extrathyroidal invasion.[18] Although the spatial resolution of MRI is lower than both ultrasound and CT, the tissue contrast resolution is higher. However, punctate calcifications relevant to identifying disease are not apparent by MRI. MRI examinations are lengthy, which may require use of sedation or anesthesia to ensure patient immobility.

RAI scintigraphy capitalizes on the physiologic uptake of iodine by most differentiated thyroid cancers and may be used in post-surgical disease staging. ^{18}F-FDG PET/CT is not typically used but may play a role in the evaluation of undifferentiated tumors that are not iodine avid. ^{68}Ga-DOTATATE PET/CT may be useful for medullary thyroid cancer disease evaluation.[19]

Imaging at Diagnosis

High resolution ultrasound of the thyroid and neck with a high frequency (12-18 MHz) linear transducer is recommended as the primary imaging modality for tumor diagnosis. (GRADE: A; SOR 1.07, very strong recommendation) This enables evaluation of the morphologic features of the thyroid nodule as well as location within the thyroid, evaluation for extrathyroidal extension, and involvement of important adjacent anatomic structures, which may impact management.

At ultrasound, there are both pattern-based and point-based risk stratification guidelines that have been evaluated in both adults and children to differentiate benign and malignant thyroid nodules.[9,12,16,20-25] Generally, features such as solid composition, taller than wide orientation, irregular margins, microcalcifications or punctate echogenic foci, and extrathyroidal extension are considered suspicious for malignancy. It is important to recognize intrathyroidal ectopic thymic tissue at ultrasound, which appears as a hypoechoic nodule with linear and punctate echogenic foci, is unique to children, and should not be mistaken for PTC.[26,27] Although color Doppler may be useful for distinguishing solid components from debris in nodules and may be useful to predict bleeding risk during fine-needle aspiration (FNA), Doppler pattern appears to be less helpful in determining malignancy than grayscale appearance.[28,29] **An important distinction between adult and pediatric guidelines is the size threshold to guide FNA decisions. Although adult guidelines specify nodule size cut-offs to proceed to FNA, in children, size thresholds are not recommended in the decision-making process, but rather the ultrasound appearance is prioritized and a lower threshold to proceed with further diagnostic work-up recommended, particularly in children with risk factors.** [5,9,12,16,23,30] (GRADE: B; SOR 1.64, strong recommendation) This is because in adults, the goal of imaging is not to diagnose every thyroid malignancy, but to balance the benefit of identifying clinically significant cancers against the cost of subjecting patients with benign nodules or indolent cancers to unnecessary treatment.[20,31]

Ultrasound lymph node mapping of the neck with a meticulous evaluation of lymph node levels in the central neck (level 6), lateral neck (levels 1-5), and mediastinum (level 7) is required because PTC metastasizes to regional lymph nodes in most children. [9] (GRADE: B; SOR 1.57, strong recommendation) Ultrasound is highly sensitive and specific for predicting cervical lymph node metastasis preoperatively.[32] Preoperative suspicion of locoregional metastatic disease is important to plan an appropriate, compartment-oriented lymph node dissection at the time of initial surgery.[6] Preoperative ultrasound has been shown to improve surgical outcome, decrease rate of recurrence or need for more surgeries, and to guide further medical therapy.[33-35]

Ultrasound guidance is recommended for FNA of the thyroid nodule, targeted to the solid or most suspicious component of the nodule to provide the highest diagnostic yield specimen. (GRADE: A; SOR 1.28, very strong recommendation) **Ultrasound guidance is also recommended to guide FNA of suspicious lymph nodes, if needed preoperatively to plan lymph node dissection approach.** [9] (GRADE: B; SOR 1.93, strong recommendation) Ultrasound-guided FNA is both sensitive

and specific to diagnose pediatric thyroid cancer. Without ultrasound guidance, rates of non-diagnostic and false negative thyroid nodule cytologic results are higher.[9,16]

CT or MRI of the neck is not routinely recommended, but is reserved for select cases where bulky lymphadenopathy or large tumor burden can hinder ultrasound visualization of the deep compartments of the neck (levels 6 and 7, retropharyngeal, and supraclavicular regions) or if local invasion is suspected.[18,36] Neck CT requires iodinated IV contrast material injection to adequately visualize anatomy, and therefore is not recommended. Neck CT without IV contrast is not recommended. **Therefore, neck MRI is preferred over CT in the evaluation of the extent of bulky cervical metastatic disease prior to surgery.** (GRADE C; SOR 2.0, moderate recommendation)

Although current ATA guidelines recommend either chest radiographs or CT in intermediate and high-risk patients to evaluate for pulmonary metastatic disease, CT is the most sensitive imaging modality for this purpose.[37] Therefore, **CT of the chest without IV contrast should be performed in initial staging to detect pulmonary metastases in patients in the ATA Intermediate and High-Risk categories.** (GRADE: C; SOR 1.92, strong recommendation) **Chest CT is not routinely recommended in patients categorized as Low-Risk.**(GRADE: C; SOR 1.86, strong recommendation) While intravenous contrast material can improve detection of mediastinal and hilar lymphadenopathy in the chest, pulmonary metastases can be detected without IV contrast. Axial imaging with 3 mm or smaller slice thickness complemented by coronal and sagittal reconstructions is recommended, with maximal intensity projections (MIPs). Use of MIPs has been shown to improve the detection of small pulmonary nodules.[38]

Imaging Post-Thyroidectomy

Whole-body RAI scintigraphy with ^{123}I is recommended within 12 weeks following surgery for postoperative staging in ATA Intermediate and High-Risk patients to detect residual locoregional disease and distant metastasis [37] in order to identify patients who may benefit from additional surgery or RAI for remnant ablation or therapy.[39] (GRADE A; SOR 1.07, very strong recommendation) ^{123}I is preferred due to superior imaging resolution, the ability to utilize single photon emission computed tomography with integrated conventional CT (SPECT/CT), and slightly lower dose to the patient, however higher cost may be prohibitive. In such cases, ^{131}I remains an acceptable alternative. While planar imaging is generally used for whole-body RAI scintigraphy, the addition of targeted SPECT/CT when focal abnormal uptake is identified offers improved disease localization and characterization.[9] **Therefore, when focal RAI uptake is identified on planar imaging, SPECT/CT is recommended.** (GRADE C; SOR 2.36, moderate recommendation).

Imaging Off Therapy/Surveillance

Six months postoperatively, all patients without evidence of active disease should undergo surveillance imaging with neck ultrasound, including the surgical bed, central and lateral neck, and upper mediastinum. [9] (GRADE C; SOR 2.0, moderate recommendation) For patients in the ATA pediatric low risk level, ultrasound surveillance should be performed annually for 5 years. In both the ATA pediatric Intermediate and High-Risk groups, ultrasound surveillance should be performed every 6-12 months for 5 years. Neck ultrasound can continue less frequently after 5 years for the intermediate and high-risk levels based on individual recurrence risk.[9] Thyroglobulin levels can be useful to guide imaging assessment as a marker of residual or recurrent disease and are performed at similar time points.

^{123}I-diagnostic whole-body scan is recommended in patients treated with RAI at 1-2 years following therapy. (GRADE C; SOR 1.36, very strong recommendation)**^{123}I-diagnostic whole-body scan is also recommended in patients with increasing thyroglobulin levels or with concern for recurrence at other imaging.** [9] (GRADE A; SOR 1.07, very strong recommendation) Table 3 details timing of imaging surveillance.

Are there late effects that change the goal of surveillance imaging?

Differentiated thyroid cancer recurrence has been reported several decades after initial treatment, therefore

long-term surveillance is necessary.[9] In addition, relative risk of a secondary primary malignancy, most commonly leukemia, is increased in those treated with RAI.[39-43]

Advancements in imaging

Novel ultrasound techniques may prove useful in the future for both the diagnosis and follow-up of children with thyroid cancer but are not currently standard of care. Ultrasound elastography is a non-invasive method to evaluate the stiffness of tissue. Its use has been studied in adults and shown to increase the sensitivity and negative predictive value in the assessment of thyroid nodules for malignancy.[44] Ultrasound elastography may also be useful in the future to help distinguish benign from malignant cervical lymph nodes.[45] However, further study is needed in children.[25]

Contrast-enhanced ultrasound (CEUS) is another newer ultrasound technique that uses the IV administration of an ultrasound contrast agent to assess enhancement features. CEUS has been shown to increase the accuracy of thyroid nodule diagnosis in adults, particularly when combined with grayscale ultrasound features.[46,47]Confirmatory studies of its utility in children with thyroid nodules are needed.

Conflict of Interest statement:

Jennifer E. Lim-Dunham. Consultant, Koios Medical, NY, NY (2020-2021).

Andrew T. Trout. Related disclosures: none. Unrelated disclosures: Investigator initiated grant support, Siemens Healthineers. Investigator initiated grant support, Canon Medical Systems. Consulting, Lantheus. Royalties (authorship), Elsevier, Wolters-Kluwer.

The following authors report no conflict of interest:

Judy H. Squires, Claudia Martinez-Rios, James C. Davis, Kelly R. Dietz, Monica S. Epelman, Hollie A. Lai, Janice D. McDaniel, Joyce C. Mhlanga, Neeta Pandit-Taskar, Marguerite T. Parisi, Elizabeth K. Weidman, Adina L. Alazraki

Acknowledgements : This manuscript was funded in part by the National Clinical Trials Network Operations Center Grant U10CA180886.

References:

1. SEER Cancer Statistics Review, 1975-2017. Accessed October 1, 2021, seer.cancer.gov/archive/csr/1975_-2017/results_merged/sect_26_thyroid.pdf

2. Dermody S, Walls A, Harley EH, Jr. Pediatric thyroid cancer: An update from the SEER database 2007-2012. *Int J Pediatr Otorhinolaryngol* . Oct 2016;89:121-6. doi:10.1016/j.ijporl.2016.08.005

3. Golpanian S, Perez EA, Tashiro J, Lew JI, Sola JE, Hogan AR. Pediatric papillary thyroid carcinoma: outcomes and survival predictors in 2504 surgical patients. *Pediatr Surg Int* . Mar 2016;32(3):201-8. doi:10.1007/s00383-015-3855-0

4. Qian ZJ, Jin MC, Meister KD, Megwalu UC. Pediatric Thyroid Cancer Incidence and Mortality Trends in the United States, 1973-2013.*JAMA Otolaryngol Head Neck Surg* . Jul 1 2019;145(7):617-623. doi:10.1001/jamaoto.2019.0898

5. Ahmad H, Al-Hadidi A, Bobbey A, et al. Pediatric adaptions are needed to improve the diagnostic accuracy of thyroid ultrasound using TI-RADS.*J Pediatr Surg* . Jun 2021;56(6):1120-1125. doi:10.1016/j.jpedsurg.2021.02.034

6. Chan CM, Young J, Prager J, Travers S. Pediatric Thyroid Cancer.*Adv Pediatr* . Aug 2017;64(1):171-190. doi:10.1016/j.yapd.2017.03.007

7. Paulson VA, Rudzinski ER, Hawkins DS. Thyroid Cancer in the Pediatric Population. *Genes (Basel)* . Sep 18 2019;10(9)doi:10.3390/genes10090723

8. Karapanou O, Tzanela M, Vlassopoulou B, Kanaka-Gantenbein C. Differentiated thyroid cancer in childhood: a literature update.*Hormones (Athens)* . Oct 2017;16(4):381-387. doi:10.14310/horm.2002.1758

9. Francis GL, Waguespack SG, Bauer AJ, et al. Management Guidelines for Children with Thyroid Nodules and Differentiated Thyroid Cancer.*Thyroid* . Jul 2015;25(7):716-59. doi:10.1089/thy.2014.0460

10. Bhatti P, Veiga LH, Ronckers CM, et al. Risk of second primary thyroid cancer after radiotherapy for a childhood cancer in a large cohort study: an update from the childhood cancer survivor study.*Radiat Res* . Dec 2010;174(6):741-52. doi:10.1667/RR2240.1

11. Polat YD, Ozturk VS, Ersoz N, Anik A, Karaman CZ. Is Thyroid Imaging Reporting and Data System Useful as an Adult Ultrasonographic Malignancy Risk Stratification Method in Pediatric Thyroid Nodules? *J Med Ultrasound* . Jul-Sep 2019;27(3):141-145. doi:10.4103/JMU.JMU_35_19

12. Richman DM, Benson CB, Doubilet PM, et al. Assessment of American College of Radiology Thyroid Imaging Reporting and Data System (TI-RADS) for Pediatric Thyroid Nodules. *Radiology* . Feb 2020;294(2):415-420. doi:10.1148/radiol.2019191326

13. Uner C, Aydin S, Ucan B. Thyroid Image Reporting and Data System Categorization: Effectiveness in Pediatric Thyroid Nodule Assessment.*Ultrasound Q* . Mar 2020;36(1):15-19. doi:10.1097/RUQ.0000000000000476

14. Parisi MT, Eslamy H, Mankoff D. Management of Differentiated Thyroid Cancer in Children: Focus on the American Thyroid Association Pediatric Guidelines. *Semin Nucl Med* . Mar 2016;46(2):147-64. doi:10.1053/j.semnuclmed.2015.10.006

15. Brauckhoff K, Biermann M. Multimodal imaging of thyroid cancer.*Curr Opin Endocrinol Diabetes Obes* . Oct 2020;27(5):335-344. doi:10.1097/MED.0000000000000574

16. Haugen BR, Alexander EK, Bible KC, et al. 2015 American Thyroid Association Management Guidelines for Adult Patients with Thyroid Nodules and Differentiated Thyroid Cancer: The American Thyroid Association Guidelines Task Force on Thyroid Nodules and Differentiated Thyroid Cancer. *Thyroid* . Jan 2016;26(1):1-133. doi:10.1089/thy.2015.0020

17. Grant EG, Tessler FN, Hoang JK, et al. Thyroid Ultrasound Reporting Lexicon: White Paper of the ACR Thyroid Imaging, Reporting and Data System (TIRADS) Committee. *J Am Coll Radiol* . Dec 2015;12(12 Pt A):1272-9. doi:10.1016/j.jacr.2015.07.011

18. Hoang JK, Branstetter BFt, Gafton AR, Lee WK, Glastonbury CM. Imaging of thyroid carcinoma with CT and MRI: approaches to common scenarios. *Cancer Imaging* . Mar 26 2013;13:128-39. doi:10.1102/1470-7330.2013.0013

19. Tuncel M, Kilickap S, Suslu N. Clinical impact of (68)Ga-DOTATATE PET-CT imaging in patients with medullary thyroid cancer. *Ann Nucl Med* . Sep 2020;34(9):663-674. doi:10.1007/s12149-020-01494-3

20. Tessler FN, Middleton WD, Grant EG, et al. ACR Thyroid Imaging, Reporting and Data System (TI-RADS): White Paper of the ACR TI-RADS Committee. *J Am Coll Radiol* . May 2017;14(5):587-595. doi:10.1016/j.jacr.2017.01.046

21. Creo A, Alahdab F, Al Nofal A, Thomas K, Kolbe A, Pittock ST. Ultrasonography and the American Thyroid Association Ultrasound-Based Risk Stratification Tool: Utility in Pediatric and Adolescent Thyroid Nodules. *Horm Res Paediatr* . 2018;90(2):93-101. doi:10.1159/000490468

22. Lim-Dunham JE, Erdem Toslak I, Alsabban K, et al. Ultrasound risk stratification for malignancy using the 2015 American Thyroid Association Management Guidelines for Children with Thyroid Nodules and Differentiated Thyroid Cancer. *Pediatr Radiol* . Apr 2017;47(4):429-436. doi:10.1007/s00247-017-3780-6

23. Lim-Dunham JE, Toslak IE, Reiter MP, Martin B. Assessment of the American College of Radiology Thyroid Imaging Reporting and Data System for Thyroid Nodule Malignancy Risk Stratification in a

Pediatric Population. *AJR Am J Roentgenol* . Jan 2019;212(1):188-194. doi:10.2214/AJR.18.20099

24. Martinez-Rios C, Daneman A, Bajno L, van der Kaay DCM, Moineddin R, Wasserman JD. Utility of adult-based ultrasound malignancy risk stratifications in pediatric thyroid nodules. *Pediatr Radiol* . Jan 2018;48(1):74-84. doi:10.1007/s00247-017-3974-y

25. Essenmacher AC, Joyce PH, Jr., Kao SC, et al. Sonographic Evaluation of Pediatric Thyroid Nodules. *Radiographics* . Oct 2017;37(6):1731-1752. doi:10.1148/rg.2017170059

26. Frates MC, Benson CB, Dorfman DM, Cibas ES, Huang SA. Ectopic Intrathyroidal Thymic Tissue Mimicking Thyroid Nodules in Children.*J Ultrasound Med* . Mar 2018;37(3):783-791. doi:10.1002/jum.14360

27. Abramson Z, Morin C, Craig S, Helmig S. The Dot-Dash Sign of Intrathyroidal Ectopic Thymus: Implications in the Context of TI-RADS Reporting. *AJR Am J Roentgenol* . Jan 19 2022;doi:10.2214/AJR.21.27223

28. Richman DM, Benson CB, Doubilet PM, et al. Thyroid Nodules in Pediatric Patients: Sonographic Characteristics and Likelihood of Cancer. *Radiology* . Aug 2018;288(2):591-599. doi:10.1148/radiol.2018171170

29. Rosario PW, Silva AL, Borges MA, Calsolari MR. Is Doppler ultrasound of additional value to gray-scale ultrasound in differentiating malignant and benign thyroid nodules? *Arch Endocrinol Metab* . Feb 2015;59(1):79-83. doi:10.1590/2359-3997000000014

30. Lim-Dunham JE. Ultrasound guidelines for pediatric thyroid nodules: proceeding with caution. *Pediatr Radiol* . Jun 2019;49(7):851-853. doi:10.1007/s00247-019-04391-8

31. Welch HG, Doherty GM. Saving Thyroids - Overtreatment of Small Papillary Cancers. *N Engl J Med* . Jul 26 2018;379(4):310-312. doi:10.1056/NEJMp1804426

32. Hwang HS, Orloff LA. Efficacy of preoperative neck ultrasound in the detection of cervical lymph node metastasis from thyroid cancer.*Laryngoscope* . Mar 2011;121(3):487-91. doi:10.1002/lary.21227

33. Gonzalez HE, Cruz F, O'Brien A, et al. Impact of preoperative ultrasonographic staging of the neck in papillary thyroid carcinoma.*Arch Otolaryngol Head Neck Surg* . Dec 2007;133(12):1258-62. doi:10.1001/archotol.133.12.1258

34. Kouvaraki MA, Shapiro SE, Fornage BD, et al. Role of preoperative ultrasonography in the surgical management of patients with thyroid cancer. *Surgery* . Dec 2003;134(6):946-54; discussion 954-5. doi:10.1016/s0039-6060(03)00424-0

35. Stulak JM, Grant CS, Farley DR, et al. Value of preoperative ultrasonography in the surgical management of initial and reoperative papillary thyroid cancer. *Arch Surg* . May 2006;141(5):489-94; discussion 494-6. doi:10.1001/archsurg.141.5.489

36. Iakovou I, Giannoula E, Sachpekidis C. Imaging and Imaging-Based Management of Pediatric Thyroid Nodules. *J Clin Med* . Feb 1 2020;9(2)doi:10.3390/jcm9020384

37. Bal CS, Kumar A, Chandra P, Dwivedi SN, Mukhopadhyaya S. Is chest x-ray or high-resolution computed tomography scan of the chest sufficient investigation to detect pulmonary metastasis in pediatric differentiated thyroid cancer? *Thyroid* . Mar 2004;14(3):217-25. doi:10.1089/105072504773297894

38. Jabeen N, Qureshi R, Sattar A, Baloch M. Diagnostic Accuracy of Maximum Intensity Projection in Diagnosis of Malignant Pulmonary Nodules. *Cureus* . Nov 11 2019;11(11):e6120. doi:10.7759/cureus.6120

39. Parisi MT, Khalatbari H, Parikh SR, Alazraki A. Initial treatment of pediatric differentiated thyroid cancer: a review of the current risk-adaptive approach. *Pediatr Radiol* . Oct 2019;49(11):1391-1403. doi:10.1007/s00247-019-04457-7

40. Albano D, Bertagna F, Panarotto MB, Giubbini R. Early and late adverse effects of radioiodine for pediatric differentiated thyroid cancer. *Pediatr Blood Cancer* . Nov 2017;64(11)doi:10.1002/pbc.26595

41. Sawka AM, Thabane L, Parlea L, et al. Second primary malignancy risk after radioactive iodine treatment for thyroid cancer: a systematic review and meta-analysis. *Thyroid* . May 2009;19(5):451-7. doi:10.1089/thy.2008.0392

42. Marti JL, Jain KS, Morris LG. Increased risk of second primary malignancy in pediatric and young adult patients treated with radioactive iodine for differentiated thyroid cancer. *Thyroid* . Jun 2015;25(6):681-7. doi:10.1089/thy.2015.0067

43. Van Nostrand D. The benefits and risks of I-131 therapy in patients with well-differentiated thyroid cancer. *Thyroid* . Dec 2009;19(12):1381-91. doi:10.1089/thy.2009.1611

44. Zhao CK, Xu HX. Ultrasound elastography of the thyroid: principles and current status. *Ultrasonography* . Apr 2019;38(2):106-124. doi:10.14366/usg.18037

45. Choi YJ, Lee JH, Baek JH. Ultrasound elastography for evaluation of cervical lymph nodes. *Ultrasonography* . Jul 2015;34(3):157-64. doi:10.14366/usg.15007

46. Zhang Y, Zhou P, Tian SM, Zhao YF, Li JL, Li L. Usefulness of combined use of contrast-enhanced ultrasound and TI-RADS classification for the differentiation of benign from malignant lesions of thyroid nodules. *Eur Radiol* . Apr 2017;27(4):1527-1536. doi:10.1007/s00330-016-4508-y

47. Xu Y, Qi X, Zhao X, Ren W, Ding W. Clinical diagnostic value of contrast-enhanced ultrasound and TI-RADS classification for benign and malignant thyroid tumors: One comparative cohort study. *Medicine (Baltimore)* . Jan 2019;98(4):e14051. doi:10.1097/MD.0000000000014051

Table legends

TABLE 1 American Joint Committee on Cancer (AJCC) Tumor-Node-Metastasis (TNM) staging system (8^{th} edition) for differentiated thyroid carcinoma (adapted from reference 9).

TABLE 2 Pediatric thyroid cancer patient risk groups defined by ATA guidelines[9]

TABLE 3 Surveillance imaging timeline based on ATA risk group

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`Tables.docx` available at https://authorea.com/users/500964/articles/581578-imaging-of-pediatric-thyroid-tumors-a-cog-diagnostic-imaging-committee-spr-oncology-committee-white-paper