Thyroid Ultrasound

From Simple to Complex

Alexander N. Sencha
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Editors

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ISBN 978-3-030-14450-0 ISBN 978-3-030-14451-7 (eBook)
https://doi.org/10.1007/978-3-030-14451-7

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Preface

The book is based on our own research and experience in the application of modern multiparametric ultrasound for the diagnosis of thyroid disease. Special attention is paid to the technologies of modern ultrasound beginning with conventional gray-scale examination and Doppler imaging ending with elastography and contrast-enhanced technique. Complex analysis of the diagnostic value of basic and innovative technologies is provided. Ultrasound-guided fine needle puncture biopsy is also reviewed in detail.

Special focus is put on the practical aspects of echography. The characteristic features of the normal thyroid gland are highlighted. Diffuse changes and thyroid lesions are discussed in depth. Close attention is paid to their early detection with special accent to differential diagnosis of thyroid tumors. TIRADS classification as a practical approach to the stratification of the risk of thyroid malignancies is provided. The authors summarized their own experience in utilization of qualitative parameters of compression elastography and quantitative data of shear-wave elastography, and analyzed the possibilities, diagnostic significance, advantages and disadvantages of these methods in diagnosis of thyroid lesions. The role of contrast-enhanced ultrasound in differential diagnosis of thyroid neoplasms is comprehensively discussed based on clarification of tumoral neoangiogenesis. The place of various ultrasound options in algorithms and programs of diagnostic search and differentiation is disputed.

The material is well structured and presented in the form of reference information. It is succinct and comprehensive. The monograph pushes you to think, compare, and analyze. It aims to assist specialists of ultrasound diagnostics, radiologists, endocrinologists, oncologists, surgeons, and general practitioners to systematize their knowledge on the ultrasound diagnosis of thyroid diseases, the principles and techniques of multiparametric ultrasound imaging, contrast ultrasound, and ultrasound guided biopsy. The monograph will be of interest to the wide range of specialists from the beginners in ultrasound diagnostics, students, and residents to experienced radiologists and experts of postgraduate education.

The edition is well illustrated with a large number of echograms, schemes, figures, and tables.

Moscow, Russia — Alexander N. Sencha
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Introduction

The diagnostic capabilities for the diseases of the thyroid gland are constantly being improved due to the development of knowledge and technology. Over the past 20–30 years, ultrasound imaging became the leading modality in the early and differential diagnosis of thyroid abnormalities. Improvement of diagnostic equipment with the emergence of new technologies and modalities makes the work of the ultrasound diagnostician more automated and standardized, effective, and less subjective. However, the obtained results still largely depend on the timeliness and correct choice of effective imaging techniques, and a comprehensive analysis of their data. Adequate diagnostic tactics determine the volume and the cost for the following treatment. Rational sequence of manipulations is important: from simple and low-cost to more complex and less accessible, from non-invasive to minimally invasive, from outpatient to inpatient, from organ-preserving to radical.

In order to manage the diseases properly, it is not enough just to apply the ultrasound probe, but is important to understand the things you see, analyze, and make prognosis. The technology of automatic analysis is still imperfect and requires further technical and intellectual improvement. The physician needs fundamental and systemic knowledge of the indications and limitations of the ultrasound method, as well as the specific features of the thyroid gland and neck tissues in normal and diseased condition. Knowledge and experience with strict following the methodology of the examination are more important than ever. It determines the vector and the accuracy of the diagnostic search resulting in the correct and timely conclusion.

To make a "conventional" thyroid ultrasound is not a big issue today. It is much more important (and therefore more difficult) to perform the studies at such an expertly high level with constant and reproducible quality, which would be fully trusted by other colleagues, clinicians, and patients. It is even more difficult to work in continuous cooperation with colleagues-clinicians to follow-up the patients under the therapy to assess the tiny ultrasound changes. Many expectations are related to the improvement and standardization of ultrasound conclusions in connection with the implementation of TIRADS system. It facilitates the stratification of the risk of thyroid malignancies and determination of further management. In such a case, standards and algorithms that are clear for any doctor are of high importance.

The authors of this monograph attempted to summarize and analyze all issues and perspectives of ultrasound diagnostics of various thyroid diseases based on

literature and personal experience. They analyze the results of more than 100,000 exams of the thyroid gland with utilization of the whole spectrum of multiparametric ultrasound, more than 5000 ultrasound-guided biopsies, and more than 1200 contrast-enhanced ultrasound studies conducted in 2000–2018. This extensive experience permitted to form well-grounded opinion about the possibilities of ultrasound imaging at the current level of medicine.

Undoubtedly, all problems of ultrasound diagnostics of thyroid diseases have not been solved yet. As always, the reader is left with the opportunity for analysis, reflection, comments, further scientific search, and practical verification. We hope for favorable reader's comments and suggestions, which will be gratefully accepted and taken into consideration in further practical work and scientific research.

Dear friends and colleagues, we wish you further professional achievements! Knowledge is power. Be strong!

Abbreviations

3D	Three-dimensional image reconstruction
3DPD	Three-dimensional power Doppler imaging (3D-reconstruction of the image in the vascular mode)
4D	Real-time three-dimensional imaging
AIT	Autoimmune thyroiditis
AITD	Autoimmune thyroid disease
AJCC	American Joint Committee on Cancer
AT	Acute thyroiditis
ATA	American Thyroid Association
BI-RADS	Breast imaging reporting and data system
BSA	Body surface area
BSRTC	Bethesda system for reporting thyroid cytopathology
CCA	Common carotid artery
CDI	Color Doppler imaging
CEUS	Contrast-enhanced ultrasound
CPD	Color pixel density
CT	Computed tomography
EDV	End diastolic velocity
FNA	Fine needle aspiration
FNAB	Fine needle aspiration biopsy
hCG	Human chorionic gonadotropin
HPT	Hyperparathyroidism
IJV	Internal jugular vein
ITA	Inferior thyroid artery
IVF	In vitro fertilization
LN	Lymph node(s)
MEN	Multiple endocrine neoplasia
MRI	Magnetic resonance imaging
PDI	Power Doppler imaging
PET	Positron emission tomography
PI	Pulsatility index
PSV	Peak systolic velocity
PTH	Parathyroid hormone
PW	Pulsed-wave Doppler

RI	Resistive index
SAT	Subacute thyroiditis
SPECT	Single photon emission computed tomography
STA	Superior thyroid artery
SWE	Shear wave elastography (elastometry)
TIRADS	Thyroid imaging reporting and data system
TSH	Thyroid stimulating hormone
US	Ultrasound (echography)
USE	Ultrasound elastography

1 Current State of the Problem of Thyroid Diseases: Principles and Technology of Thyroid Ultrasound

Alexander N. Sencha, Yury N. Patrunov, Stanislav V. Pavlovich, Liubov A. Timofeyeva, Munir G. Tukhbatullin, and Antonina A. Smetnik

Iodine deficiency in endemic regions and high incidence of thyroid disorders remain important social and medical problems. Prevention and treatment of thyroid diseases are important priority projects of national healthcare systems in many countries of the world. The diseases of the thyroid gland rank second among all endocrine pathology in terms of prevalence. They are registered in 8–20% of the adult population of the world. According to the WHO reports, more than 200 million people suffer from this pathology. The number exceeds 50% in endemic regions [1–6].

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A. N. Sencha, Y. N. Patrunov (eds.), *Thyroid Ultrasound*,
https://doi.org/10.1007/978-3-030-14451-7_1

Thyroid cancer accounts for 1–3% of all malignant tumors. Recent studies demonstrate the increase in the incidence of thyroid diseases inclusive with malignant neoplasms in virtually all countries [5, 7–12]. For example, in the USA, the incidence of thyroid cancer in 1973–2009 increased 3.6 times, from 3.5 to 12.5 cases per 100,000 population [13–15]. The incidence of thyroid malignancies grows mainly due to differentiated thyroid cancer.

Mortality of patients with malignant thyroid tumors exhibits a persistent tendency to decrease. For example, in Russia the number of deaths within a year from the date of diagnosis of malignant thyroid neoplasm in 2007–2017 decreased from 5.9% to 3.5% [16]. It may be the consequence of both achievements in early diagnosis of thyroid cancer associated with widespread introduction of ultrasound imaging and new approaches to treatment and follow-up.

Oncological awareness is an important component of professional activities of any diagnostician. Undoubtedly, this applies to the diagnosis of thyroid lesions. According to Davydov [1], the risk of malignancy in diffuse toxic goiter is 2.5–8.4%, in nodular goiter 4.6–31.4%, in autoimmune thyroid disease (AITD) 1.2–8.2% (nodular type of AIT – 4.7–29.5%), and in thyroid adenoma 5.0–24.4%.

The principle tasks of thyroid ultrasound (US) are to detect the thyroid gland; to characterize its relationship with the other neck tissues; to assess the size and volume, margins, and echostructure; to characterize the pathology; to define the condition of the surrounding organs and lymph nodes; to determine the further diagnostic tactics; and to suggest the type of further treatment and follow-up.

The following methods are utilized in the diagnosis of thyroid diseases:

1. Preoperative
   a. Primary:
      - Palpation of the thyroid gland and the lymph nodes of the neck
      - Thyroid US
      - Determination of thyroid hormones and TSH in blood
   b. Additional:
      - US-guided fine-needle aspiration biopsy (FNAB) with cytology
      - Determination of antithyroid antibodies
      - Thyroid radionuclide scan
      - X-ray of the mediastinum with contrasted esophagus
      - Computed tomography (CT)
      - Magnetic resonance imaging (MRI)
      - Molecular-genetic typing of a tumor
      - Other
2. Intraoperative
   a. Intraoperative thyroid US
   b. Urgent histological investigation in cases of suspected thyroid malignancy
3. Postoperative
   a. Basic
      - Histological examination of the excised thyroid tissue
   b. Additional
      - Immunohistochemical examination of the tumor (detection of tumor markers)

Radiological methods, such as US, thyroid radionuclide scan, CT, MRI, and general radiography, are especially valuable for diagnosing thyroid diseases. Modern examination of the thyroid gland involves application of various methods in an optimal combination and sequence to reveal morphological and functional changes. To date, none of the diagnostic methods can claim absolute certainty and infallibility. When choosing diagnostic methods, it is necessary to take into account its advantages and disadvantages, such as radiation exposure (for radionuclide scan, X-ray, and CT), limited information (for palpation), long duration of the study, availability (MRI, PET/CT), etc. With different thyroid diseases, the diagnostic value of the methods is not the same. It often depends on concomitant diseases, previous treatment, patient's age, individual features of thyroid location, and some other factors.

One promising method is molecular-genetic typing of the tumor before surgery to determine the biological potential and detect patients with increased oncologic risk. Clinical guidelines for molecular diagnostics of thyroid FNA of the European and American thyroid associations indicate the importance and perspectives of the molecular-genetic panel in the diagnosis of thyroid cancer, the differentiation of thyroid lesions BSRTC categories 3 and 4. In particular the definition of the mutation markers BRAF V600E, RAS/MAPK, RET/PTC, EIF1AX, and AKT1 and their combined use in the diagnostic panels ThyroSeg v2, Afirma, TheGenX, Thyra MIR, and others is sown valuable [11].

Thyroid ultrasound is readily available, noninvasive, and highly informative. Thus, US is the leading imaging modality. Its safety and comparatively low cost are additional factors in favor of the wide use of sonography for diagnosing thyroid diseases. Since the first report of the application of US for diagnostic purposes was published, no scientifically proven adverse effect resulting from the medical use of US has been reported. It is possible that harmful effects may be identified in the future. However, the evidence available indicates that the benefits of US to patients are much greater than the risks, if any exist. Diagnostic doses of ultrasound do not accumulate, and the US examinations are short enough not to cause any significant biological effect. Hence, US can be performed several times without any limitations on the time interval between sessions. This enables the pathology to be assessed dynamically.

Modern US scanners are sensitive enough to differentiate fluid and solid thyroid lesions of 1 mm in size. Sonography can be effective in the detection of retrosternal goiter when it is in the upper mediastinum. However, localization of the goiter below the tracheal bifurcation limits the possibilities of US. One disadvantage of thyroid US is its high dependence on the level of training, experience, and skills. The variability in the results obtained when different US specialists examine the same patient is 10–30%. The diagnostic value and reproducibility of the method depend significantly on the quality of the equipment.

The sensitivity of the echography in the diagnosis of thyroid cancer is 69–100%, specificity 55–98%, and diagnostic accuracy 54–99% [3, 4, 7, 17, 18]. Color Doppler imaging (CDI), power Doppler imaging (PDI), 3D image reconstruction, multiplanar scan, ultrasound elastography (USE), contrast-enhanced ultrasound (CEUS), and other modern options increase the value of conventional ultrasound.

The incidence of metastatic deposits in regional lymph nodes in differentiated thyroid cancer reaches 50–60% [13, 19, 20]. The diagnostic value of US in the detection of thyroid cancer metastases in neck lymph nodes is also high. The sensitivity is 76–100%, specificity 72–91%, and diagnostic accuracy 82–94% [13, 19, 21].

The logistics of diagnostic care with implementation of ultrasound imaging, the routing of patients with various pathology of the thyroid gland, the sequence of diagnostic procedures, and the choice of treatment and further tactics are illustrated with the following chart flow (Fig. 1.1).

One main task of thyroid US is to analyze the nature of changes in the thyroid parenchyma with stratification of the risk of thyroid cancer and the necessity of FNAB.

Combination of several diagnostic modalities is most effective and permits the character and the severity of the pathology to be assessed. Modern complex diagnostics do not assume the use of all possible methods. It is necessary to find a rational range and sequence of diagnostic techniques to obtain the maximum information in each case.

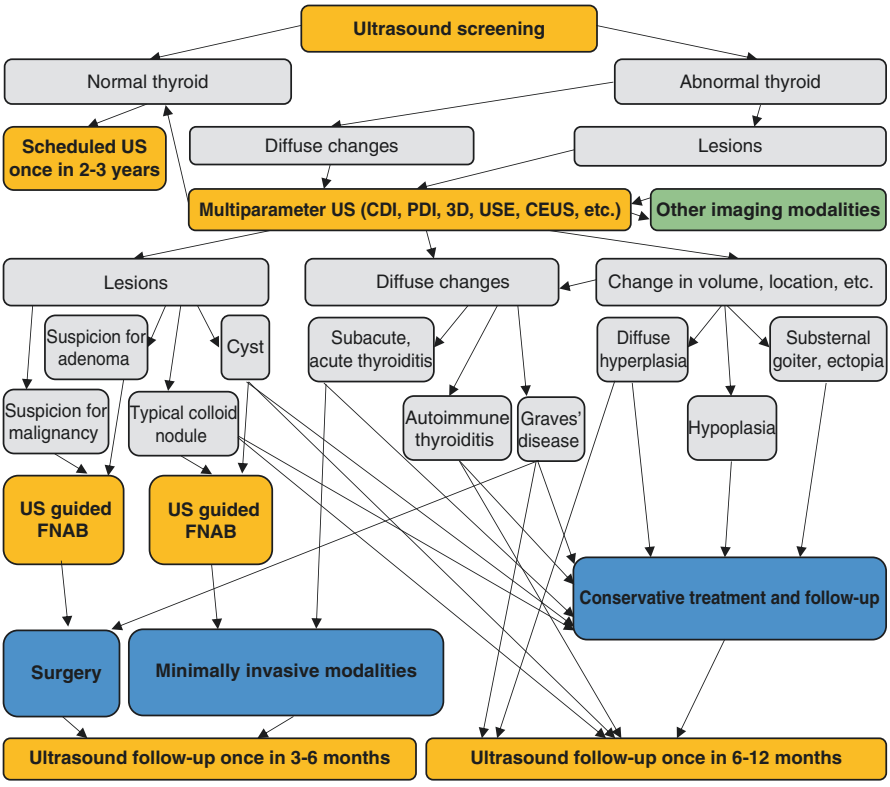

Fig. 1.1 The position of multiparametric ultrasound in the diagnostic flow in patients with thyroid diseases