Ultrasound of the Thyroid Gland

12

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12.1 Introduction: The Thyroid Examination

To simplify the thyroid ultrasound (US) examination and to make it more practical and systematic (according to thyroid ultrasound features), it is reasonable to group the examination into two parts: the general thyroid examination and special thyroid examination.

Before using US to go deep into thyroid problems, it is important to have a general overview. The first step should be to measure the thyroid size (width, length, height). While obtaining these measurements, the examiner will acquire the first impression of the thyroid: Is it normal in size, small, or enlarged? Is it substernal? Does it have nodules? Is the thyroid tissue homogenous or heterogeneous? On the basis of these findings, it is possible to start to diagnose pathology.

A more thorough, special thyroid US examination is important to completely evaluate thyroid nodules, to find the presence or absence of pretracheal and paratracheal lymph nodes, and to perform elastography of thyroid nodules.

A substantial US report regarding thyroid nodules should always begin with the position of the nodules in the thyroid: the upper pole, the lower pole, the middle third of the thyroid, or the isthmus. To complete the evaluation, the following US characteristics should be considered [1, 2]:

- The number of nodules in the thyroid
- The size of each nodule
- The echogenicity of the nodules (hypoechoic, hyperechoic, isoechoic, anechoic, homogeneous, heterogeneous, cystic, solid, posterior enhancement, spongiform)
- The presence of calcification (microcalcifications, coarse calcifications, peripheral rim calcification [eggshell phenomenon])
- The form of the nodules (round, oval, irregular, "taller-than-wide" phenomenon)
- Regularity of the borders
- Halo effect
- Comet-tail sign
- Vascularization of the nodules (peripheral ring of flow, internal flow)

Thyroid US can also estimate the nature of lymph nodes surrounding thyroid. The appearance and form of lymph nodes suggest whether they might be suspicious. Oval lymph nodes with hilum represent benign lymph nodes, whereas lymph nodes without hilum and with extensive internal flow are very suspicious and must be further investigated by performing fine needle aspiration biopsy [3]. It is not usual to find lymph nodes in the pretracheal or paratracheal compartment, so it is essential to investigate all lymph nodes found in this area. But it should be expected to find such lymph nodes in patients with autoimmune thyroid disease (Hashimoto thyroiditis); the characteristics of Hashimoto thyroiditis are discussed in a later section of this chapter.

A relatively new US method to help distinguish soft from hard thyroid nodules is elastography. Soft nodules are more likely to have a benign etiology, whereas hard nodules have a higher rate of malignancy [4]. Elastography findings alone are not currently enough to make a decision about surgery, but it is a helpful diagnostic tool to decide whether fine needle aspiration biopsy should be performed.

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12.2 Evaluation of Thyroid Nodules

As noted above, many factors need to be evaluated in the US examination of thyroid nodules; the findings have important clinical implications.

12.2.1 Size (Small Nodules, Large Nodules, Large Goiter)

Measuring the size of the thyroid and thyroid nodules is important not only to get a first impression but also to start to decide whether further nodule evaluation is needed. Recent reports have recommended that thyroid nodules smaller than 1 cm should not be further investigated (Fig. 12.1). Large thyroid nodules (Fig. 12.2), especially ones larger than 4 cm, present a higher incidence of developing thyroid cancer. Large thyroid goiter (Fig. 12.3)—especially substernal and retrosternal goiter—can cause difficult swallowing and shortness of breath; smaller nodules can have a similar effect, especially if they are located close to the trachea or esophagus. Nevertheless, nodule size is not predictive of malignancy [5].

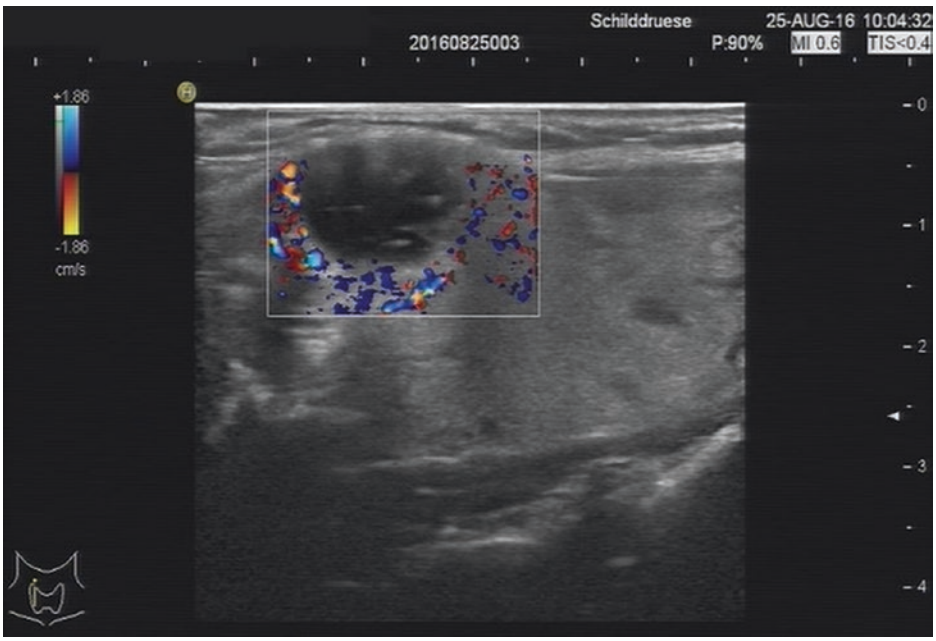

Fig. 12.1 Small hypoechoic thyroid nodule in upper pole of the right thyroid lobe

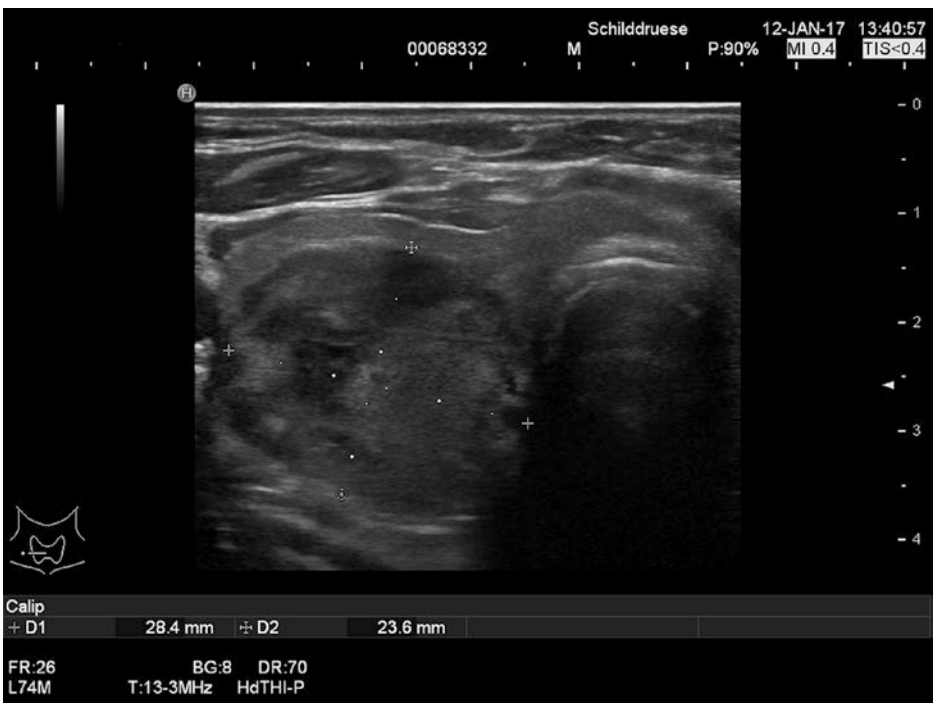

Fig. 12.2 A large, heterogeneous, isoechoic thyroid nodule with hypoechoic areas in the middle of the right thyroid lobe

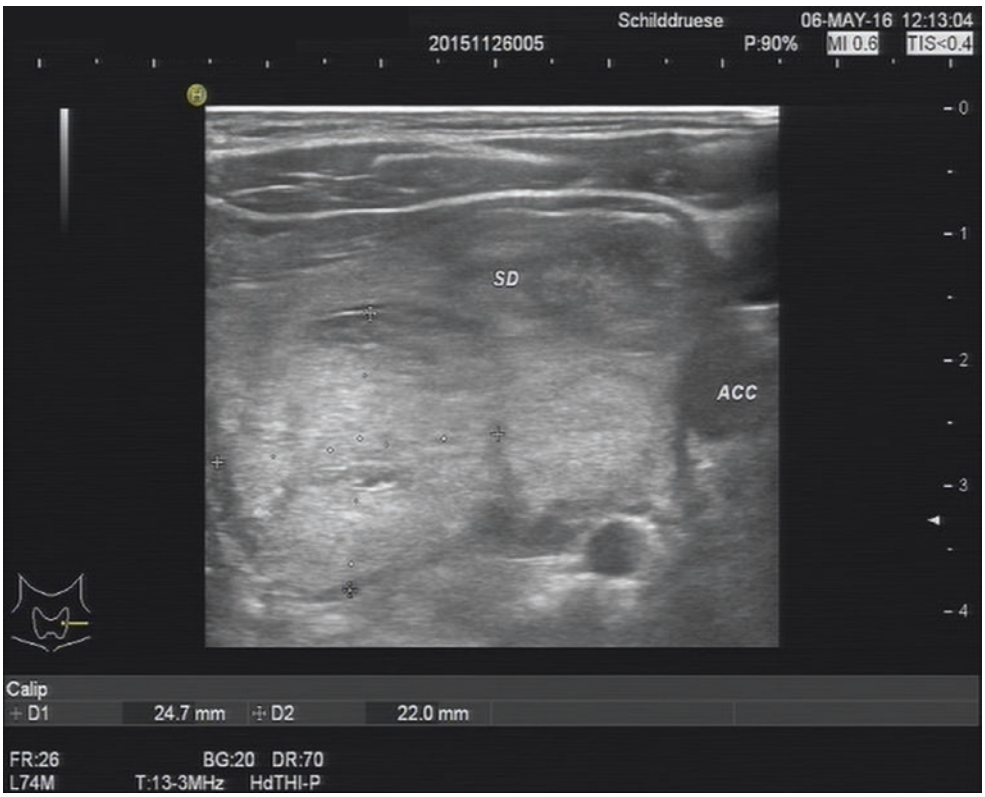

Fig. 12.3 Large, multinodular goiter of the left thyroid lobe

Fig. 12.4 Small, hypoechoic nodule of the left thyroid lobe without suspicious ultrasound characteristics

12.2.2 Echogenicity (Hyperechoic, Hypoechoic, Isoechoic)

The term *echogenicity* is used to illustrate the ability to return the US signal coming from the probe to the tissue and back to the probe. The quality of the signal can be characterized as *hypoechoic* (lower echogenicity, a darker image) (Fig. 12.4; Video 12.1), *hyperechoic* (higher echogenicity, a lighter image) (Fig. 12.5), *isoechoic* (the same echogenicity as the surrounding tissue) (Fig. 12.6; Video 12.2),

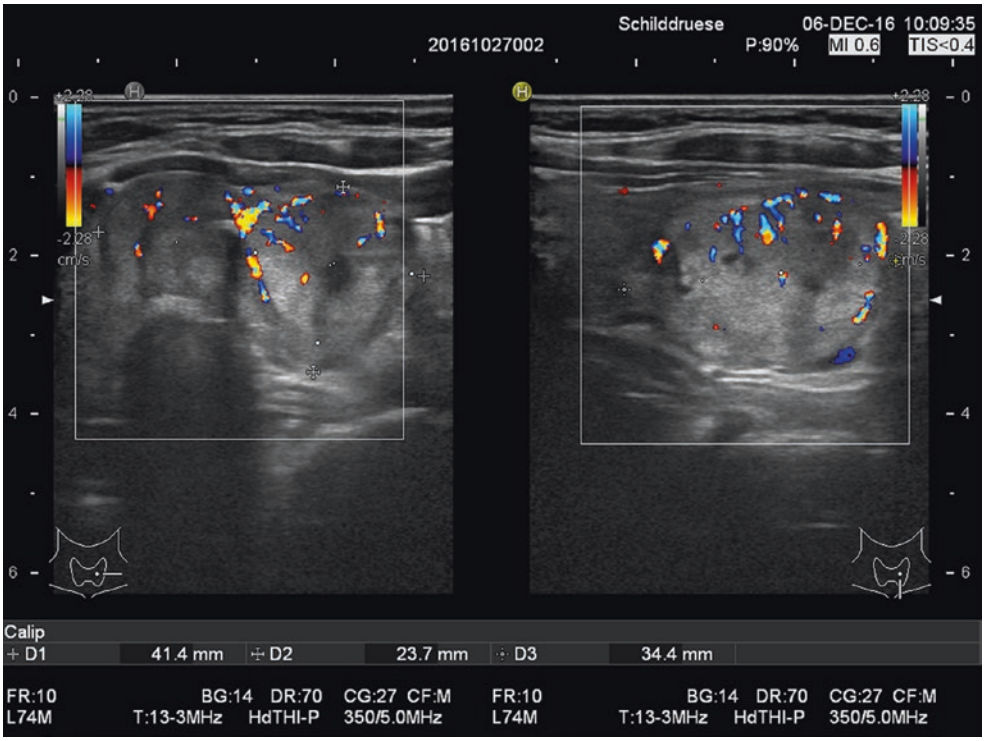

Fig. 12.5 Hyperechoic thyroid nodule in the left lobe of the thyroid, with a small, isoechoic nodule in the isthmus

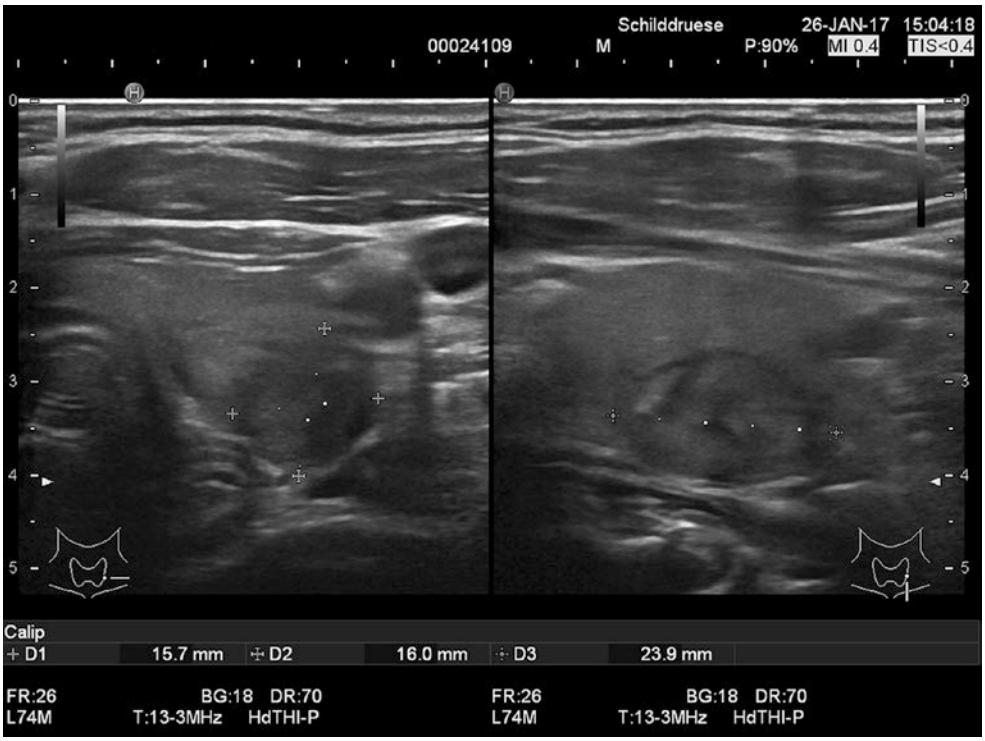

Fig. 12.6 Relatively small, isoechoic nodule in the lower pole of the left thyroid lobe, with well-defined margins

and *anechoic* (without echogenicity, completely dark) (Fig. 12.7). Echogenicity of a thyroid nodule is important because it can be a predictor of thyroid disease. Most thyroid carcinomas are hypoechoic, and almost all hyperechoic nodules are benign, but to decide whether a particular nodule is benign, malignant, or suspicious for malignancy, we must also consider other US characteristics and perform fine needle biopsy to prove the diagnosis, because benign thyroid nodules can also be hypoechoic [6].

Fig. 12.7 Typical presentation of a thyroid cyst in the upper pole of the right thyroid lobe; the cyst is completely anechoic, with posterior enhancement

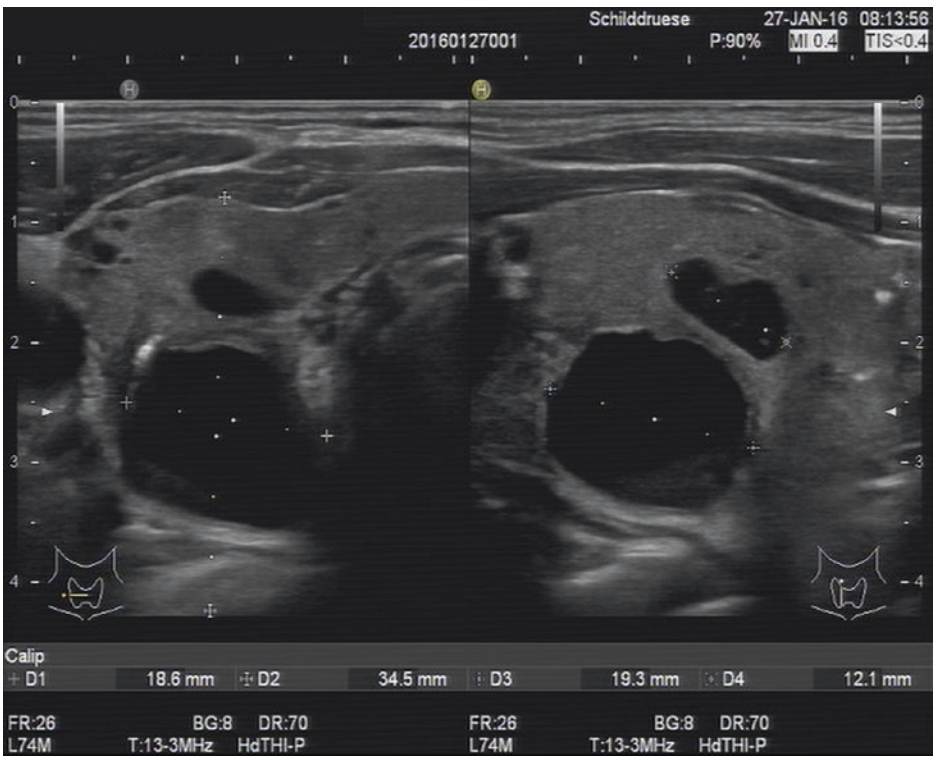

Fig. 12.8 Two small cysts of the right thyroid lobe, both anechoic; the bigger cyst shows posterior enhancement, but the smaller cyst does not

12.2.3 Content and Echo Structure (Cyst, Partly Cystic Nodule, Solid Nodule, Comet-Tail Sign, Calcifications)

Thyroid *cysts* appear as homogenous hypoechoic or anechoic nodules; they typically have a hyperechoic rim behind them (called *posterior enhancement*), but this rim is not always present. Thyroid cysts are actually enlarged, fluid-filled parts of the thyroid gland. The cysts can range in size from small (Fig. 12.8) to large (Fig. 12.9), or they can be partly cystic (Video 12.3) and partly solid (Fig. 12.10). Another classic US feature of one variant of thyroid cyst (the colloid cyst

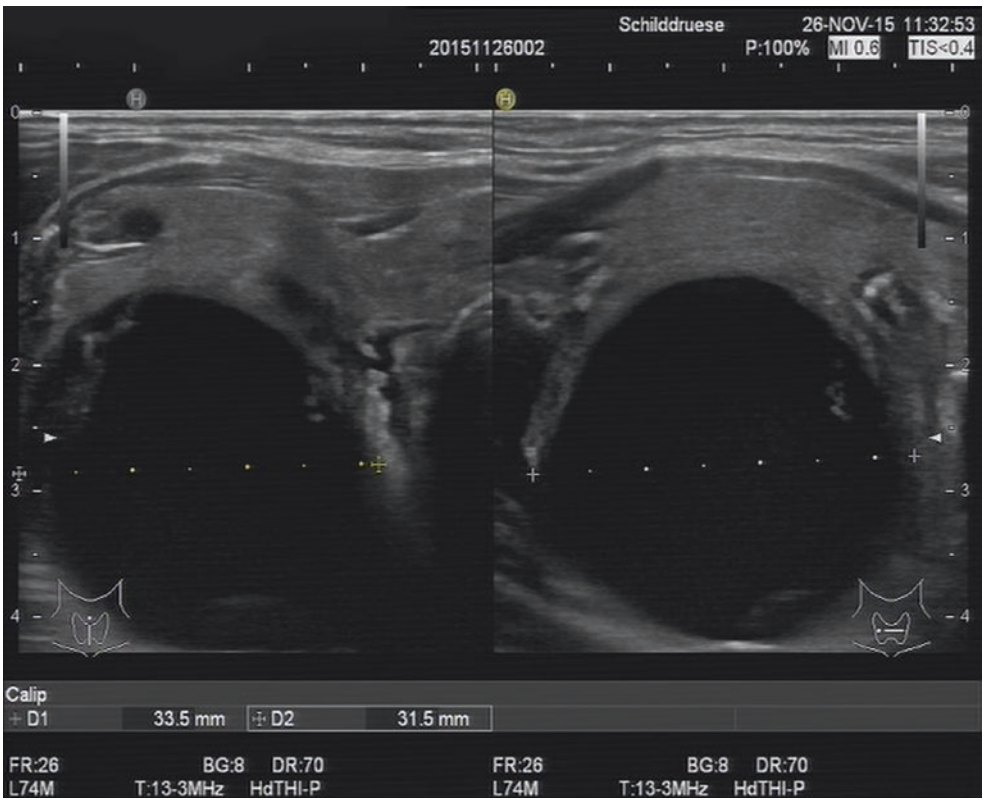

Fig. 12.9 Large thyroid cyst of the right thyroid pole; the cyst is anechoic with posterior enhancement

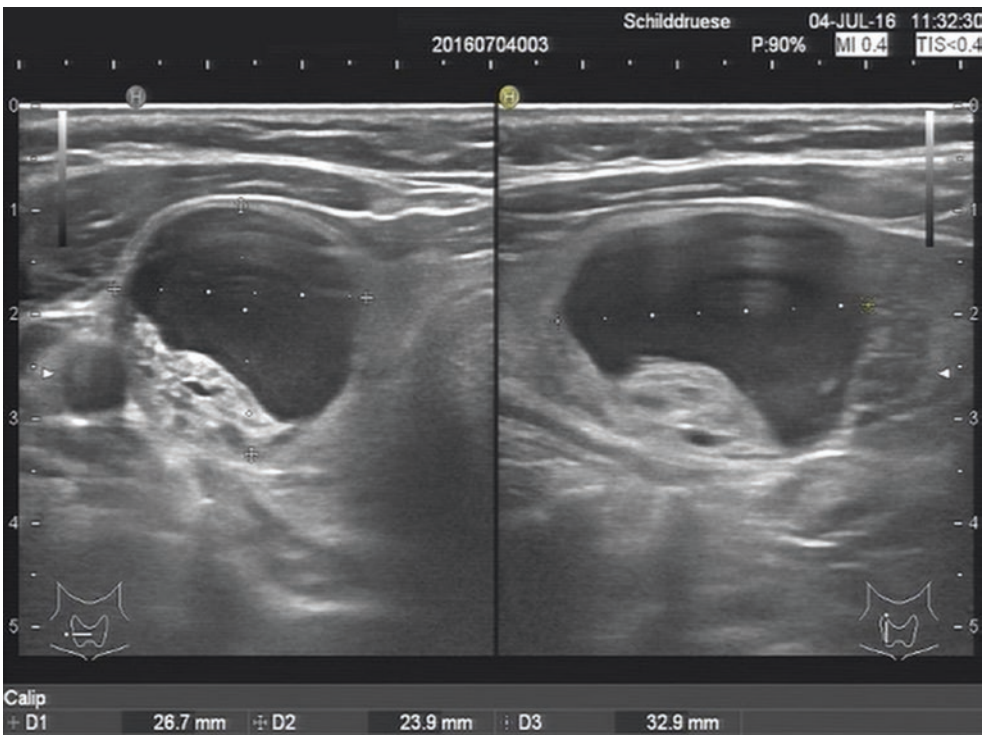

Fig. 12.10 Partly cystic thyroid nodule of the right thyroid lobe, with a solid, hyperechoic component in the lower lateral part of the nodule

[Video 12.4]) is the so-called comet-tail sign (Fig. 12.11). This US feature is a form of reverberation artifact characteristic of benign thyroid nodules.

Pure thyroid cysts are associated with benign etiologies. Partially cystic thyroid nodules with a solid component have a greater possibility of malignancy, and further evaluation is required.

Solid thyroid nodules (Fig. 12.12) can be hypoechoic, hyperechoic, or isoechoic. Many thyroid nodules have calcification. It is very important to differentiate microcalcifica-

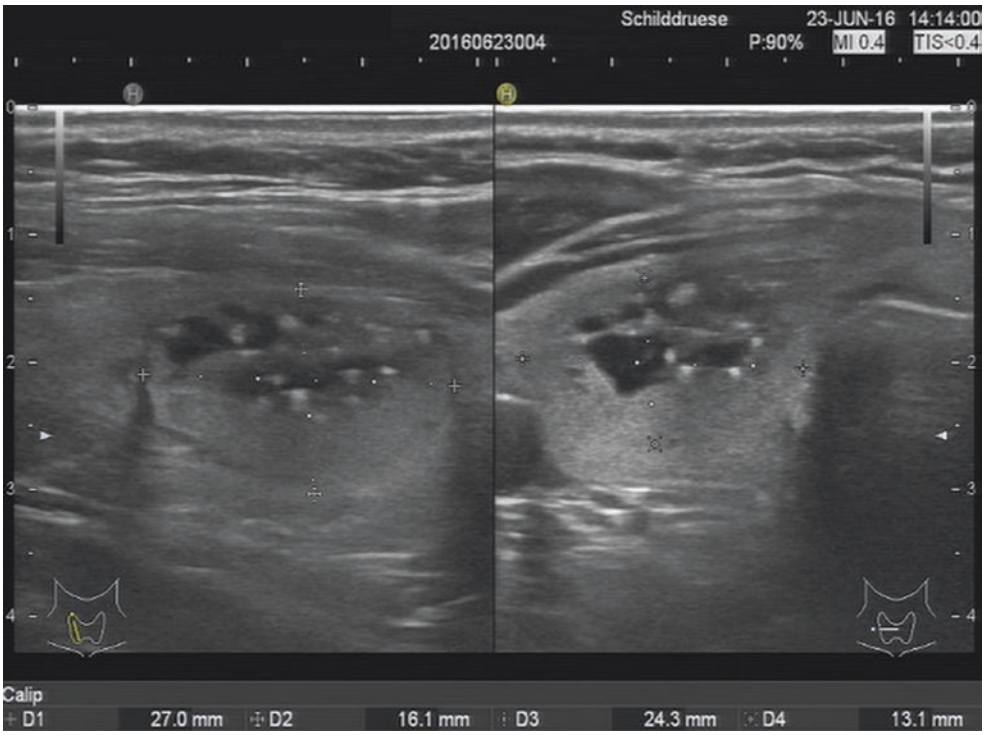

Fig. 12.11 Partly cystic, partly solid thyroid nodule of the right thyroid lobe. In the upper (cystic) part of the nodule can be seen a lot of small, hyperechoic areas (reverberation artifact), called the comet-tail sign

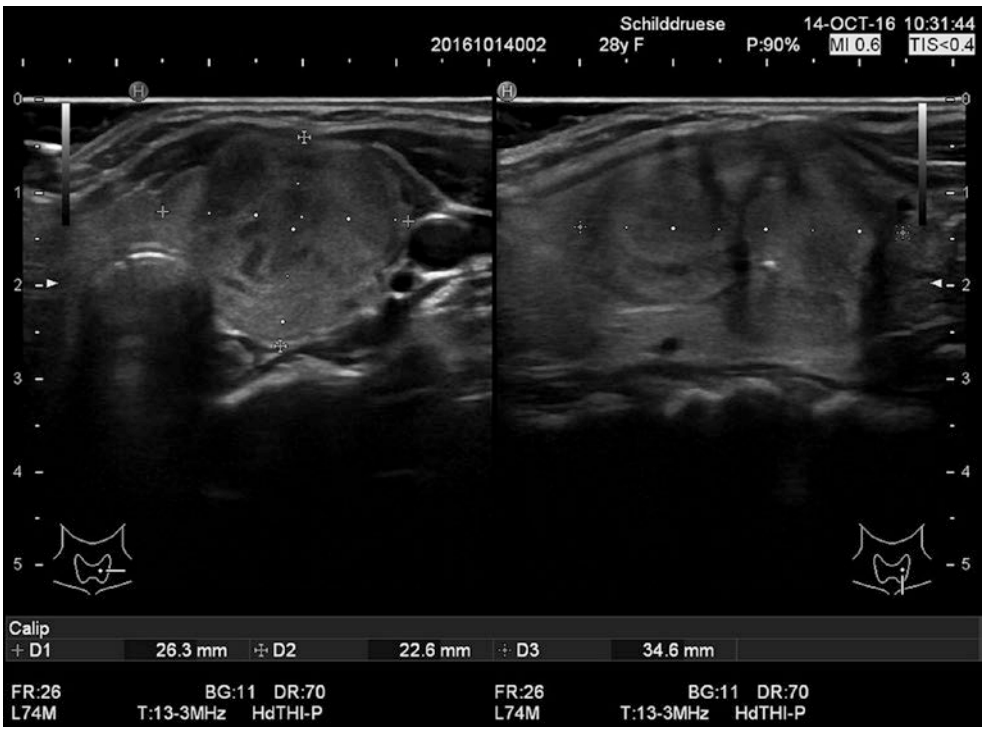

Fig. 12.12 Solid, heterogeneous thyroid nodule in the upper part of the left thyroid lobe, in contact with the isthmus and trachea

tion (Fig. 12.13) from coarse calcification (Figs. 12.14 and 12.15). Microcalcifications belong to group of suspicious US features that also include irregular margins and hypervascularity. The round, laminated calcifications called *psammoma bodies* are one of the most specific features of thyroid malignancy. It is important not to mistake the comet-tail sign for this kind of microcalcification.

Coarse calcifications usually can be seen in thyroid goiter (a benign thyroid condition), but they can also be present in malignant thyroid nodules, with or without microcalcifications. Unlike

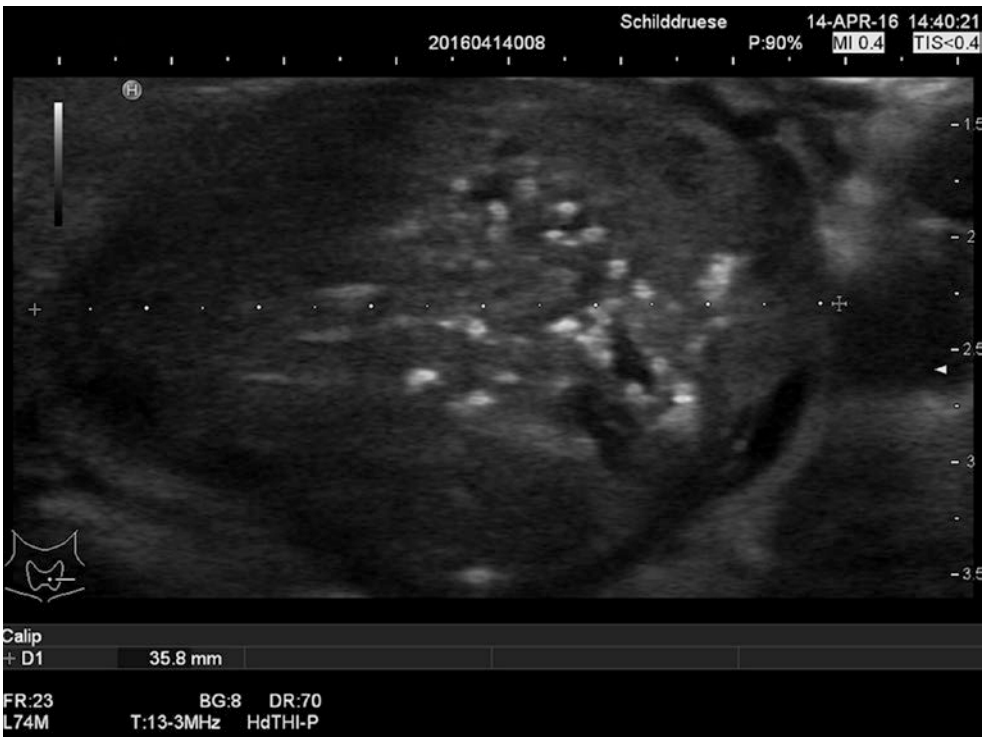

Fig. 12.13 A large, heterogeneous nodule of the left thyroid lobe with suspicious ultrasound characteristics (microcalcifications, seen as a lot of small, hyperechoic spots)

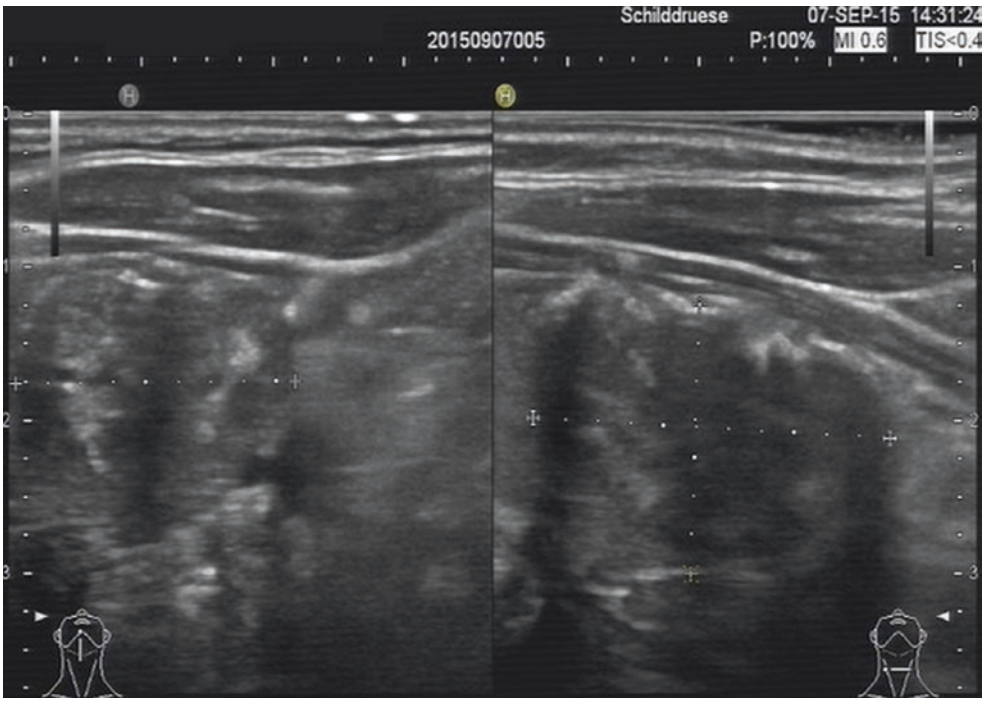

Fig. 12.14 Several coarse calcifications in the pyramidal lobe of the thyroid. Behind every calcification can be seen posterior acoustic shadowing; the area behind the calcification cannot be interpreted

microcalcifications, coarse calcification always produces posterior acoustic shadowing, which is easy to recognize.

Eggshell calcification of thyroid nodules is another suspicious US characteristic. Some authors describe the eggshell phenomenon as more useful in diagnosing thyroid malignancy than hypoechogenicity or a taller-than-wide shape of thyroid nodules.

A homogeneous nodule without suspicious US features or a thyroid nodule with a spongiform pattern (Fig. 12.16) generally indicates a benign etiology [7–10].

Fig. 12.15 A small nodule in the upper pole of the left thyroid lobe. At the upper edge of the nodule is visible a hyperechoic rim, presenting coarse calcification. Behind the calcification, everything is dark (hypoechoic) because of posterior acoustic shadowing, so nothing is detectable

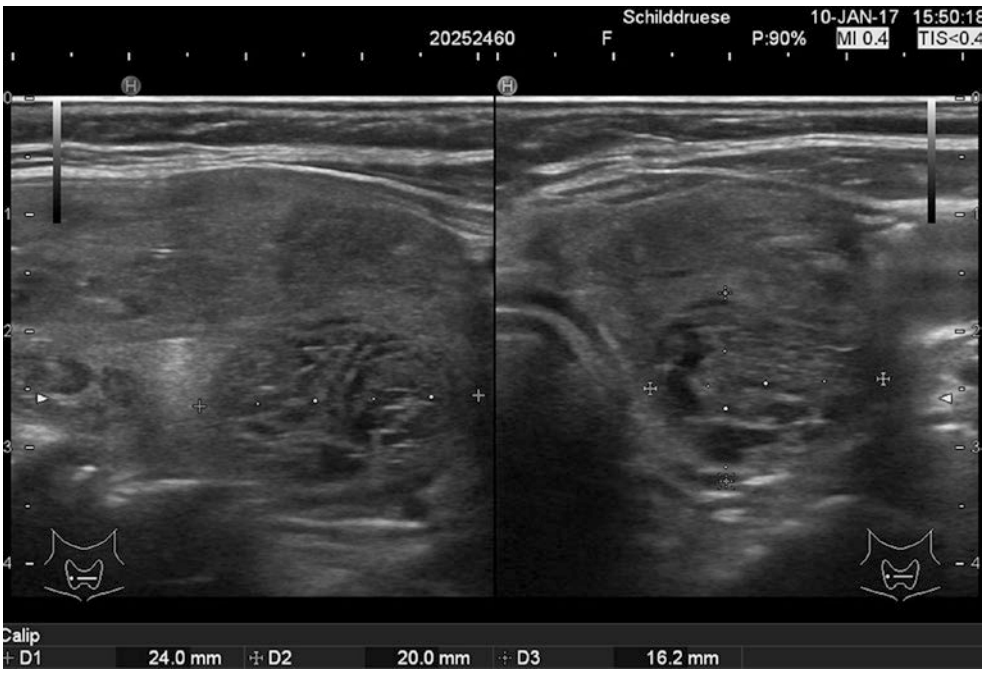

Fig. 12.16 Heterogeneous nodule in the lower pole of the left thyroid lobe, with characteristic spongiform pattern

12.2.4 Margins (Regular, Suspicious, Irregular)

The margins of thyroid nodules are excellent predictors of the nature of thyroid disease. Benign thyroid nodules usually have regular, well-defined margins (Fig. 12.17). On the other hand, suspicious thyroid nodules have irregular borders (Fig. 12.18; Video 12.5). In such cases, this US feature serves as a negative diagnostic factor explaining the potentially more aggressive behavior of the nodule, with infiltration of the surrounding tissue (extrathyroidal extension).

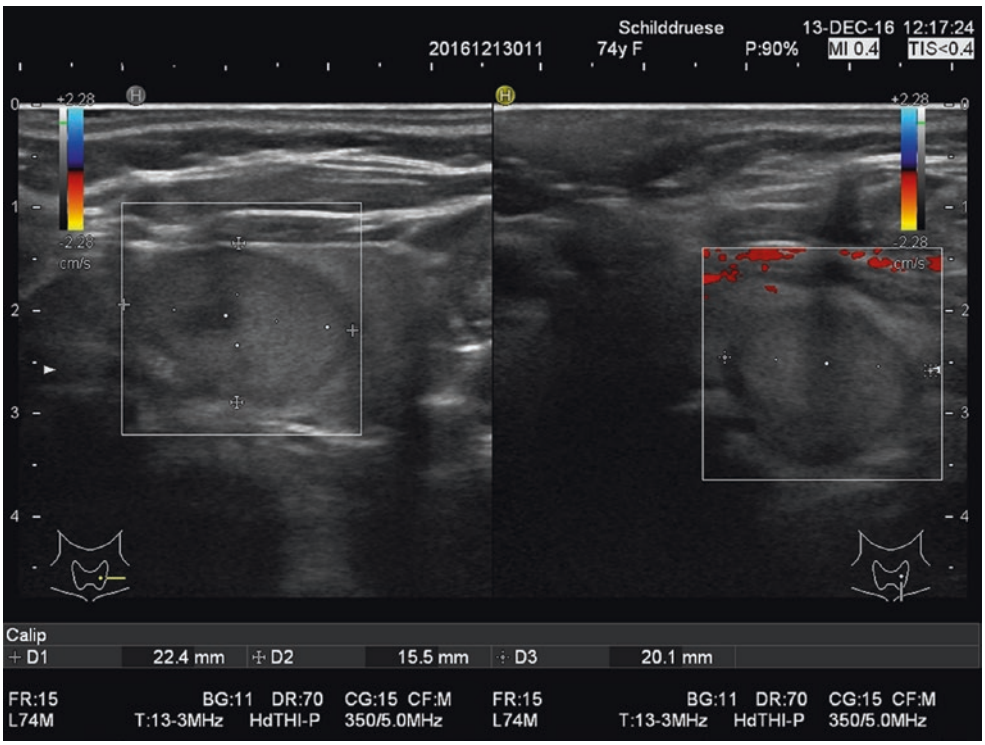

Fig. 12.17 A relatively small, isoechoic thyroid nodule with regular margins and "halo effect" (hypoechoic rim)

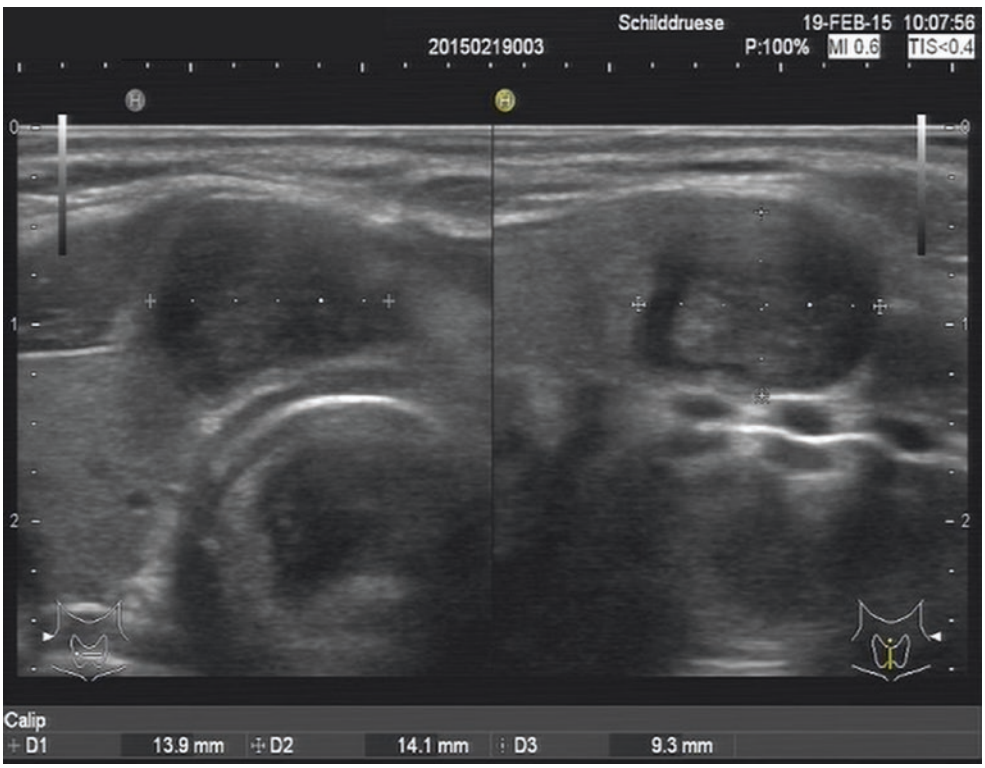

Fig. 12.18 Thyroid nodule in the isthmus with irregular margins, especially in the upper part of the nodule

Sometimes it is not easy to evaluate whether a nodule has regular or irregular margins, especially when it is positioned near the capsule of the thyroid close to the strap muscles. We advocate performing a fine needle aspiration biopsy (Video 12.6) when the margins of a nodule are clearly irregular or if it is uncertain whether they may be irregular (Fig. 12.19) [11].

12.2.5 Form (Round, Oval, Irregular, Taller than Wide)

It is usually hard to assess whether thyroid nodules are likely to be benign or malignant on the basis of their shape. Almost all thyroid nodules—both benign and malignant—are round (Fig. 12.20) or oval (Fig. 12.21) in shape, and the margins

Fig. 12.19 Thyroid nodule with suspicion of irregular margins. The upper part of the nodule is not visible. It is also hard to find the border with strap muscles. This is a highly suspicious nodule

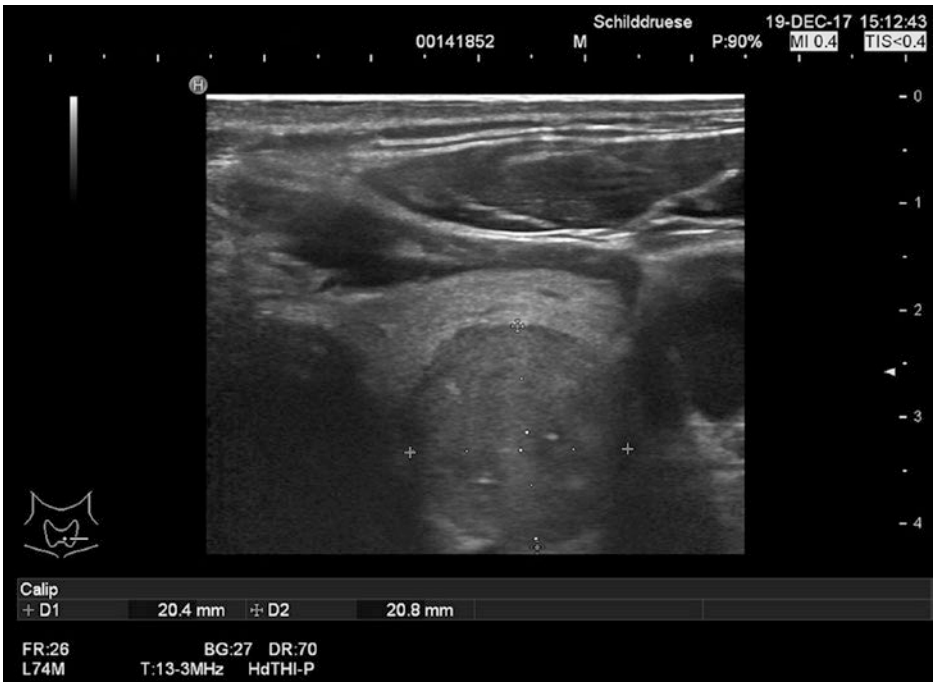

Fig. 12.20 Mildly hypoechoic, round nodule of the left thyroid lobe, with well-defined margins

are almost always regular. A possibility of malignancy is suggested by a nodule with an irregular shape, which can represent extranodular infiltration, especially with synchronous, ill-defined margins (Fig. 12.22). An enlarged thyroid with irregular nodules also may represent a large multinodular thyroid goiter, however (Fig. 12.23). Round and oval nodules are more likely to be benign, especially if other suspicious US criteria are negative, but one special shape of thyroid nodule, called "taller than wide," indicates a higher rate of thyroid malignancy [12, 13] (Fig. 12.24).

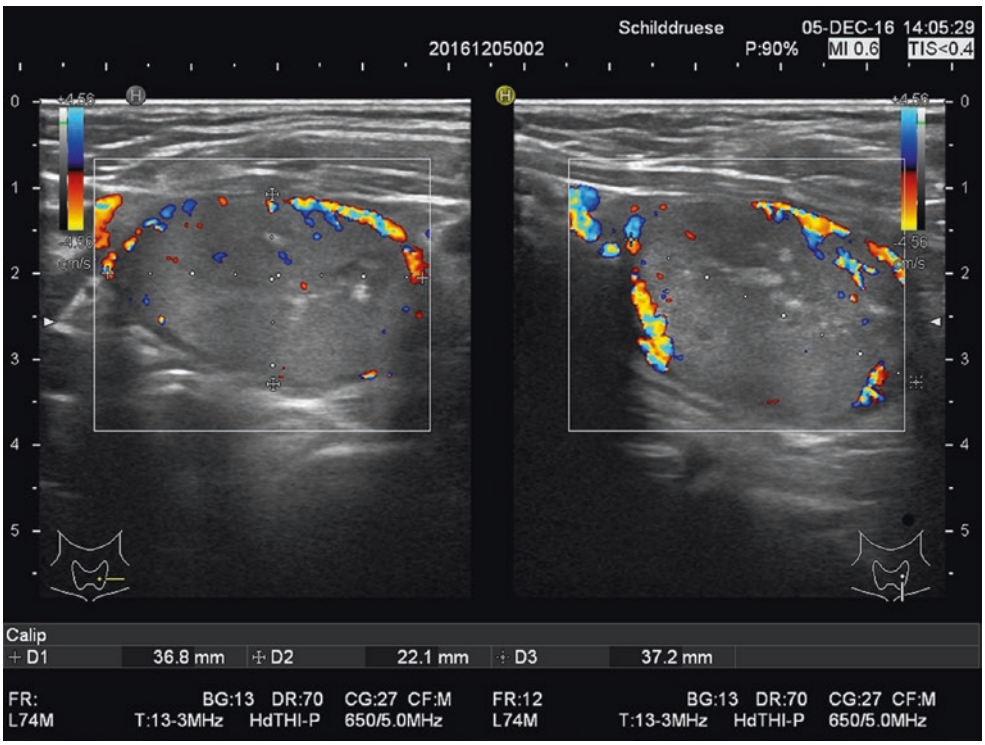

Fig. 12.21 Oval, isoechoic nodule of the left thyroid lobe, with well-defined margins and peripheral vascularity; it has no suspicious ultrasound characteristics

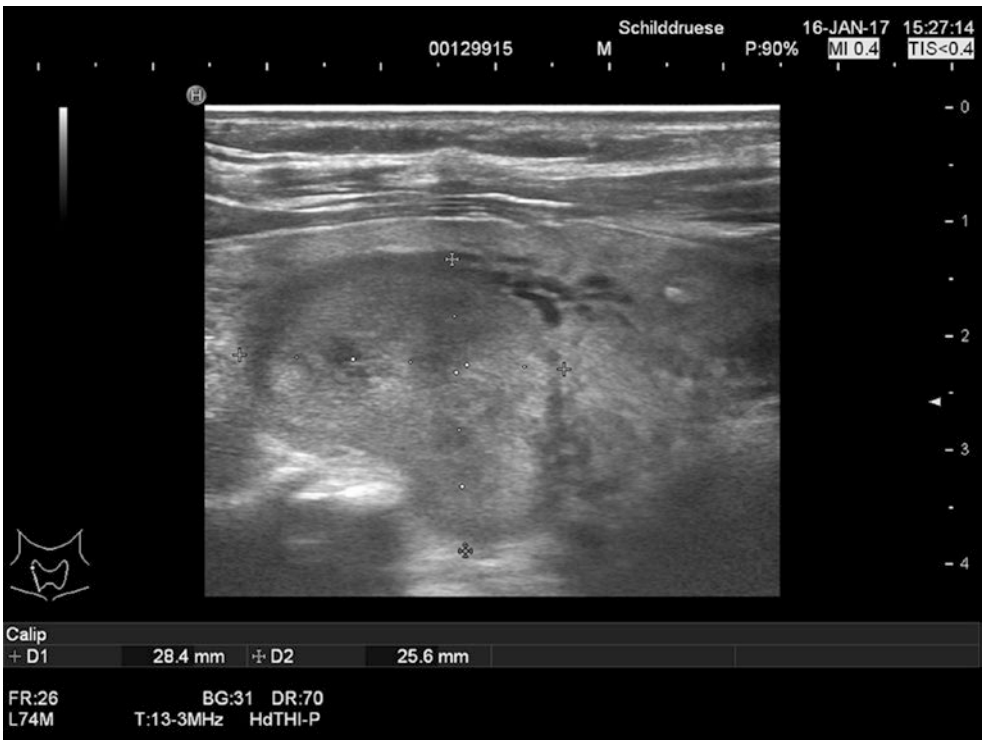

Fig. 12.22 Heterogeneous thyroid nodule with irregular shape and ill-defined margins. (Pathology report: thyroid cancer)

Fig. 12.23 Large, relatively homogeneous nodule with irregular shape and well-defined margins (thyroid goiter)

Fig. 12.24 Isoechoic nodule of the right thyroid lobe with "halo effect." It also is taller than wide (a suspicious ultrasound characteristic)

12.2.6 Vascularity (Peripheral Ring of Flow, Internal Flow)

Using color Doppler during a thyroid ultrasound examination can be very useful in detecting thyroid malignancy (Video 12.7). Peripheral ring of flow is associated with benign thyroid etiology (Fig. 12.25). When internal flow is positive, the nodule is highly suspicious for malignancy (Fig. 12.26). This interpretation is also valid for lymph nodes. In that case, lymph nodes with increased color Doppler flow are very suspicious for metastatic disease. While performing thyroid US examinations, it is very valu-

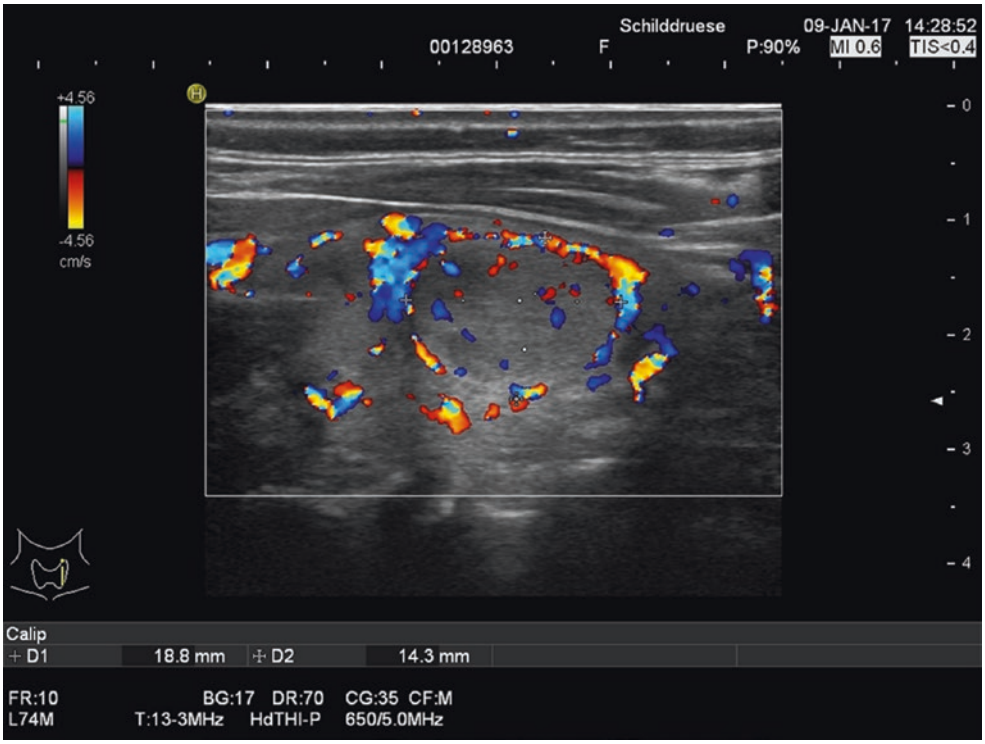

Fig. 12.25 Isoechoic thyroid nodule in a lower pole of the left thyroid lobe, with peripheral ring of flow

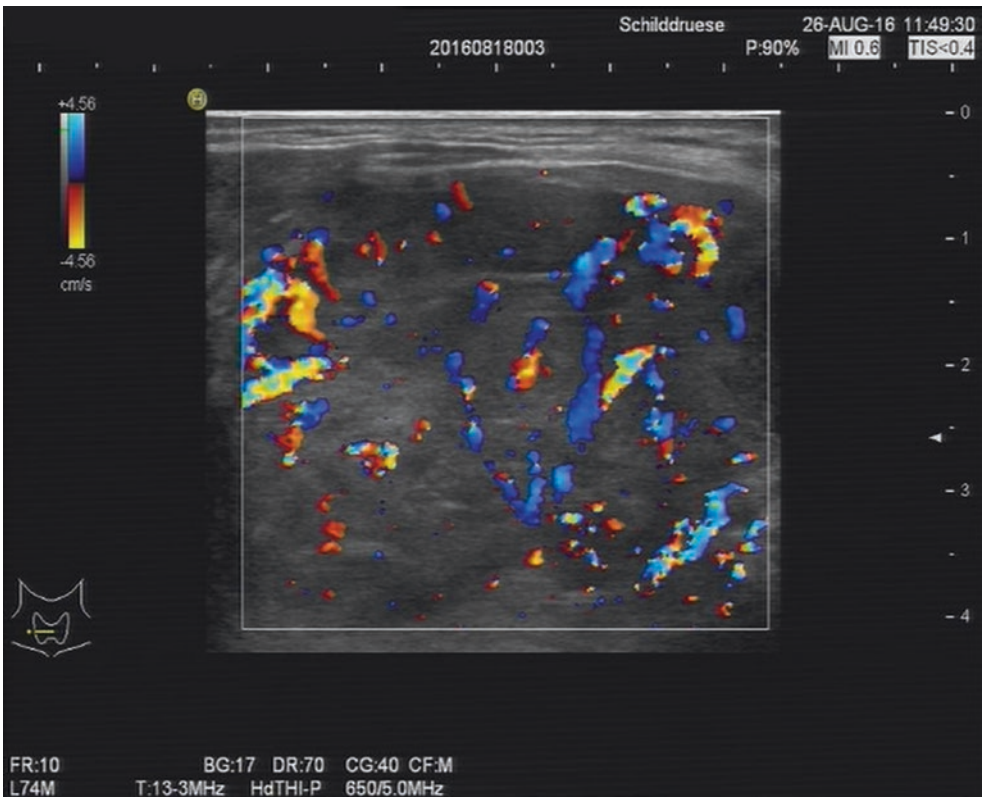

Fig. 12.26 A large, heterogeneous thyroid nodule with positive internal flow, very suspicious for malignancy

able to assess lymph nodes around the thyroid and paratracheal, prelaryngeal, and pretracheal lymph nodes to exclude or confirm potential metastatic disease. Enlarged lymph nodes in these levels can be the first sign of malignant disease.

Pure thyroid cysts are completely avascular, anechoic thyroid nodules (Fig. 12.27). The absence of vascularity can be proven using color Doppler [14].

12.2.7 Elastography

Elastography is a dynamic imaging technique that can help to distinguish differences in firmness between thyroid nodules and surrounding thyroid tissue. To get feedback on whether the thyroid nodule is soft or hard, it is important to use the US probe to compress the thyroid gland. The US device can measure tissue modification that happens under the compression of the probe, and the elasticity of the thyroid nodule can be interpreted and presented on a color scale. It has been empirically noted that thyroid masses related to malignant etiology are more likely to be hard (Fig. 12.28), whereas soft thyroid nodules (Fig. 12.29) tend to be benign. On our US machine, hard thyroid nodules can be seen as blue (Fig. 12.28), and soft nodules can be seen as red or green (Fig. 12.29) on the color scale [15]. This additional diagnostic information can help with decision-making (Video 12.7).

12.3 Thyroiditis

Thyroiditis is a group of inflammatory thyroid diseases with various causes. It is important to describe thyroiditis as a special entity dissociated from thyroid nodal diseases. The main difference between these two groups of thyroid disorders is that thyroid nodal disease is a localized change of thyroid tissue, whereas thyroiditis is usually a diffuse change affecting the whole thyroid gland.

Thyroiditis can be classified as one of several types:

- Chronic lymphocytic thyroiditis (Hashimoto thyroiditis) (Fig.12.30; Video 12.8)
- Subacute lymphocytic thyroiditis (postpartum thyroiditis and sporadic painless thyroiditis)
- Granulomatous thyroiditis (de Quervain's thyroiditis) (Fig. 12.31; Video 12.9)
- Microbial inflammatory thyroiditis (suppurative thyroiditis, acute thyroiditis)
- Invasive fibrous thyroiditis (Riedel's struma, Riedel's thyroiditis) (Fig. 12.32)

The changes of thyroiditis can be detected with US, and the diagnosis then can be determined, especially in patients with Hashimoto thyroiditis (the most common type, caused by thyroid antibodies). The thyroid changes will be more or less visible and are often pathognomonic. In Hashimoto thyroiditis, the thyroid is of small or normal size, and a lot of

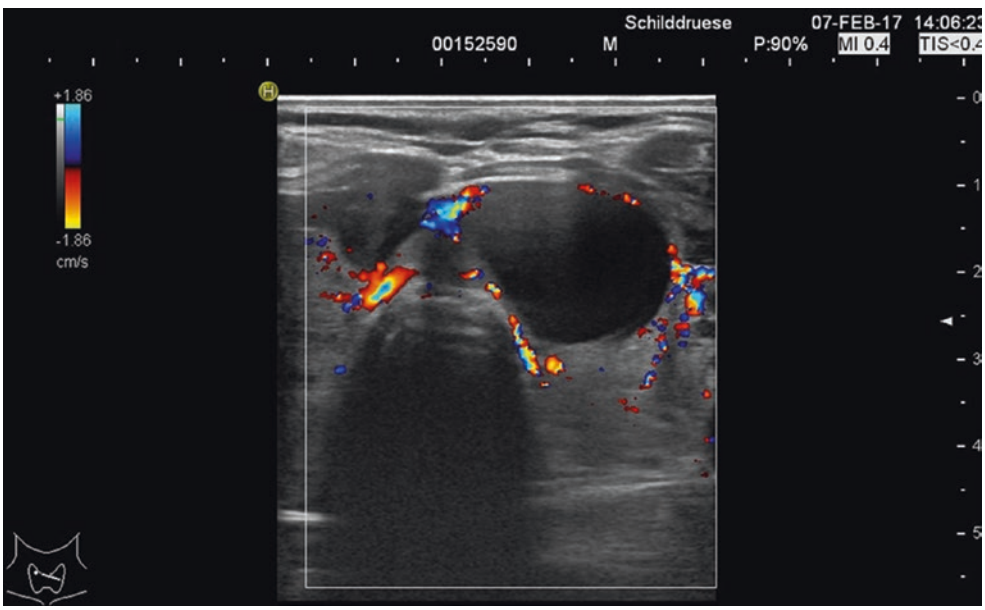

Fig. 12.27 Pure thyroid cyst, an avascular thyroid nodule

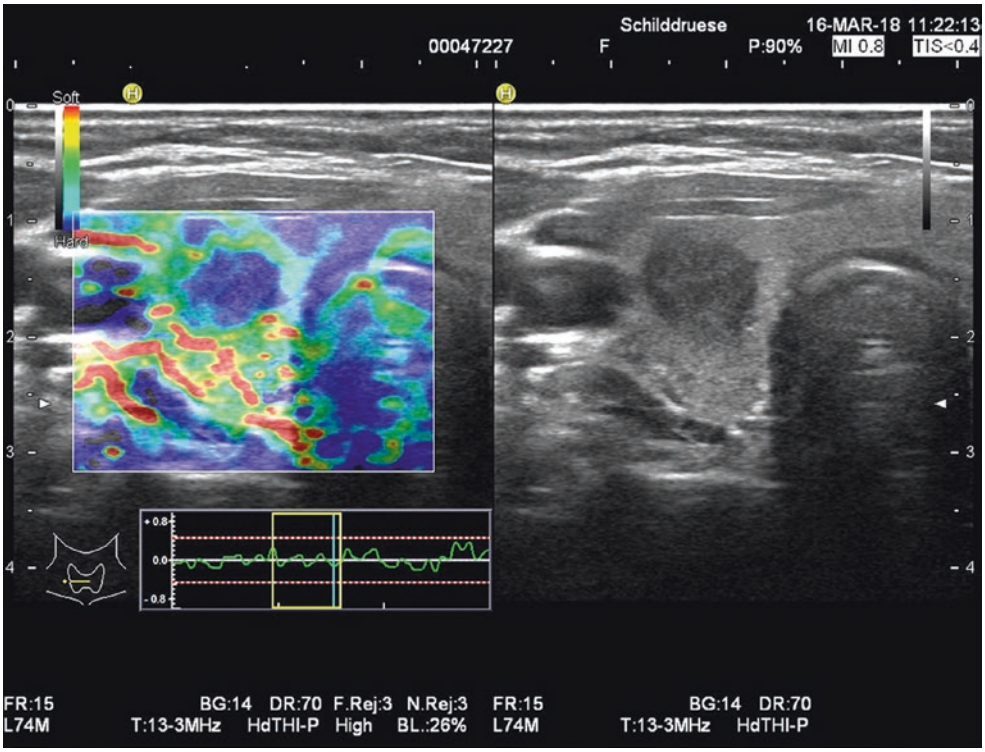

Fig. 12.28 Hypoechoic thyroid nodule with ill-defined margins; elastography (*left*) shows it to be hard (mostly blue). (Pathology report: follicular thyroid cancer)

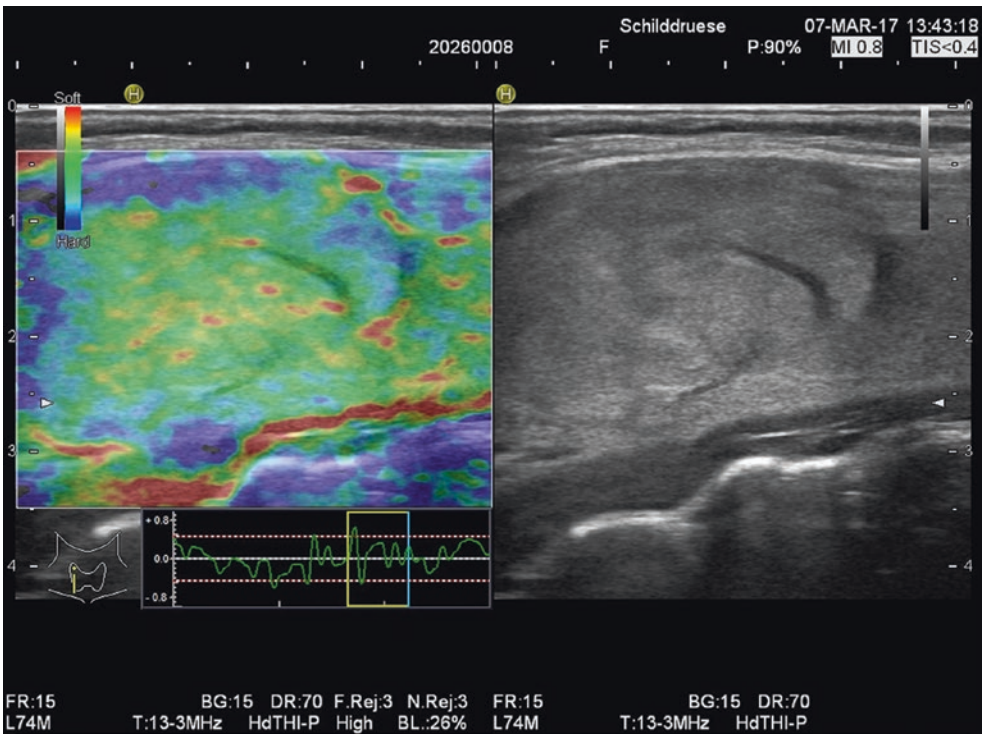

Fig. 12.29 A large, isoechoic nodule of the right thyroid lobe, without suspicious ultrasound characteristics; it is soft on elastography (mostly green)

Fig. 12.30 Thyroid of normal size, diffusely changed with many hypoechoic areas and hyperechoic lines—typical findings for Hashimoto thyroiditis

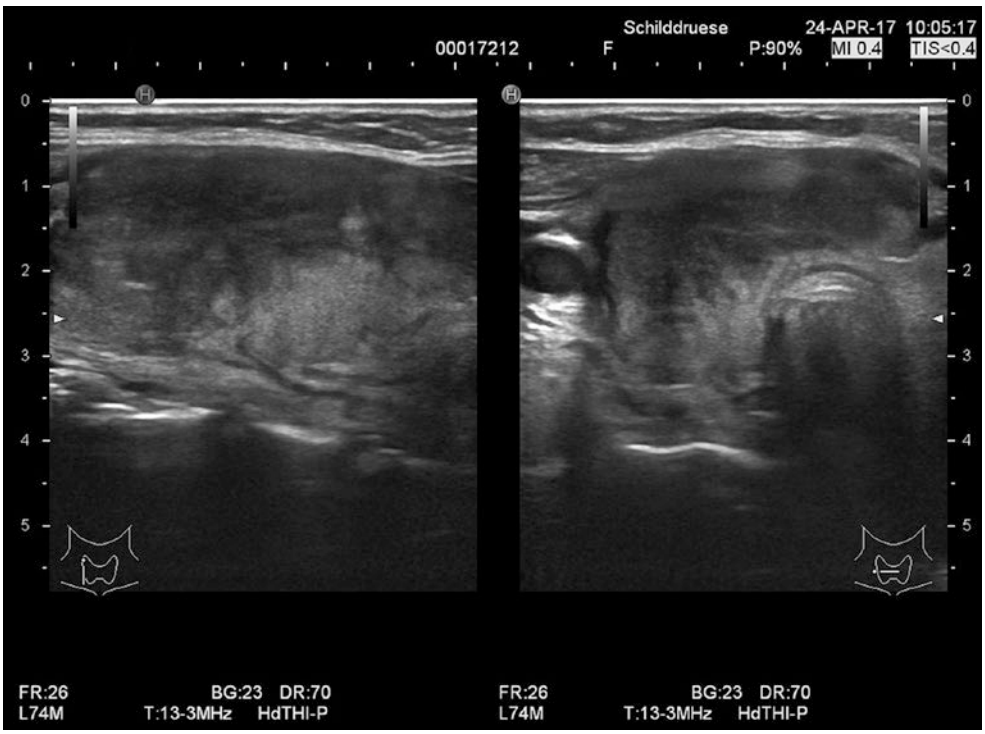

Fig. 12.31 Enlarged, heterogeneous right thyroid lobe with many hypoechoic areas of different sizes, which can be separated with small, hyperechoic part of the thyroid tissue, typical finding for de Quervain's thyroiditis

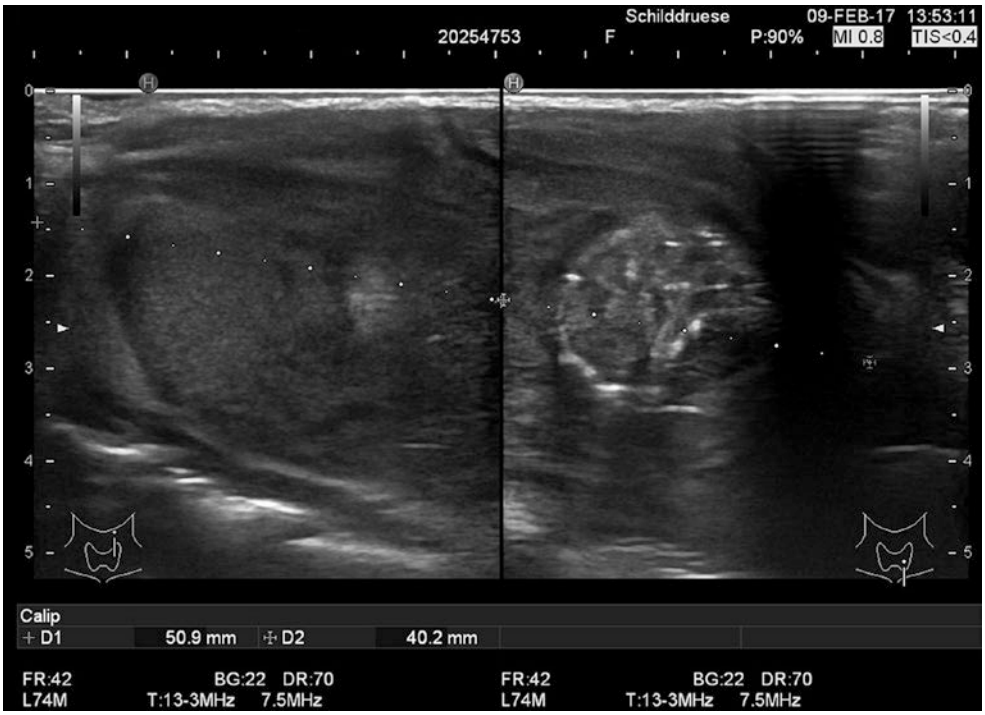

Fig. 12.32 Heterogeneous thyroid tissue with suspicious nodule in the lower pole of the left lobe. (Pathology report: Riedel's thyroiditis)

small, hypoechoic areas are surrounded by hyperechoic lines. Because this pattern sometimes gives an impression of thyroid nodules, it is called pseudonodular.

12.4 Graves' Disease

Graves' disease is an autoimmune thyroid disease characterized by positive specific thyroid-stimulating antibodies causing the production of an excessive amount of thyroid hormones. This condition is diagnosed with scintigraphy, positive thyroid antibodies, and specific thyroid US (Fig. 12.33). Although thyroid US can be specific, the first diagnostic tool after the diagnosis of hyperthyroidism should be thyroid scintigraphy. Performing US, we can usually see an enlarged, inhomogeneous thyroid, which may be hyperechoic, or a normal-size thyroid with diffuse changes (heterogeneous echotexture). The diffuse changes can be more or less visible depending on the stage of the disease [16].

12.5 Thyroid Nodule Guidelines and Classification

12.5.1 American Thyroid Association (ATA) Guidelines

In 2015, the American Thyroid Association (ATA) had presented guidelines for adult patients with thyroid nodules and differentiated thyroid cancer [17]. The part of the guidelines related to US can help us to determine the probability of thyroid malignancy using sonography. Five groups of nodules were described in regard to potential malignancy:

1. Benign (suspicion less than 1%): *Cyst* (Fig. 12.7)
   Pure cystic lesions do not express a high probability of malignancy. Because they are filled with liquid, there are not many cells capable of malignant alteration. They can usually be seen as a hypoechoic or anechoic nodule with or without posterior enhancement.
2. Very low suspicion (less than 3%): Spongiform nodules; partly cystic nodule without suspicious features (Fig. 12.16)
   Spongiform thyroid nodules (also known as "honeycomb" or "puff pastry") are thyroid changes without suspicious US features, usually organized in bundles of small, hypoechoic echogenic fields separated with hyperechoic palisades.
3. Low suspicion (5–10%):
   - Hyperechoic solid nodules with regular margin (Fig. 12.5)
   - Isoechoic solid nodules with regular margin (Fig. 12.6)
   - Partly cystic nodules with eccentric area (Fig. 12.10)
     Hyperechoic and isoechoic thyroid nodules do not have high potential for malignant alteration, especially when the nodules have regular margins. These kinds of nodules are easy to recognize. They can be situated in every part of the thyroid. Hyperechoic nodules are not as common as isoechoic. Nodules with partly cystic

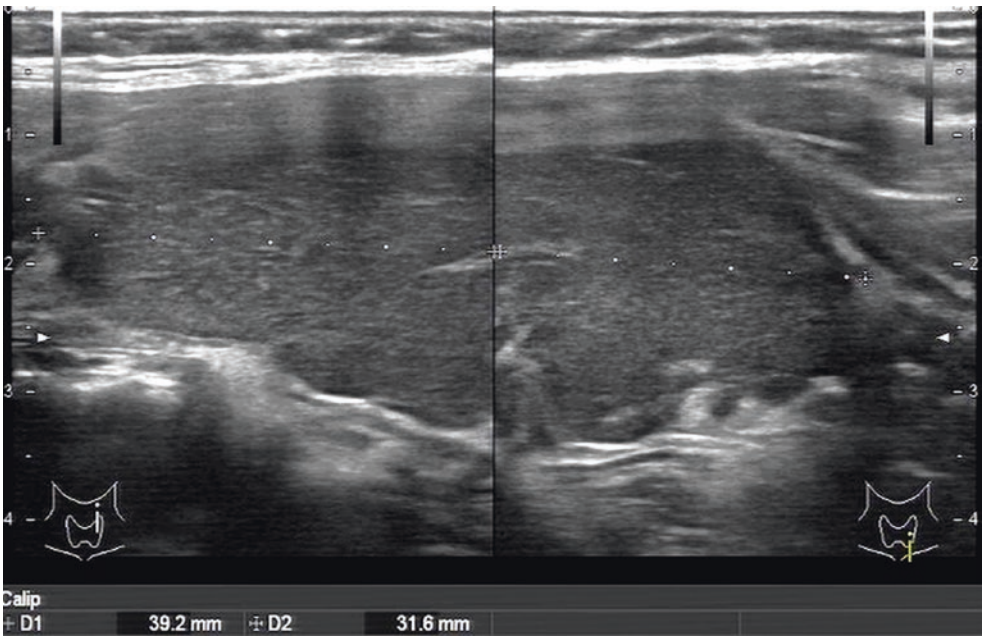

Fig. 12.33 Enlarged, heterogeneous left thyroid lobe with diffuse changes, relatively hyperechoic with many hyperechoic lines and no nodule—typical findings for Graves' disease

areas also belong in this group of nodules with low suspicion. The parts of the nodule that are not cystic have almost the same tendency to malignancy as a purely solid nodule with the same US characteristics.

4. Intermediate suspicion (10–20%): Hypoechoic solid nodules with regular margin (Figs. 12.1 and 12.4)

   Although hypoechoic nodules bear intermediate suspicion for thyroid cancer, only a minority of hypoechoic nodules are actually positive for malignancy (of course, without other suspicious US features). It is common to see a lot of hypoechoic nodules in clinical practice.

5. High suspicion (more than 70–90%):
   - Hypoechoic nodules with microcalcifications and irregular margin (Fig. 12.13)
   - Hypoechoic nodules with irregular margins (Fig. 12.18; Video 12.10)
   - Hypoechoic nodules that are taller than wide (Fig. 12.24)
   - Hypoechoic nodule with irregular margins and extrathyroidal extension (Fig. 12.19)
   - Hypoechoic nodule with interrupted rim calcification with soft-tissue extrusion, irregular margins, and surrounding suspicious lymph nodes

   To this group of thyroid nodules with high suspicion for thyroid cancer are assigned all the thyroid nodules with any suspicious US characteristic. Some of the unfavorable ultrasound features, like hypoechoic nodule with irregular margins and extrathyroidal extension, bear very high suspicion for malignancy. It is crucial to point out that all nodules with any of the abovementioned characteristics must be further examined, and these patients will probably have to undergo thyroid surgery.

The ATA risk stratification does take into consideration elastography and thyroid nodule vascularity [17, 18].

12.5.2 Thyroid Imaging Reporting and Data System (TIRADS) Classification

TIRADS is a classification system proposed by the American College of Radiology (ACR), which recommends which thyroid nodules require fine needle aspiration (FNA) biopsy and how often US follow-up is needed [19]. The recommendations are the result of a scoring system based on US findings. Five groups are designated as TIRADS 1 through TIRADS 5, with higher scores reflecting a higher probability of malignancy and a need for FNA biopsy. The following is a list of US features with the corresponding scores:

- *Composition*: Cystic or completely cystic, 0 points; spongiform, 0 points; mixed cystic and solid, 1 point; solid or almost completely solid, 2 points
- *Echogenicity*: Anechoic, 0 points; hyperechoic or isoechoic, 1 point; hypoechoic, 2 points; very hypoechoic, 3 points
- *Shape*: Wider than tall, 0 points; taller than wide, 3 points
- *Margin*: Smooth, 0 points; ill-defined, 0 points; lobulated or irregular, 2 points; extrathyroidal extension, 3 points
- *Echogenic foci*: None, 0 points; large comet-tail artifact, 0 points; macrocalcifications, 1 point; peripheral (rim) calcifications, 2 points; punctate echogenic foci, 3 points

The scoring divides nodules into the five TIRADS groups, with recommendations:

- *TIRADS1*: 0 points—benign, no FNA required
- *TIRADS2*: 2 points—not suspicious, no FNA required
- *TIRADS3*: 3 points—mildly suspicious; FNA if ≥2.5 cm, follow-up if ≥1.5 cm
- *TIRADS4*: 4–6 points—moderately suspicious; FNA if ≥1.5 cm, follow-up if ≥1 cm
- *TIRADS5*: ≥7 points or more—highly suspicious; FNA if ≥1 cm, follow-up if ≥0.5 cm

References

1. Ghervan C. Thyroid and parathyroid ultrasound. Med Ultrason. 2011;13:80–4.
2. Xie C, Cox P, Taylor N, LaPorte S. Ultrasonography of thyroid nodules: a pictorial review. Insights Imaging. 2016;7:77–86.
3. Tavares MR, Cruz JA, Waisberg DR, Toledo SP, Takeda FR, Cernea CR, et al. Lymph node distribution in the central compartment of the neck: an anatomic study. Head Neck. 2014;36:1425–30.
4. Cantisani V, Lodise P, Grazhdani H, Mancuso E, Maggini E, Di Rocco G, et al. Ultrasound elastography in the evaluation of thyroid pathology. Current status. Eur J Radiol. 2014;83:420–8.
5. Shin JJ, Caragacianu D, Randolph GW. Impact of thyroid nodule size on prevalence and post-test probability of malignancy: a systematic review. Laryngoscope. 2015;125:263–72.
6. Park M, Park SH, Kim EK, Yoon JH, Moon HJ, Lee HS, Kwak JY. Heterogeneous echogenicity of the underlying thyroid parenchyma: how does this affect the analysis of a thyroid nodule? BMC Cancer. 2013;13:550.
7. Popoveniuc G, Jonklaas J. Thyroid nodules. Med Clin North Am. 2012;96:329–49.
8. Wu H, Zhang B, Li J, Liu Q, Zhao T. Echogenic foci with comet-tail artifact in resected thyroid nodules: not an absolute predictor of benign disease. PLoS One. 2018;13:e0191505.
9. Virmani V, Hammond I. Sonographic patterns of benign thyroid nodules: verification at our institution. AJR Am J Roentgenol. 2011;196:891–5.
10. Campanella P, Ianni F, Rota CA, Corsello SM, Pontecorvi A. Quantification of cancer risk of each clinical and ultrasonographic suspicious feature of thyroid nodules: a systematic review and meta-analysis. Eur J Endocrinol. 2014;170:R203–11.
11. Yoon JH, Han K, Kim EK, Moon HJ, Kwak JY. Diagnosis and management of small thyroid nodules: a comparative study with six guidelines for thyroid nodules. Radiology. 2017;283:560–9.
12. Brito JP, Gionfriddo MR, Al Nofal A, Boehmer KR, Leppin AL, Reading C, et al. The accuracy of thyroid nodule ultrasound to predict thyroid cancer: systematic review and meta-analysis. J Clin Endocrinol Metab. 2014;99:1253–63.
13. Intenzo CM, Dam HQ, Manzone TA, Kim SM. Imaging of the thyroid in benign and malignant disease. Semin Nucl Med. 2012;42:49–61.
14. Sultan LR, Xiong H, Zafar HM, Schultz SM, Langer JE, Sehgal CM. Vascularity assessment of thyroid nodules by quantitative color Doppler ultrasound. Ultrasound Med Biol. 2015;41:1287–93.
15. Veer V, Puttagunta S. The role of elastography in evaluating thyroid nodules: a literature review and meta-analysis. Eur Arch Otorhinolaryngol. 2015;272:1845–55.
16. Pishdad P, Pishdad GR, Tavanaa S, Pishdad R, Jalli R. Thyroid ultrasonography in differentiation between Graves' disease and Hashimoto's thyroiditis. J Biomed Phys Eng. 2017;7:21–6.
17. Haugen BR, Alexander EK, Bible KC, Doherty GM, Mandel SJ, Nikiforov YE, 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. 2016;26:1–133.
18. Kim JY, Jung SL, Kim MK, Kim TJ, Byun JY. Differentiation of benign and malignant thyroid nodules based on the proportion of sponge-like areas on ultrasonography: imaging-pathologic correlation. Ultrasonography. 2015;34:304–11.
19. Grant EG, Tessler FN, Hoang JK, Langer JE, Beland MD, Berland LL, et al. Thyroid ultrasound reporting lexicon: white paper of the ACR Thyroid Imaging, Reporting and Data System (TIRADS) Committee. J Am Coll Radiol. 2015;12:1272–9.