Ovarian Masses

The Value of Acoustic Shadowing on Ultrasound Examination

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Adnexal lesions are a common finding in women and pose a clinical challenge since ovarian cancer is a highly lethal disease. However, most adnexal masses are benign, benefiting from a more conservative approach. In preoperative assessment, transvaginal ultrasound plays a key role in evaluating morphologic features that correlate with the risk of malignancy. The acoustic shadow is the loss of echo behind sound-absorbing components, such as calcifications or fibrous tissues, which are predominantly found in benign lesions. However, recognizing the acoustic shadow is a difficult skill to master, and its usefulness may be underappreciated.

Key Words—acoustics; adnexal diseases; ovarian cysts; ovarian neoplasms; preoperative care; ultrasonography

Adnexal lesions are routinely encountered in general practice since 35% of premenopausal, and 17% of postmenopausal women develop at least one pelvic mass during their lifetime.[1] The extensive differential diagnosis includes both gynecologic and nongynecologic etiologies.[2] Primary neoplasms of the ovary derive from several different tissue types, including epithelial, germ-cell, and sex cord-stromal. It is known that ovarian cancer (OvCa) is rare in women younger than 40, and most OvCa becomes clinically manifest after menopause.[2,3] The incidence of OvCa is low (1.2%), but the threshold for surgery to remove an adnexal mass is low as well since it is a highly lethal disease, ranking as the fifth most common cancer death among women in the United States.[4] The majority of the patients are diagnosed at an advanced stage and, therefore, experience overall poor survival (<30%).[4,5] Early intervention and referral to a gynecologic oncologist are known to significantly increase the chance of long-term survival if malignancy is found.[6,7] However, not every mass requires oncologic assessment, and most (around 85%) adnexal masses prove to be benign and can be managed in a more conservative, fertility-sparing way.[6–8] Even in the postmenopausal age group, most adnexal masses are benign, with serous or mucinous cystadenomas, simple cysts, and fibromas as the main diagnoses.[7,9] In the premenopausal group, the most prevalent benign lesions are endometriomas and mature cystic teratomas,[4] and it can be further subcategorized according to different age groups. Hermans et al[10] published a population-based cohort study among children,

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Abbreviations
IOTA, International Ovarian Tumor Analysis; MRI, magnetic resonance imaging; O-RADS, Ovarian-Adnexal Reporting and Data System; OvCa, ovarian cancer

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adolescents, and women of reproductive age, and found that while the incidence of adnexal masses increased exponentially with age, the risk of malignancy is highest in premenarchal children.[10] Still, adnexal lesions are rare in children and adolescents[11] (Figure 1).

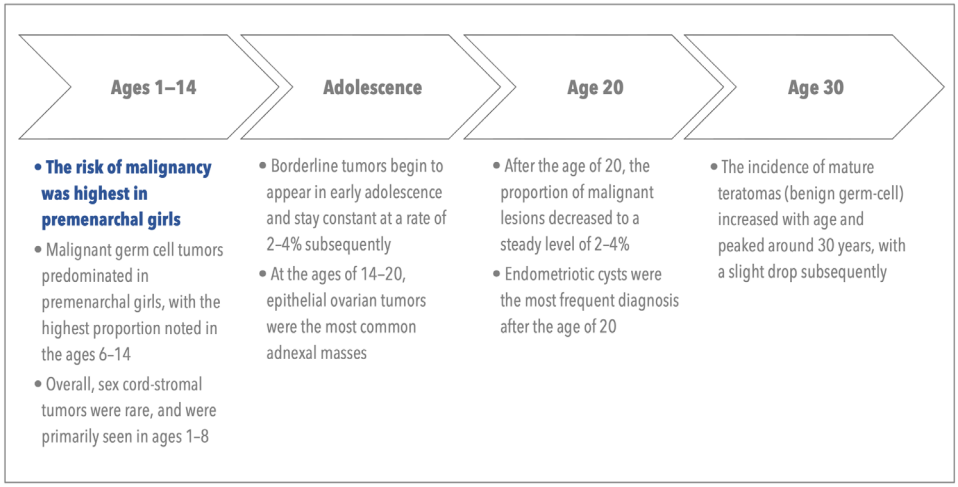
The correct diagnosis and optimal management are often difficult and require the integration of clinical history and physical examination, imaging, tumor markers, and integration of risk factors (eg, age, family history of cancer). Transvaginal ultrasound is the most important imaging modality to differentiate between benign and malignant adnexal masses in the preoperative assessment.[6,7,12] The sonographic assessment is based on several standardized features that correlate with the risk of malignancy. Acoustic shadowing is one of the characteristics that is associated with benign lesions. It is, however, not routinely searched for or recognized when evaluating patients. We discuss the significance of incorporating the acoustic shadow assessment as part of the routine practice, as well as part of all ultrasound-based risk models.

The Presence of Acoustic Shadowing

Acoustic shadow is an ultrasound imaging artifact occurring at boundaries between different tissue impedances, resulting in signal loss and a dark appearance.[13] It generally occurs behind structures that strongly absorb or reflect ultrasonic waves, such as bones, renal stones, or intrauterine devices. When assessing adnexal lesion, the presence or absence of the acoustic shadow is of primary importance, with no weight given to the thickness or the amount of shadowing. Timmerman et al[14] studied the sonographic manifestation of the adnexal lesion and found that acoustic shadow was present in 17.4% of benign tumors and a small number (4.2%) of malignant tumors. Araujo et al[15] also found that acoustic shadow, preoperatively noted in 30.2% of the patients studied, was strongly associated with benign lesions. Although the presence of a shadow is considered a benign predictor in adnexal masses, it may also be seen in malignant lesions.

Considering the origin of the shadowing in assessing and predicting malignancy is valuable. Wilson et al[16] point out that many solid components with fibromatous origin often present as hypoechoic lesions with acoustic shadowing. These manifestations correlate with benign findings on magnetic resonance imaging (MRI) scans, such as hypointensity on a T2-weighted MRI.[16] Furthermore, Sibal et al[17] studied 100 adnexal masses with 25 different histopathologic diagnoses and found that shadowing from fibrovascular tissue (high color Doppler score) was found to predict malignancy 80%–90% of the time.[17] However, 80% of adnexal masses with shadowing from cystic contents or solid tissue with inherent structural features (eg, fibroma) were benign.[17] Similarly, Hazan et al[18] found that high-intensity acoustic shadow was evident solely in benign tumors, as compared to

Figure 1. Adnexal masses in premenopausal women, modified from Hermans et al.[10]

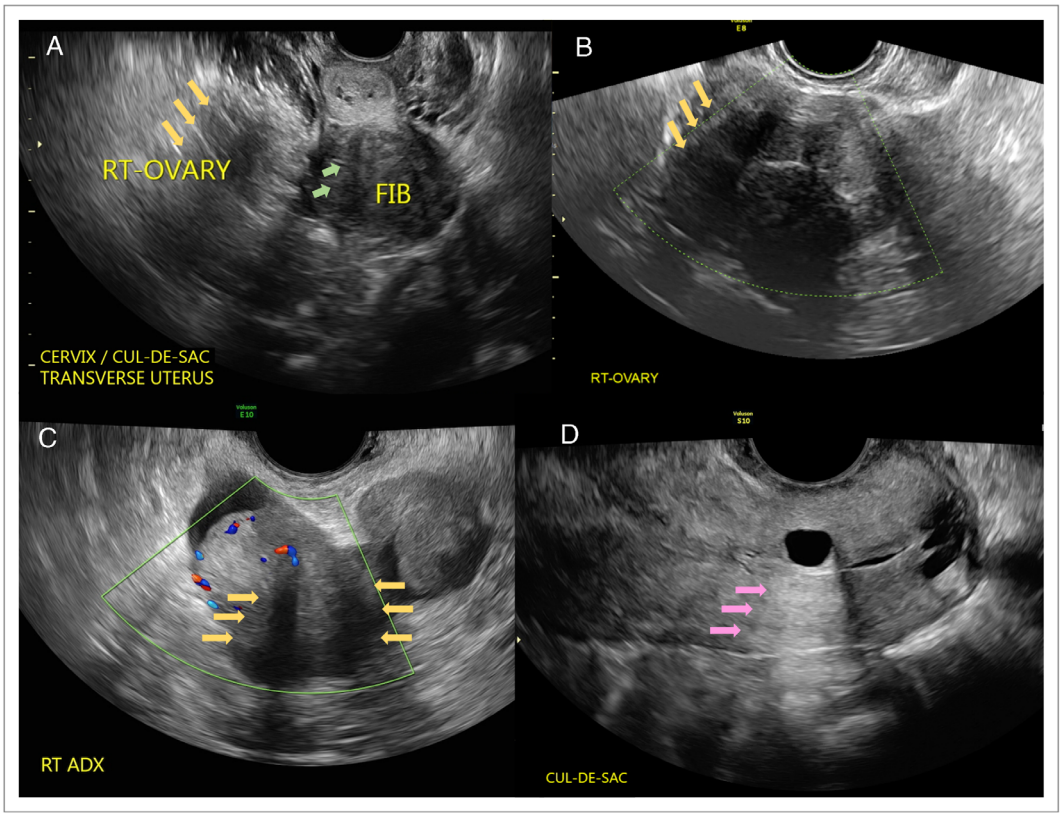


rich vascularity that was significantly correlated with malignant histology.[18] This suggests that although acoustic shadowing is usually a benign predictor, when encountering a lesion that also possesses internal blood flow, it should be considered suspicious, and the best approach would be to refer the patient to an expert or complete MRI imaging. Thus, understanding the nature of the acoustic shadow can lead to the correct preoperative diagnosis (Figure 2).

Challenges in Assessing Adnexal Masses

In 1989, Granberg et al[19] were the first to show the correlation between ultrasound mass characteristics and the risk of malignancy in ovarian lesions. Over the years, various approaches to characterizing adnexal masses have been used to help distinguish benign masses from malignancies. On ultrasound, the most common benign adnexal masses, with a classic appearance, include cystadenoma, hemorrhagic cyst, endometrioma, and mature cystic teratomas. Timmerman et al[14] found that instant diagnosis for these lesions, using the International Ovarian Tumor Analysis (IOTA) "easy descriptors" by experienced examiners, is feasible in 42%–46% of patients. Other nonovarian findings with a typical appearance include hydrosalpinx, para-ovarian cysts, and peritoneal inclusion cysts. For adnexal lesions judged to be benign, the risk of malignancy and acute complication is low, supporting conservative management and can be of value when counseling patients.[20–22] However, not all

Figure 2. Shadowing in various masses. **A**, Right ovary with a cystic lesion, lines and dots, acoustic shadow (yellow arrows), and color score 1 (no flow). The final pathology was a *dermoid tumor*. In addition, a uterine *leiomyoma* is present with a characteristic acoustic shadow (green arrows). **B**, An irregular solid lesion, acoustic shadow present (yellow arrows), color score 1 (no flow). The final pathology was an *ovarian fibroma*. **C**, An irregular solid lesion with internal blood flow and acoustic shadow (yellow arrows), thus, suspicious for malignancy. The final pathology was *Krukenberg tumor metastatic to the ovary*. **D**, The opposite of acoustic shadow: enhancement (pink arrows) behind a small cervical gland because sound travels faster in fluids. All cases are under an approved protocol by the institutional review board.



adnexal lesion has a classic appearance. Valentin et al[23] found that the histological types that present the greatest diagnostic difficulties were borderline tumors, struma ovarii, cystadenofibroma, and myomas. For those lesions, using ultrasound-based risk models can facilitate the classification between benign and malignant, thanks to the weight given to the acoustic shadowing.

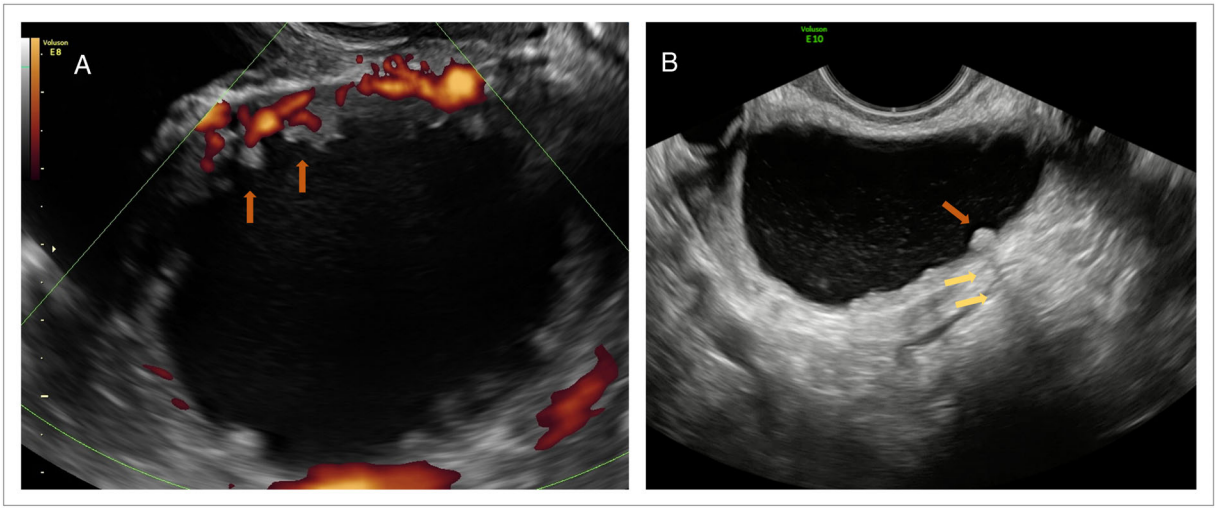
Lesions with papillary projections present a sonographic challenge. To facilitate the accurate preoperative assessment, Landolfo et al[24] showed that an acoustic shadow behind a papillary projection independently decreased the odds of malignancy. Timor-Tritsch et al[25] described the "shadow sign" as a pathognomonic characteristic of cystadenofibromas. They showed that cystadenofibromas are usually unilocular (rarely multilocular), and more than 50% have solid inner-wall fibrotic nodules, which are hyperechoic, avascular, and cast acoustic shadowing.[25] This is a reliable sign that can help differentiate cystadenofibromas from borderline ovarian tumors and ovarian malignancies[25,26] (Figure 3).

As stated previously, myomas are an important differential diagnosis of adnexal masses since subserosal myomas can mimic OvCa (Figure 2a). Leiomyomas usually appear as well-defined, solid, concentric, hypoechoic masses with a variable amount of acoustic shadowing at the edge of the lesion or as an internal fan-shaped shadow.[27,28] Depending on the level of calcification and fibrous tissue, leiomyomas may present with different echogenicity, usually as hyperechogenic or isoechogenic.[29,30] Recurrent, refractory shadowing in a pelvic mass can be a valuable diagnostic clue, indicating that the mass is likely to be a leiomyoma.[28]

Another particular challenge is the assessment of solid adnexal masses. Alcazar et al[31] examined the natural history of benign appearing purely solid ovarian lesions in a retrospective cohort of 99 asymptomatic postmenopausal women. They hypothesized that smooth, solid appearing masses with no or minimal blood flow and without ascites have a low risk of malignancy.[31] Considering all 99 cases, they found that the risk of malignancy was 2% (95% confidence interval, 0.1–7.5). Ovarian fibromas and fibrothecomas were the most common lesions diagnosed by pathology after surgery.[31] Fifty-seven women were managed with serial follow-up; no lesion demonstrated change, and the women remained asymptomatic, suggesting that conservative management might be an option.[31] Notably, acoustic shadowing was present in 59.6% of all cases[31] (Figure 2b).

Lastly, mature cystic teratomas may, sometimes, be confused with solid components (Figure 2a).

Figure 3. Adnexal lesions with papillary projections present a sonographic challenge. **A**, A unilocular solid lesion with more than four papillary projections (orange arrows), color Doppler score 3, and no acoustic shadow present. The final pathology was a *serous borderline tumor*. **B**, A unilocular solid lesion, with two papillary projections (orange arrows), color Doppler score 1 (no flow), acoustic shadow present (yellow arrows). The final pathology was a benign *serous cystadenofibroma*. All cases are under an approved protocol by the institutional review board.



Laing et al[32] showed that most mature teratomas contain a clump of hair, which both absorbs and reflects the ultrasound beam. The net effect is a focal hyperechogenic area that gradually attenuates sound and results in a characteristic gradual acoustic shadow.[32] Heremans et al[33] observed that most (81%) of mature teratoma had mixed cyst contents, and most (72%) manifested acoustic shadowing with no or minimal color Doppler signals.

In conclusion, many benign adnexal lesions with a solid component, including those that present the greatest diagnostic difficulties, will also demonstrate acoustic shadowing. This shadowing, which is of diagnostic utility, may easily be missed or ignored if shrewd attention is not paid during the imaging review. Valentin et al[23] demonstrated that an experienced ultrasound examiner using a high-end ultrasound system could be expected to

Table 1. History of Ultrasound-Based Scoring Systems

Scoring System	Date of Publication	Description
Granberg et al[19]	1989	The first to show the correlation between ultrasound macroscopic mass appearance and the risk of malignancy. They found that unilocular cyst seems to carry a very slight chance of malignancy, as compared to papillary vegetation that was most frequent in malignant tumors.
Risk of malignant index (RMI) I, II, and III[34–36]	1990, 1996, 1999	Menopausal status, level of CA-125 and ultrasound findings: multilocular cyst, solid area, metastases, ascites, bilateral lesions
Sassone scoring system[37]	1991	Morphological features: inner wall structure, wall thickness, septa, and echogenicity
Resistance index[38]	1991	The differences between peak systolic and maximum end-diastolic flow velocity divided by peak systolic flow velocity
Pulsatility index[39]	1991	The differences between peak systolic and end-diastolic flow velocity divided by the time averaged flow velocity
DePriest scoring system[40]	1993	Morphological features: tumor volume, wall structure, and septum structure
Lerner and Timor-Tritsch scoring system[41]	1994	Modification to the Sassone model, morphological features: wall structure, shadowing, septa, and echogenicity
Ferrazzi scoring system[42]	1997	Morphological features: wall structure, septa, vegetations, and echogenicity
Artificial neural network (ANN) 1[43]	1999	Menopausal status, level of CA-125, and ultrasound findings: papillary structures (>3 mm height) and color score
ANN 2[43]	1999	Menopausal status, level of CA-125, and ultrasound findings: papillary structures (>3 mm height), internal walls, unilocularity, ascites, and presence of bilateral lesions
Logistic regression (LR) models 1[44]	1999	Menopausal status, level of CA-125, and ultrasound findings: papillary projection (>3 mm height), color score
Modified morphology index[45]	2003	Modification of the classification reported by DePriest: tumor volume and wall morphology structure
LR models 2[46]	2005	Same variables as ANN 2
RMI IV[47]	2009	Same variables as RMI I–III + largest diameter of lesion

correctly discriminate between benign and malignant adnexal masses in >90% of all cases. However, that expertise and capability of pattern recognition are not easily transferred to less experienced examiners.

Acoustic Shadow in Predictive Models for Assessing Adnexal Masses

Over the years, different scoring systems, probability predictors based on logistic regression analysis, and mathematical models were developed with the intention of developing a standardized approach and facilitating the diagnosis for less-experienced examiners[34–47] (Table 1). Most ultrasound-based scoring models included morphology features such as wall structures or thickness, ovarian volume, and septation. Some models included Doppler velocimetry, echogenicity, or acoustic shadow. The IOTA group was one of the first to incorporate acoustic shadow as a key feature in the risk assessment tools for adnexal masses.[48] Currently, the most widely used ultrasound-based predictive models for assessing adnexal lesions are the IOTA Simple Rules,[49] the IOTA ADNEX model,[50] and the American College of Radiology Ovarian-Adnexal Reporting and Data System (O-RADS) model[51] (Tables 2–4). It should be noted that the current version of the O-RADS model does not take into account the presence or absence of an acoustic shadow.[51]

Table 2. The IOTA Simple Rules model

Benign Features (B)	Malignant Features (M)
A unilocular cyst (B1)	An irregular solid tumor (M1)
Presence of solid components for which the largest solid component is <7 mm in the largest diameter (B2)	Presence of ascites (M2)
Presence of acoustic shadows (B3)	At least four papillary structures (M3)
A smooth multilocular tumor (B4)	An irregular multilocular solid tumor with the largest diameter of at least 100 mm (M4)
No detectable blood flow on Doppler examination (B5)	A very high color content on color Doppler examination (M5)

Based on sonographic findings, three rules are applied:

- If only benign features are present, and there are no malignant features, the mass can be confidently considered benign.
- If only malignant features are present, in the absence of benign features, the mass is classified as malignant.
- If both malignant and benign features are present or none are, the mass is classified as inconclusive.

Modified from Timmerman et al.[49]

Table 3. The IOTA Assessment of Different NEoplasias in the adneXa (ADNEX) Model*

Three Clinical Predictors	Six Ultrasound Predictors
Age	The maximum diameter of the lesion
Serum CA-125 level[a]	The maximum diameter of the largest solid component of the lesion
Type of center (oncology centers vs. other hospitals)	Presence of more than ten cyst locules
	The number of papillary projections
	Presence of acoustic shadows
	Presence of ascites

Modified from Van Calster et al.[50]

*The ADNEX model is the first risk model to differentiate between benign and malignant tumors while offering sub-classification of malignancies into borderline tumors, Stage I and Stage II–IV primary cancers, and secondary metastatic tumors. This model has often been incorporated into ultrasound systems software for the semi-automatic calculation of risk. Link to the ADNEX model calculator—https://www.iotagroup.org/sites/default/files/adnexmodel/IOTA%20-%20ADNEX%20model.html

[a]The ADNEX model can be applied with or without serum CA-125 level. The omission of CA-125 has limited impact on the ADNEX model in differentiating between benign and malignant tumors overall; however, the inclusion of CA-125 level in risk calculations improves the differentiation between Stage-II–IV ovarian cancer and the other malignancy subtypes.[52]

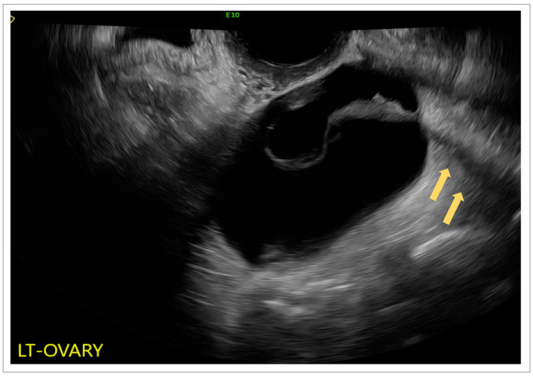
Table 4. The American College of Radiology Ovarian-Adnexal Reporting and Data System (O-RADS) Ultrasound Risk Stratification Model

O-RADS Score	Risk Category
O-RADS 0	Incomplete evaluation
O-RADS 1	Physiologic category, normal ovary
O-RADS 2	Almost certainly benign category (<1% risk of malignancy)
O-RADS 3	Low risk of malignancy (1% to 10% risk of malignancy)
O-RADS 4	Intermediate risk of malignancy (10% to 50% risk of malignancy)
O-RADS 5	High risk of malignancy (≥50% risk of malignancy)

Modified from Andreotti et al.[51]

The value of the acoustic shadow and the utility of the ultrasound-based risk model for the less-experienced examiners can be highlighted through an example (Figure 4). For a postmenopausal woman with a multilocular solid lesion with acoustic shadowing and color score 1 (no flow), using the ADNEX model,[50] the risk of malignancy would be calculated as 2% (rather than 17.7% when excluding the acoustic shadowing) (Figure 5). Using the Simple Rules,[49] the lesion would be classified as benign based on B3-features without M-features (rather than inconclusive when excluding the acoustic shadowing). However, the O-RADS[51] score would be 4 (10%–50% risk of malignancy) and would have stayed the same with or without acoustic shadowing, emphasizing that a slight change of the ultrasound parameters can dramatically alter the presumed diagnosis and the patient's management. For a younger patient who desires to maintain fertility, avoiding surgery for such a benign mass might be an option.

Figure 4. Ovarian serous cystadenofibroma in a 70-year-old woman. Transvaginal ultrasound shows a multilocular solid lesion with a maximum diameter of 70.8 mm, the maximum diameter of the solid component was 9.8 mm (not present in the attached image), color Doppler score 1 (no flow), an acoustic shadow was present (yellow arrows), and no ascites noted. The case is under an approved protocol by the institutional review board.



Pragmatic Approach to Visualizing the Acoustic Shadow

More attention should be given to the acoustic shadow as an essential parameter. We suggest searching in a systematic manner for a change in the echogenicity of the tissue, especially behind every solid component.

Figure 5. Assessment of the lesion from the presented case and Figure 4, final pathology was ovarian serous cystadenofibroma. **A**, Assessment using the ADNEX model, omitting the acoustic shadow, the risk of malignancy was calculated as 17.7%. **B**, Evaluation of the lesion, including the acoustic shadow, the risk of malignancy was calculated as 2%.

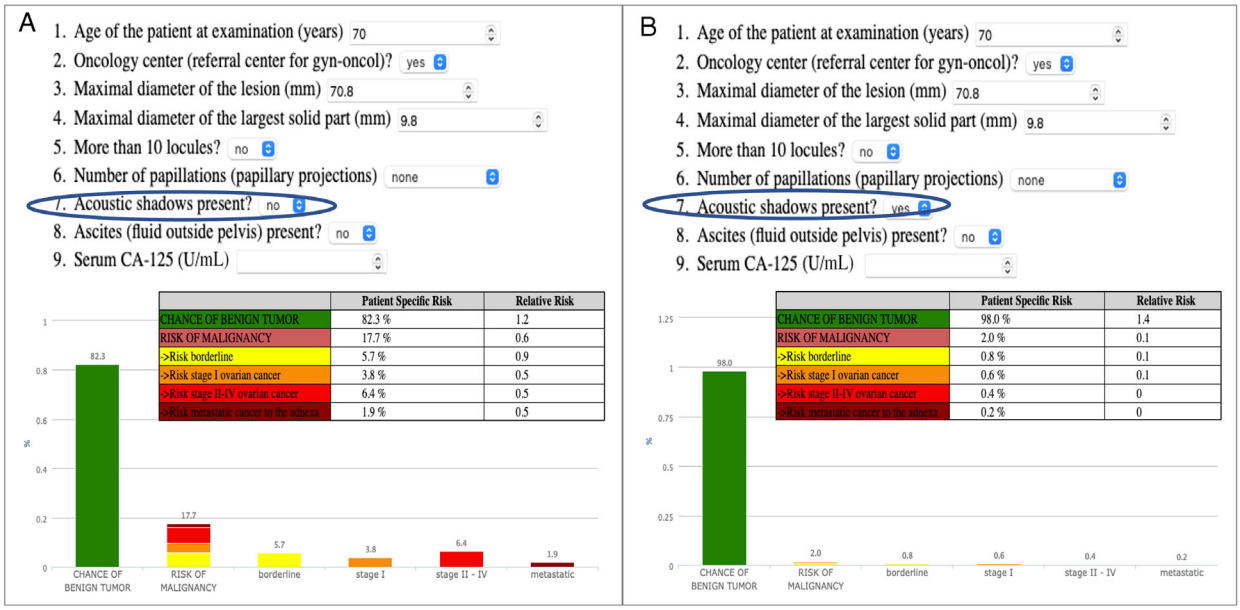


Figure 6. Left adnexal lesion and acoustic shadow (red arrows) that is secondary to an adjutant blood vessel (pink arrow), and not from the lesion. The case is under an approved protocol by the institutional review board.

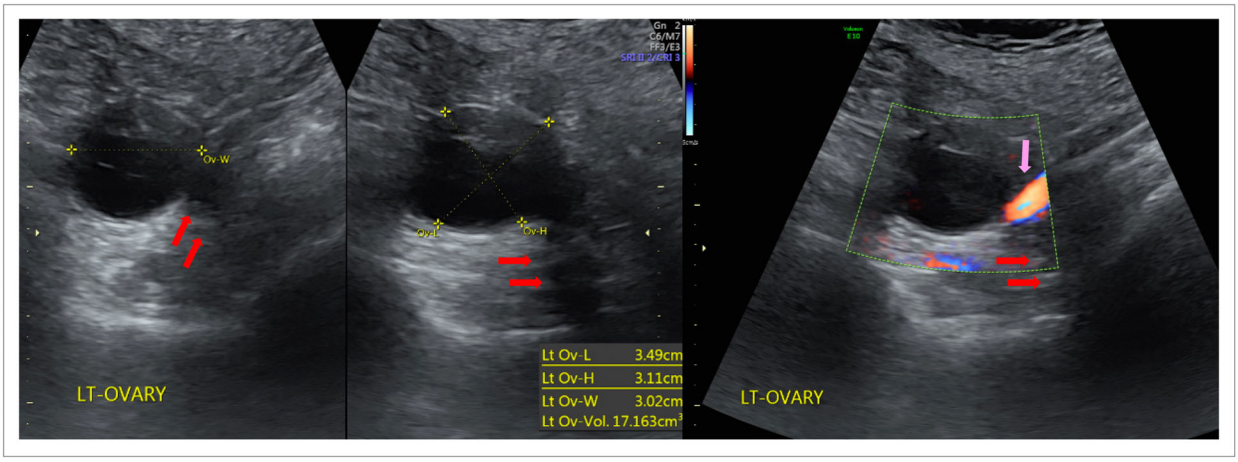
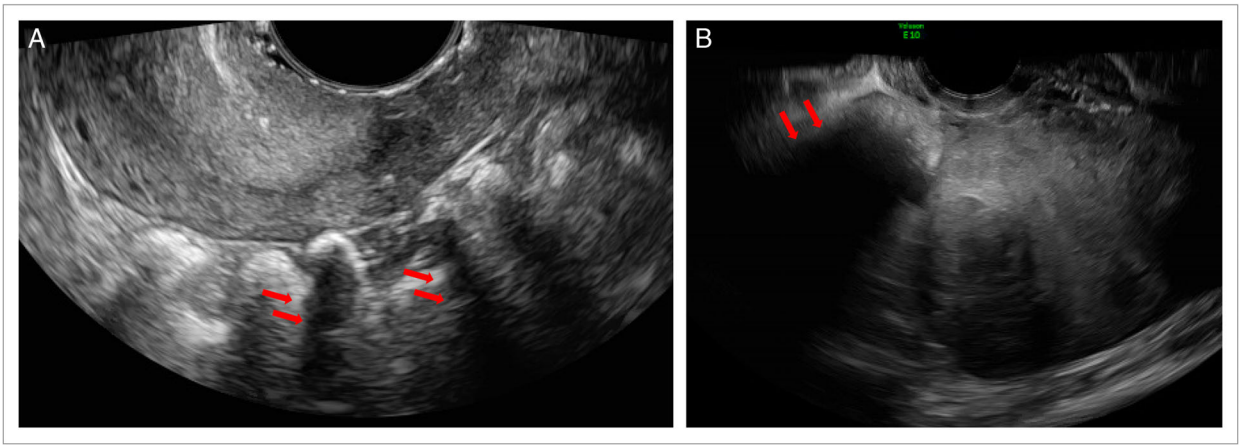


Figure 7. A,**B**, Acoustic shadowing secondary to bowels (red arrows). All cases are under an approved protocol by the institutional review board.



This approach will improve the sonographer's and physician's ability to recognize the signal loss, even when the shadow is subtle and thin (Figure 4). A possible challenge is to differentiate shadowing that arises from the lesion's component, as compared to shadowing secondary to tissue boundaries, adjutant blood vessels (Figure 6), or bowels (Figure 7). Evaluating video clips, if available, may help both with recognizing the easily missed thin shadow, as well as help, with assessing its origin. Thus, routinely saving the video clips will enhance the examiner's performance. Using the IOTA models compels the examiner to look for the acoustic shadow, potentially leading to a more accurate preoperative diagnosis, reducing further examination with computed tomography or MRI, reducing the referrals to subspecialties, and most importantly, reducing unnecessary surgeries.

Conclusion

Differentiating between a benign and malignant mass is crucial for the follow-up and management of patients. Integrating the acoustic shadow which

usually correlates with benign lesions, in the adnexal survey, will ultimately reduce unnecessary surgeries, expenses, and morbidity.

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