Imaging of Female Pelvic Malignancies Regarding MRI, CT, and PET/CT

Part 2

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Purpose: To compose diagnostic standard operating procedures for both clinical and imaging assessment for vulvar and vaginal cancer, for vaginal sarcoma, and for ovarian cancer.
Methods: The literature was reviewed for diagnosing the above mentioned malignancies in the female pelvis. Special focus herein lies in tumor representation in MRI, followed by the evaluation of CT and PET/CT for this topic.
Conclusion: MRI is a useful additional diagnostic complement but by no means replaces established methods of gynecologic diagnostics and ultrasound. In fact, MRI is only implemented in the guidelines for vulvar cancer. According to the current literature, CT is still the cross-sectional imaging modality of choice for evaluating ovarian cancer. PET/CT appears to have advantages for staging and follow-up in sarcomas and cancers of the ovaries.

Key Words: Vulvar cancer · Vaginal cancer · Vaginal sarcoma · Ovarian cancer · MRI · CT · PET/CT

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Bildgebung weiblicher Beckentumoren unter Berücksichtigung von MRT, CT und PET/CT: Teil 2

Ziel: Übersicht der aktuellen bildgebenden Diagnostik des Vulva- und des Vaginalkarzinoms, des Vaginalsarkoms und des Ovarialkarzinoms.
Methode: Durchsicht der Fachliteratur und Erstellung einer Übersicht der Diagnostik weiblicher Beckentumoren mittels MRT und CT sowie PET/CT mit Bildbeispielen unter Einschluss der tumorbezogenen Staging-Kriterien sowie empfohlenen MRT-Sequenzen.
Schlussfolgerung: Die MRT ist neben der gynäkologischen Untersuchung und dem Ultraschall eine nützliche bildgebende Ergänzung in der Diagnostik. Allerdings ist die MRT bisher nur in den Leitlinien des Vulvakarzinoms verankert. Für die Diagnostik des Ovarialkarzinoms ist die CT weiterhin Schnittbildgebung der Wahl. Die PET/CT scheint vorteilhaft beim Staging und beim Follow-up von Sarkomen und Ovarialkarzinomen zu sein.

Schlüsselwörter: Vulvakarzinom · Vaginalkarzinom · Vaginalsarkom · Ovarialkarzinom · MRT · CT · PET/CT

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Introduction

The prognosis in women with gynecologic malignancies like vulvar and vaginal cancer or ovarian cancer not only depends on local tumor spread but also on a wide range of additional findings, such as positive lymph nodes, ascites, or distant metastases. Cross-sectional imaging modalities, including ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) have increasingly been used for optimal treatment planning in gynecologic malignancies. Their staging criteria are based on the well-established International Federation of Gynecologists and Obstetricians (FIGO) staging system and the TNM classification system [33, 42]. Positron emission tomography (PET), especially if combined with CT (PET/CT) might have a benefit in staging and restaging gynecological malignancies, especially regarding lymph node metastases or recurrent tumor due to the simultaneous availability of functional and anatomical information [10, 27, 30, 37]. This paper emphasizes the role of cross-sectional imaging modalities in pretreatment staging and restaging of gynecological pelvic malignancies.

Radiological Diagnostics

CT is widely used, being the gold standard in oncology for initial staging and re-evaluation after treatment. It still plays a crucial role in systemic imaging of ovarian malignancies [6, 20, 25, 26, 31, 36, 37]. However, CT is limited by not only lower soft tissue contrast compared to MRI but also notable radiation exposure for patients. In addition, because the differentiation of recurrent tumor and radiation fibrosis is challenging on CT, MRI has become the most valuable imaging tool for diagnosing pelvic tumors in women [26]. Due to a wide variety of possible imaging sequences, high spatial resolution, and superior soft tissue contrast, nonenhanced MRI can often already provide sufficient information without the need of contrast agent application. Imaging evaluation may be improved by preparing the patient with a moderately filled bladder with urine, the application of an antiperistaltic agent i.v. (i.e., butylscopolamine) and by distending the vagina with sterile ultrasound contact gel [3, 4, 15, 46].

T1-weighted sequences easily depict pelvic structures from fat tissue, whereas T2-weighted sequences allow for the distinction of pelvic organs as well as differentiation of their internal composition and homogeneity. However, for distinguishing tumor recurrence from scar tissue, the application of contrast agent i.v. is crucial.

An additional diagnostic imaging tool in MRI is an endorectal coil. Due to its positioning inside the rectum, the endorectal coil provides more reliable tissue differentiation of all pelvic organs due to the high spatial resolution in a smaller field of view (FOV) at 1.5 T [22, 29, 35, 38].

For three-dimensional (3D) radiation planning, both CT and MRI are used to especially protect healthy tissue surrounding the tumor. Whereas the CT presents precise and clear 3D information regarding a patient's geometrical data and electron density distribution, MRI has, due to its good soft tissue differentiation, advantages in defining the tissue volume needing

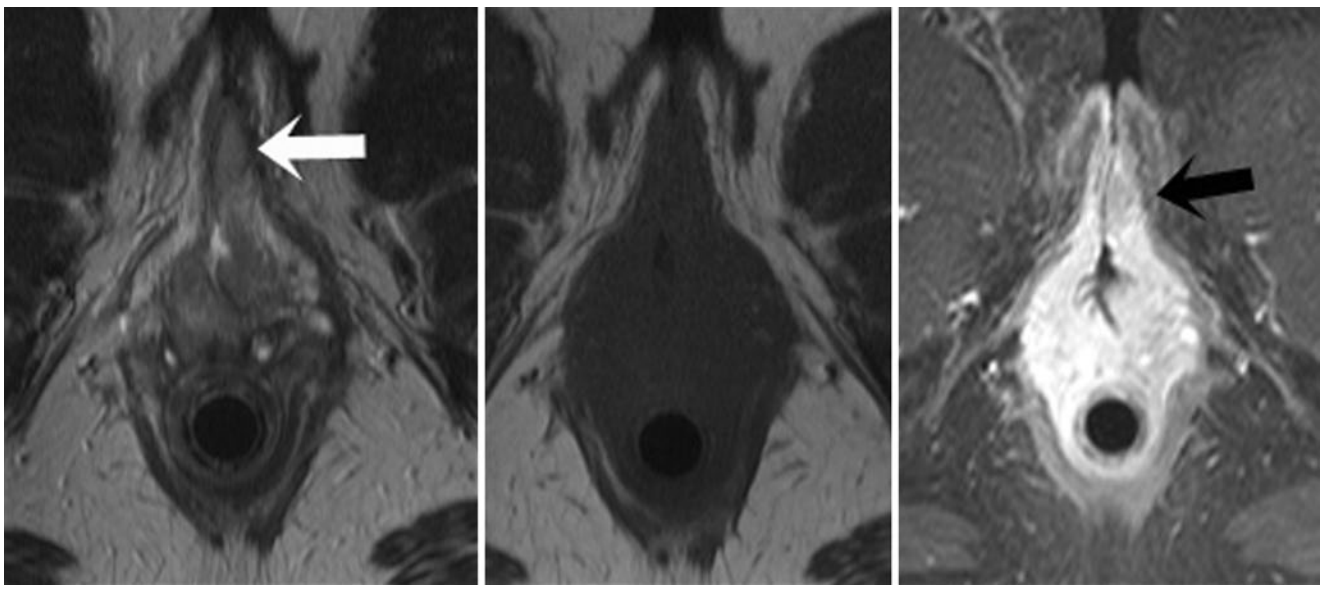

Figure 1. MRI with high spatial resolution in the transversal plane: hyperintense mass of the left labia in the T2-weighted sequence, longest diameter less than 2 cm (*white arrow*). In the T1-weighted sequence, no differentiation of the surrounding tissue is possible. After Gd i.v. the tumor is less contrast enhanced than the surrounding structures (*black arrow*). Histopathological result was vulvar cancer stage T1a.

Abbildung 1. In der transversalen hochaufgelösten T2w Nachweis einer hyperintensen Strukturvermehrung in der linken Labie mit einem Längsdurchmesser von weniger als 2 cm (*weißer Pfeil*). In der T1w ist keine Differenzierung zum umgebenden Gewebe möglich. Nach i.v. Kontrastmittelgabe nimmt der Tumor weniger Kontrastmittel auf als das umgebende Gewebe (*schwarzer Pfeil*). Histologisch gesichertes Vulvakarzinom im Stadium T1a.

radiation (gross tumor volume (GTV), clinical target volume (CTV), and planning target volume (PTV)) [39].

Around the gross tumor volume, which is defined by three planes in the MRI, a safety margin is added to define the CTV. This integrates possible, not yet visible, tumor areas and may also include lymph nodes. This gathered information can be transported to the CT performed for planning the radiation, if identical patient positioning was kept [39]. The brachytherapy finds use in patients with vaginal and vulvar malignancies [41].

Becoming of increasing interest is PET, a molecular imaging technique which can visualize metabolic differences between tissues and, therefore, might depict suspicious lesions. Its benefit lies in detecting recurrent tumor and the distinction between scar and malignant tissue. Normally the isotope used is ^{18}F-fluordeoxyglucose (^{18}F-FDG)-PET. Unfortunately, it has its limitation in the difficulty of depicting tumor lesions precisely due to accumulation, also in normal tissues or inflammatory lesions [37].

For the aforementioned female pelvic malignancies, operating procedures and MRI findings are described in detail in the following, while complementary information about CT and PET/CT findings is mentioned.

Vulvar Cancer

General Information

About 4% of all genital cancers in women have their origin in the vulva. The incidence is about 2/100,000 women every year [16]. In premenopausal women, 40–60% of malignant cancers of the vulva are associated with the human papilloma virus (HPV) [43]. HPV-negative cancers are mostly unifocal, diagnosed in postmenopausal women, and often show a fibromyxoid stroma reaction [40]. Growth and infiltration will directly involve the vagina, urethra, perineum, and/or anus. Inguinal and femoral lymph nodes may be affected in a noncontiguous manner. Pelvic lymph nodes are not affected in the majority of cases. Distant metastases into lung, liver, or bones are rarely observed.

A further malignancy worth mentioning is the cancer of Bartholin's gland with a percentage of 1–7% of all vulvar cancers [24]. The incidence peaks at 55 years of age. Frequently, the tumor is mistaken for an abscess. In 33–47% of cases, ipsilateral lymph nodes and, in 5–14% of cases, contralateral lymph nodes are affected. Distant metastases are rare.

Diagnostic Standard Operating Procedure

The diagnostic pathway for vulvar cancer almost completely relies on clinical examination, i.e., inspection of the vulva and palpation of the tumor as well as the inguinal lymph nodes. In early stages, the disease can be diagnosed with a small biopsy often taken during clinical examination without further clinical

Table 1. Staging of vulvar cancer. FIGO: International Federation of Gynecology and Obstetrics staging system, TNM: Tumor, Node, Metastasis classification system.

Tabelle 1. FIGO- und TNM-Klassifikation des Vulvakarzinoms. FIGO: International Federation of Gynecology and Obstetrics, TNM: Tumor, Node, Metastasis

Vulvar cancer	FIGO	TNM
Tumor confined to the vulva	I	T1
Lesions ≤ 2 cm in size, confined to the vulva or perineum and with stromal invasion ≤ 1.0 mm, no nodal metastasis	Ia	T1a
Lesions > 2 cm in size or with stromal invasion > 1.0 mm, confined to the vulva or perineum, with negative nodes	Ib	T1b
Tumor of any size with extension to adjacent perineal structures (1/3 lower urethra, 1/3 lower vagina, anus) with negative nodes	II	T2
Tumor of any size with or without extension to adjacent perineal structures (1/3 lower urethra, 1/3 lower vagina, anus) with positive inguinofemoral lymph nodes	III	T3
With 1 lymph node metastasis (≥ 5 mm), or	IIIa	
1–2 lymph node metastasis(es) (< 5 mm)		
With 2 or more lymph node metastases (≥ 5 mm), or	IIIb	
3 or more lymph node metastases (< 5 mm)		
With positive nodes with extracapsular spread	IIIc	
Tumor invades other regional (2/3 upper urethra, 2/3 upper vagina), or distant structures	IV	T4
Tumor invades any of the following:	IVa	
upper urethral and/or vaginal mucosa, bladder mucosa, rectal mucosa, or fixed to pelvic bone, or		
fixed or ulcerated inguinofemoral lymph nodes		
Any distant metastasis including pelvic lymph nodes	IVb	M1

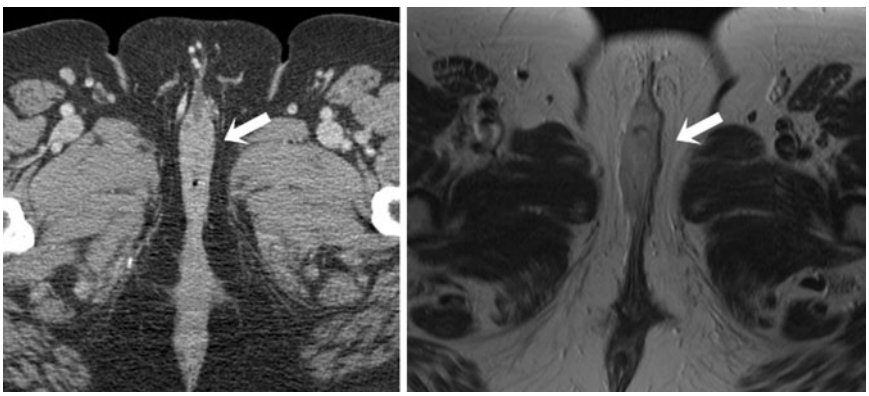

Figure 2. CT scan in the axial plane with i.v. contrast media (*left*) and the T2-weighted sequence in the transversal plane with high spatial resolution (*right*). In MRI, a hyperintense mass in the vulva can be visualized (*white arrows*). Histopathological result was vulvar cancer stage T1b.

Abbildung 2. Histologisch gesichertes Vulvakarzinom im Stadium T1b, *links* das kontrastmittelgestützte CT axial, *rechts* die hochaufgelöste T2w in transversaler Ebene mit einer hyperintensen Gewebsvermehrung vulvär (*weißer Pfeil*).

Table 2. Recommended MRI sequences for malignancies of the vulva (1) and the vagina (2). Special orientation of the slices, dependent on the tumor entity, is required (see numbers in brackets). T2w: T2-weighted, T1w: T1-weighted, tra: transverse, sag: sagittal, cor: coronal, fs fat saturated, TR: repetition time, TE: echo time, FOV: field of view, Gd: gadolinium.

Tabelle 2. Empfohlene MRT-Sequenzen für Tumoren von Vulva (1) und Vagina (2). Abhängig von der Tumorentität müssen die Sequenzen speziell gekippt werden (siehe Nummern in Klammern). T2w: T2-gewichtet, T1w: T1-gewichtet, tra: transversal, sag: sagittal, cor: koronal, fs: fettgesättigt, TR: Repetitionszeit, TE: Echozeit, FOV: field of view, Gd: Gadolinium.

Sequence		Plane	fs	TR (ms)	TE (ms)	FOV (mm)	Slice thickness (mm)	Matrix	Orientation (parallel to)
Turbo spin echo	T2w	sag	/	4,330	85	250	4	512	–
Turbo spin echo	T2w	tra oblique	/	3,950	92	280	4	512	1) short axis of the urethra 2) short axis of the vagina
Incoherent gradient echo (gradient spoiled) 2D nonenhanced	T1w	tra oblique	+	128	4.76	350	6	256	1) short axis of the urethra 2) short axis of the vagina
Turbo spin echo	T2w	cor oblique	/	3,950	92	300	4	512	1) long axis of the urethra 2) long axis of the vagina
Turbo spin echo Gd i.v.	T1w	tra oblique	+	470	12	350	4	384	1) short axis of the urethra 2) short axis of the vagina

effort or imaging. However, imaging modalities such as CT or MRI are recommended for FIGO stage II or higher (Table 1) [2].

There are no validated data for diagnostic impact of PET/CT in staging vulvar cancer.

Radiological Findings

The local staging of vulvar cancer is generally achieved by clinical inspection and palpation. However, imaging modalities play an essential role in assessing the infiltration depth into surrounding tissues, positive lymph nodes, ascites, and distant metastases [19]. Whereas CT is mainly employed for the assessment of lymph nodes, distant metastases, and peritoneal carcinomatosis, MRI appears to be superior for imaging the local situation in cases where other diagnostic options such as cysto- or rectoscopy are impracticable due to tumor size. T2-weighted turbo spin echo (TSE) sequences with high spatial resolution in the sagittal and transversal oblique (short urethral axis for vulvar cancer and short vaginal axis for vaginal cancer) planes are essential; additionally, T1-weighted TSE images in sagittal and transversal plane with and without contrast enhancement are recommended (Table 2). The degree of infiltration of the urethra is relevant for the tumor staging and can be ideally evaluated in T2-weigted sequences with high spatial resolution in sagittal and transversal oblique (short axis of the urethra) plane. In addition, T1-weighted sequences pre- and post-contrast may be helpful. Because of the hypointense presentation of the fat layer around the urethra, fat saturation at T1-weighted sequence is not helpful (Figures 1 and 2) [46].

Vaginal Cancer

General Information

Vaginal cancer is only to be referred to as a term if its primary origin is the vagina. In case of other female pelvic cancers in the patient's history, such as cervical cancer, a distant metastatic process needs to be taken into consideration. About one third of the cancerous lesions develop out of an invasive cervical cancer or a cervical intraepithelial neoplasia (CIN) [1]. According to the International Federation of Gynecology and Obstetrics, a squamous cell carcinoma occurring within 5 years of treatment for a vulvar or cervical cancer is considered a recurrence of the vulvar or cervical tumor rather than a new primary focus [44]. Primary cancer of the vagina, i.e., squamous cell carcinomas, has a low incidence (0.7/100,000 women; < 2% of all female malignant genital tract cancers) and is diagnosed in 15% of malignant vaginal tumors. It is often located near the posterior vaginal fornix and infiltrates into the vaginal cavity and often occupies the upper third of the vagina. Infiltration directly into the cervix, the uterus, the ovaries, the bladder, or the intestinal tract is often seen [43]. Mostly postmenopausal women are affected [18, 28, 43].

Diagnostic Standard Operating Procedure

Besides the standard procedures such as gynecological and colposcopic examinations and cytological biopsy, further imaging, e.g., MRI or CT, requires individual discussion and is not explicitly recommended by recent guidelines (Table 3) [1].

There are no validated data for diagnostic impact of PET/CT in staging vaginal cancer.

Table 3. Staging of vaginal cancer. FIGO: International Federation of Gynecology and Obstetrics staging system, TNM: Tumor, Node, Metastasis classification system.

Tabelle 3. FIGO- und TNM-Klassifikation des Vaginalkarzinoms. FIGO: International Federation of Gynecology and Obstetrics , TNM: Tumor, Node, Metastasis.

Vaginal cancer	FIGO	TNM
Vaginal wall	I	T1
Paravaginal tissue	II	T2
Pelvic bone	III	T3
Mucosa of bladder and/or rectum, beyond pelvis	IV	T4
Regional lymph node metastases	IVa	N1
Distant metastases	IVb	M1

Radiological Findings

Since the vaginal cavity normally appears collapsed, instillation of sterile ultrasound gel is recommended before starting the MR examination. By this, the anterior and posterior vaginal wall can be adequately separated from each other. In the MRI, the vagina presents in its typical three layer formation: mucosa (T1-weighted hypointense, T2-weighted hyperintense); submucosa and muscularis layer (T1-weighted and T2-weighted hypointense), and adventitia (T1-weighted and T2-weighted hyperintense) [11]. In MRI, vaginal cancer can often only be detected at a certain minimum lesion size. In order to diagnose vaginal cancer and its infiltration into the vaginal wall, the transversal planes are to be angulated parallel to the short axis of the vagina. In a T2-weighted image, the cancer appears highly hyperintense, in which case a T2-weighted transversal oblique and sagittal sequence should be performed to verify the tumor size and any infiltration into surrounding structures (Table 2) [17].

In case recurrence is suspected in a scar region more than 6 months after hysterectomy, MRI may help to differentiate between scar tissue (T1-weighted

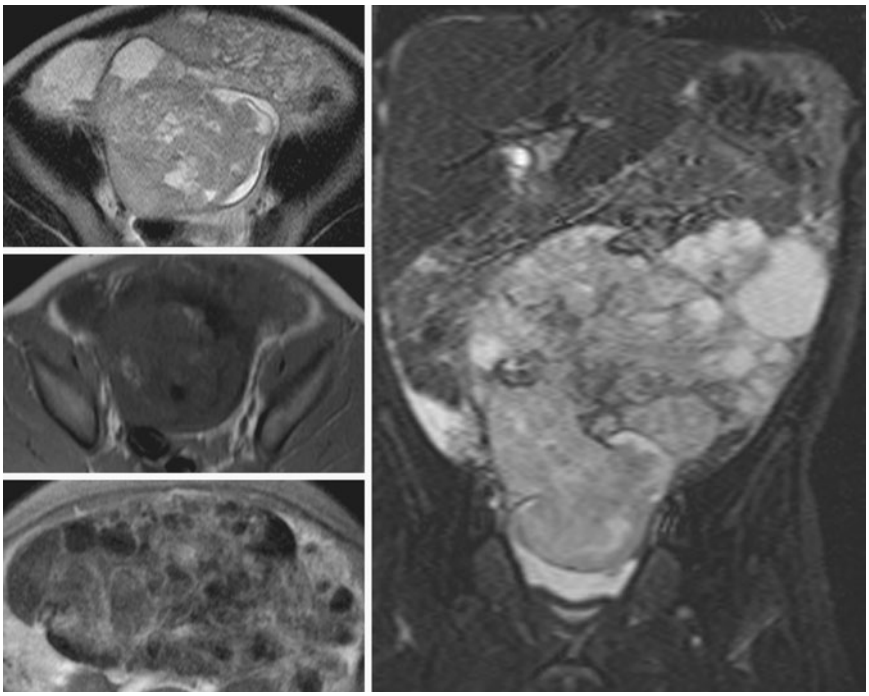

Figure 3. A large multicystic intraabdominal mass with solid parts and papillary growth (*top* to *bottom*) in a T2-weighted haste sequence (single shot technique) in the transversal plane, in the T1-weighted FL2D sequence (gradient spoiled) in the transversal plane, and in the T1-weighted FL3D sequence (gradient spoiled) fat saturated in the transversal plane after Gd i.v., and in the T2-weighted TIRM (turbo inversion recovery magnitude) sequence in the coronal plane. The histopathological result was malignant epithelial tumor.

Abbildung 3. Große multizystische Raumforderung des Ovars mit soliden Anteilen und papillärem Wachstum in der T2w haste transversal, in der T1w FL2D transversal, in der T1w FL3D fs transversal nach Kontrastmittelgabe und in der T2 TIRM koronal. Histologisch gesichertes malignes Epithelkarzinom.

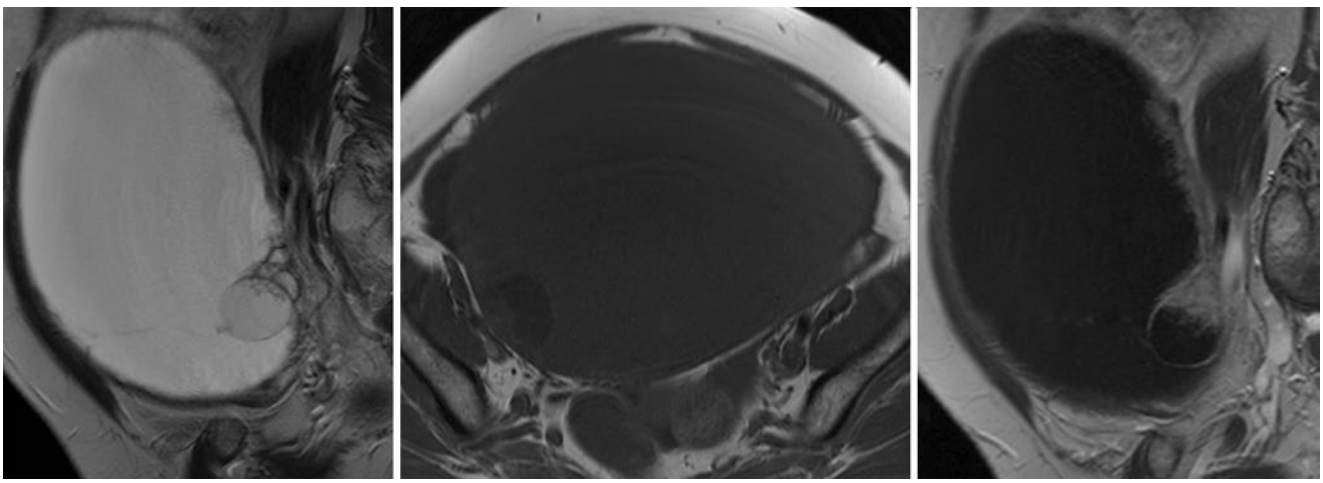

Figure 4. A large cystic mass with inlaying cystic structures with solid parts. T2-weighted sequence in the sagittal plane with high spatial resolution, non-enhanced T1-weighted sequence in the transversal plane, and T1-weighted FL2D (gradient spoiled) fat saturated post Gd i.v. in the sagittal plane. The histopathological result was serous cystadenocarcinoma of the right ovary.

Abbildung 4. Große zystische Raumforderung des Ovars mit einliegenden zystischen Strukturen mit soliden Anteilen. Darstellung in der hochaufgelösten sagittalen T2w, in der nativen transversalen T1w und in der kontrastmittelgestützten T1w FL2D fs sagittal. Histologisch gesichertes seröses Zystadenokarzinom des rechten Ovars.

post contrast no enhancement, T2-weighted hyperintense) and inflammatory or cancerous lesions (T1-weighted post contrast strong enhancement due to a higher level of local perfusion and/or angiogenesis, T2-weighted hyperintense) [11, 19, 46].

Contrast-enhanced CT is useful in higher tumor stages for abdominal staging regarding lymph node metastases, ascites, or distant metastases, but not for local tumor depiction [26].

Vaginal Sarcoma

General Information

About 2% of the malignant vaginal cancers are sarcomas, of which rhabdomyosarcoma is the most common soft tissue tumor entity diagnosed in children under the age of 5, while leiomyosarcoma is the most common soft tissue entity in adults [8, 17].

Diagnostic Standard Operating Procedure

For diagnosing vaginal sarcomas of the female genital tract, no guidelines have been published recently.

Radiological Findings

Due to tumor necrosis and hemorrhage, rhabdomyosarcoma presents as an inhomogeneous structure in the MRI hypointense signal prevails in T1-weighted sequences and hyperintense signal in T2-weighted sequences. After contrast application, the tumor also presents an inhomogeneous pattern. Some tumors have a pseudocapsula which is hypointense in both T1-weighted and T2-weighted sequences [12, 23]. Regarding leiomyosarcoma of the vagina, which is often already palpable due to fast tumor growth and large size, MR images may reveal an extensive tumor mass in the pelvis. Vaginal leiomyosarcoma presents as a cystic tumor with solid parts, characteristically showing an irregular and infiltrative growth pattern with moderate hypointensity in T1-weighted sequences and increased hyperintensity in T2-weighted sequence as well as after contrast [45].

Contrast-enhanced CT can only give an overview about infiltrated structures and may detect distant metastases, ascites, or suspicious lymph nodes, but primary tumor will only present as an inhomogeneous mass without characteristic morphologic criteria [26].

PET/CT may be significantly important for grading, staging, and follow-up in sarcomas [5].

Table 4. General overview of ovarian tumors (benign or malignant).

Tabelle 4. Überblick und Dignität von Ovarialtumoren.

Primarily cystic	Primarily solid	Mixed type
Mucinous cystadenoma (benign)	Fibroma (benign)	Dermoid (teratoma, usually benign, may produce thyroid hormone)
Serous cystadenoma (benign)	Brenner tumor (usually benign)	Clear cell carcinoma (usually malignant)
Adenocarcinoma (malignant)	Granulosa cell tumor (malignant, produces estrogen)	Adenocarcinoma (malignant)
	Thecoma (benign, produces estrogen, occasionally androgens)	Endometrioid carcinoma (malignant)
	Sertoli-Leydig cell tumors (generally benign, may produce androgens and/or estrogen)	
	Dysgerminoma (malignant)	

Table 5. Staging of ovarian cancer. FIGO: International Federation of Gynecology and Obstetrics staging system, TNM: Tumor, Node, Metastasis classification system.

Tabelle 5. FIGO- und TNM-Klassifikation des Ovarialkarzinoms. FIGO: International Federation of Gynecology and Obstetrics, TNM: Tumor, Node, Metastasis.

Ovarian cancer	FIGO	TNM
Tumor is limited to one or both ovaries	I	T1
Tumor is limited to one ovary. The capsule, or outer wall of the tumor, is intact, there is no tumor on the ovarian surface, and there are no cancer cells in ascites or peritoneal washings	Ia	T1a
Tumor is limited to both ovaries. The capsule is intact, there is no tumor on the ovarian surface, and there are no cancer cells in ascites or peritoneal washings	Ib	T1b
Tumor is limited to one or both ovaries with any of the following: ruptured capsule, tumor on ovarian surface, or cancer cells in the ascites or peritoneal lavage.	Ic	T1c
Tumor involves one or both ovaries with pelvic extension	II	T2
Extension and/or implants on uterus and/or tube(s); no malignant cells in ascites or peritoneal washings	IIa	T2a
Extension to other pelvic tissues; no malignant cells in ascites or peritoneal washings	IIb	T2b
Pelvic extension (2a or 2b) with malignant cells in ascites or peritoneal washings	IIc	T2c
Tumor involves one or both ovaries with microscopically confirmed peritoneal metastases outside the pelvis and/or regional lymph node metastases	III	T3
Microscopic peritoneal metastasis beyond pelvis	IIIa	T3a
Macroscopic peritoneal metastasis beyond pelvis, 2 cm or less in greatest dimension	IIIb	T3b
Peritoneal metastases, more than 2 cm in greatest dimension and/or regional lymph node metastases	IIIc	T3c
Distant metastases (excludes peritoneal metastases)	IV	M1

Ovarian Cancer

General Information

The category of ovarian tumors consists of diverse entities with a wide morphological spectrum of ovarian and testicular stroma-type cells. Ovarian neoplasms may vary in their degree of malignancy from totally benign over slowly progressive to aggressively invasive and highly malignant. They may appear as either solid, or fluid-filled (serous or mucinous) or mixed (complex) forms. Their clinical significance is generally not related to their microscopic condition. The dermoid tumor, rarely malignant concerning distant spread, is the single most critical benign tumor entity. There is a high growth-related tendency of rotation and, thus, constriction of the vascular stalk, leading as a consequence to ovarian necrosis (Table 4).

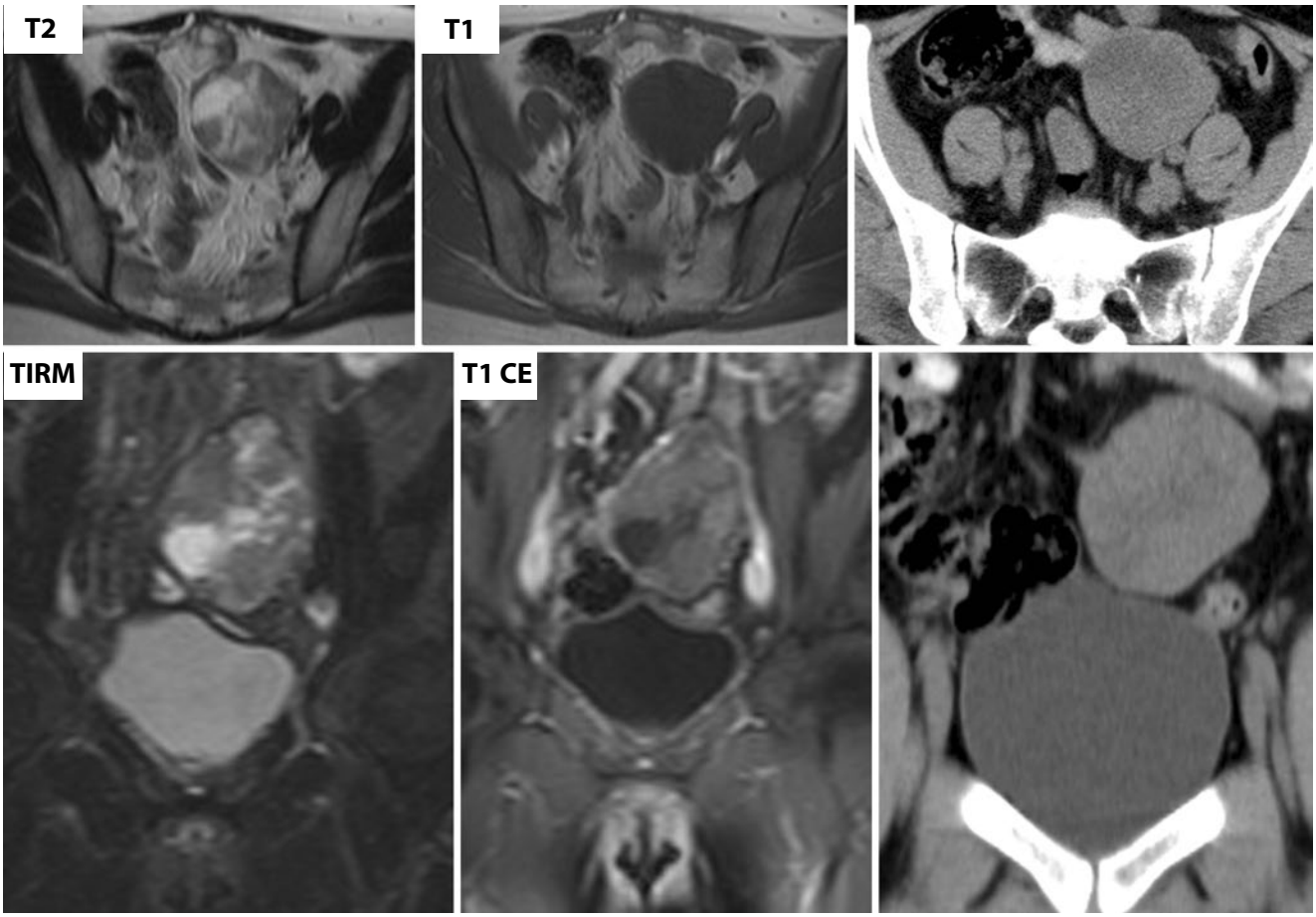

Figure 5. MRI with T2-weighted TIRM (turbo inversion recovery) in the coronal plane, T2-weighed in the transversal plane with high spatial resolution and T1-weighted sequence FL2D (gradient spoiled) non-enhanced, in the transversal plane and with fat saturation after Gd i.v. in the coronal plane shows a cystic mass with solid parts originating in the left ovary. Portal venous phase CT in the axial and coronal planes only shows an inhomogeneous mass in the entire pelvis. The histopathological result was a granulosa cell tumor.

Abbildung 5. Zystische Raumforderung des linken Ovars mit soliden Anteilen, im MRT dargestellt in der T2w TIRM koronal, in der T2w TSE transversal, in der nativen T1w transversal und in der kontrastmittelgestützten T1w FL2D (fs) koronal. In der portalvenösen Phase im CT zeigt sich axial und koronal lediglich eine inhomogene Strukturvermehrung im kleinen Becken. Histologisch gesicherter Granulosazelltumor.

Ovarian cancer is the sixth most common malignant cancer in women with an incidence of 9/100,000 [32]. It is the fifth most frequent cancer-related cause of death for women in the United States [26]. The incidence increases with age. Between the ages of 40–44, the incidence of ovarian cancer ranges around 15/100,000 women, whereas it is about 57/100,000 in women aged 70–74 [34]. About 61,000 cases in Europe are diagnosed every year and almost 3,900 women die of ovarian cancer each year [9]. Often, it is only diagnosed at an advanced stage with distant metastases already present [26]. The prognosis of

Table 6. Recommended MRI sequences for malignancies of the ovaries. T2w: T2-weighted, T1w: T1-weighted, tra: transverse, sag: sagittal, cor: coronal, fs fat saturated, TR: repetition time, TE: echo time, FOV: field of view, Gd: gadolinium.

Tabelle 6. Empfohlene MRT-Sequenzen zur Diagnostik von Ovarialkarzinomen. T2w: T2-gewichtet, T1w: T1-gewichtet, tra: transversal, sag: sagittal, cor: koronal, fs: fettgesättigt, TR: Repetitionszeit, TE: Echozeit, FOV: field of view, Gd: Gadolinium..

Sequence		Plane	fs	TR (ms)	TE (ms)	FOV (mm)	Slice thickness (mm)	Matrix
Turbo spin echo	T2w	tra	+	4,270	115	300	5	512
Turbo spin echo	T2w	sag	/	3,460	85	280	5	512
Turbo spin echo	T1w	tra	/	593	13	250	5	448
Short T1 inversion recovery	T1w	cor	+	6,700	70	350	6	256
Incoherent gradient echo (gradient spoiled) 3D native, Gd i.v. after 25 s and 70 s	T1w	tra	/	3.41	1.25	380	2.77	256
Turbo spin echo Gd i.v.	T1w	tra	/	500	1–2	280	5	512

ovarian cancer correlates directly with the overall tumor stage [13, 32].

Diagnostic Standard Operating Procedure

According to recent German guidelines, transvaginal ultrasound is the option of choice for diagnosing ovarian malignancies, and surgery appears to still be the most reliable staging modality for ovarian cancer and cannot, at least not now, be replaced by any imaging modality (Table 5) [2].

Nevertheless, according to international guidelines, ultrasound plays a role in visualizing and characterizing ovarian tumors, whereas CT is the imaging modality of choice for preoperative evaluation of ovarian cancer and MRI, with its excellent tissue contrast, for defining the tumor entity [21]. In higher tumor stages (T3, T4), however, studies found no statistical differences between CT and MRI in defining disease extent [21, 26].

Radiological Findings

Transvaginal ultrasound is the basic imaging tool used for diagnosing ovarian cancer, but multidetector CT is essential for the staging of ovarian cancer correctly, especially regarding metastases of lung, bones, and lymph nodes. Besides estimating the tumor size, an evaluation of peritoneal spread, lymph node metastases, or resectability is feasible [14]. For the detection of any calcifications in ovarian cancer, CT proves to be the most practicable imaging modality. Nevertheless, early stages of ovarian malignancies may not be detectable in CT [14, 21]. PET/CT is a useful tool for pretreatment staging in addition to surgical staging with laparoscopy and for restaging [10, 37].

High resolution MRI offers additional information for soft tissue differentiation, especially in T2-weighted sequences, and is superior to CT for pelvic imaging (Table 6). It is the imaging tool of choice for the assessment of local tumor progress or further identification of a tumor entity [14, 36]. In MRI, cancer of the ovary can be evaluated in T2-weigted TSE sequences in the transversal plane with high spatial resolution and T1-weighted images in the transversal plane in three sequences (nonenhanced, fat suppressed, and contrast enhanced) to identify the different components of the tumor (Table 7) [14]. After application of Gd i.v., MRI allows for better differentiation between benign and malignant tumors by revealing necrotic areas, septa and cysts, papillary growth, peritoneal, omental, or lymph node metastases [14, 26]. In addition with CT, malignancy may be reasonably suspected in any cystic ovarian mass with solid components, tumor diameter greater than 4 cm, thickness of a cyst wall greater than 3 mm, or nodular structure (Figures 3–7) [7, 26].

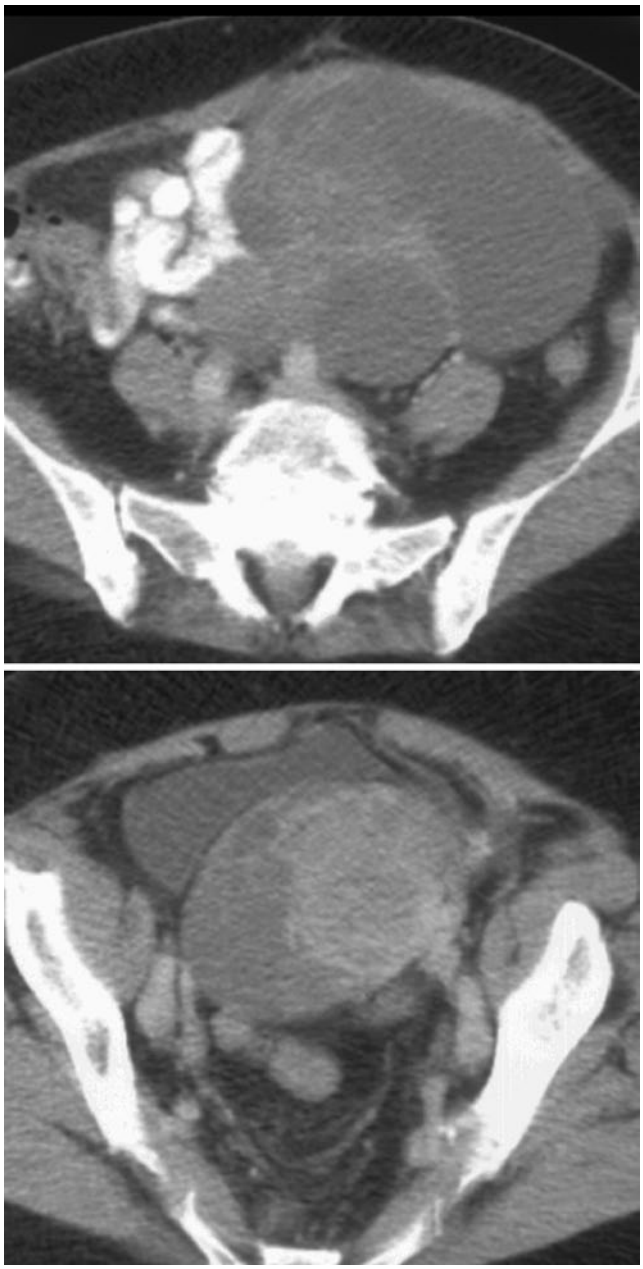

Figure 6. Portal venous phase CT shows cystic and chambered mass with contrast-enhanced solid parts and septa originating from the left ovary. The histopathological result was serous cystadenoma originating from a serous borderline tumor.

Abbildung 6. In der portalvenösen Phase des CT zeigt sich eine zystische Raumforderung des linken Ovars mit soliden Anteilen und Septen. Histologisch gesichertes Zystadenom auf dem Boden eines Borderline-Tumors.

Conclusion

Female pelvic malignancies are more frequently visualized with cross-sectional imaging modalities like MRI and CT for further treatment planning, whereas ultrasound still remains the gold standard in diagnosis. Advantages of MRI are better tumor delineation, superior tissue contrast, and additional information concerning accompanying pathologies and morphological tumor characteristics of ovarian cancer. Nonetheless, it has only been explicitly listed in the guidelines of vulvar cancer. With further developments in MRI technology, increasing acceptance of MRI for pretreatment staging is envisaged, comple-

menting basic gynecological diagnostics such as inspection, palpation, and ultrasound.

CT provides important information about accompanying peritoneal implants, affected lymph nodes, ascites, or distant metastases (e.g., of the lung and the liver) and is widely used for abdominal staging and restaging of ovarian cancer, although it has a poor soft tissue contrast in the entire pelvis.

According to the literature, PET/CT is beneficial in visualizing involved abdominal lymphatic pathways and might be helpful for restaging of recurrent tumor or distant metastases, especially in ovarian cancer or sarcomas. Unfortunately, with its low spatial resolution and bowel or urinary artifacts due to excretion of the radiotracer, local tumor depiction might be challenging.

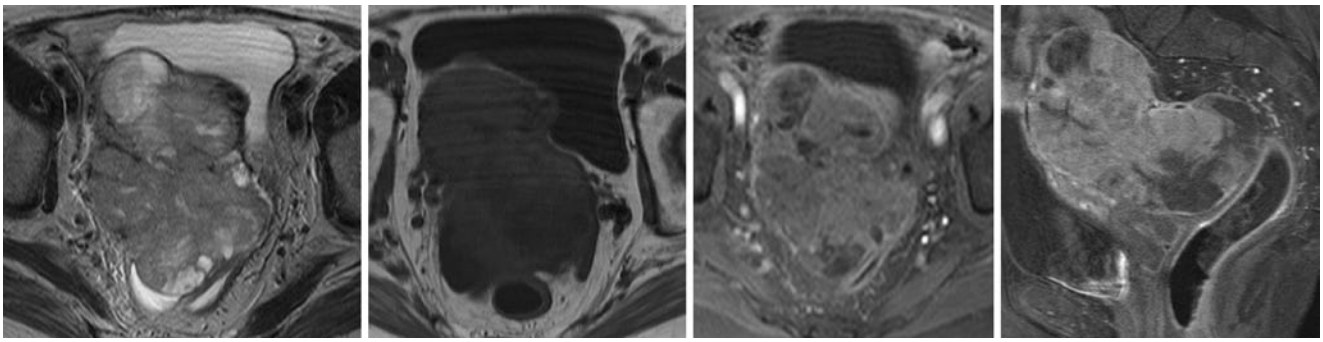

Figure 7. A large mass in the entire pelvis with cystic and solid parts, compressing the anteflected uterus. T2-weighted and T1-weighted sequences with high spatial resolution in the transversal plane and contrast-enhanced T1-weighted sequence in the transversal and sagittal planes. The histopathological result was carcinosarcoma of the right ovary.

Abbildung 7. Große Raumforderung im kleinen Becken mit zystischen und soliden Anteilen, welche den anteflektierten Uterus komprimiert. Hochaufgelöste T2w und T1w in transversaler Ebene sowie kontrastmittelgestützte T1w in transversaler und sagittaler Ebene. Histologisch gesichertes Karzinosarkom des rechten Ovars.

Table 7. Characteristic signal conditions in MRI examination of ovarian malignancies. Contrast enhancement can be found in all solid and septated tumors and is not separately mentioned for each tumor entity.

Tabelle 7. Charakteristisches Signalverhalten von Ovarialtumoren im MRT. Septen und solide Tumoranteile nehmen immer Kontrastmittel auf, so dass darauf nicht näher eingegangen wird.

Ovarian Tumor	Appearance	Signal T2	Signal T1
Malignant epithelial tumor	Cystic and solid, often papillary growth	Low	High
Serous cystadenocarcinoma	Multilocular cystic with papillary growth in the cysts	Higher	Intermediate to low
Mucinous cystadenocarcinoma	Multilocular cystic with solid parts and nodular areas in the cyst lumen	Higher	Intermediate to low
Pseudomyxoma peritonei	Multicystic mass with mucinous fluid	High	Low
Endometrioid carcinoma	Large, cystic mass with few solid parts, often bilateral	High	Low
Clear cell carcinoma	Mostly unilocular, large cyst with enlarged cyst wall and multiple nodular changes or multilocular cystic mass	High	Low to very high
Immature teratoma	Solid tumor mass with necrosis and hemorrhage, diffuse calcifications, fat areas	High	High (Fat)
Dysgerminoma	Multilobular, solid lesion with prominent fibrovascular septical structures, central necrosis and hemorrhage	Intermediate to low (septum)	Low
	In large tumors diffuse calcifications	High (necrosis)	
Granulosa cell tumor	Multilocular cystic to solid heterogeneous appearance, no papillary growth	High	Low
	Hemorrhage in the tumor, infarction, fibrous degeneration		
Sertoli-Leydig cell tumor	Solid mass, lobular, cystic	Intermediate to high (solid parts)	Higher (cysts)
Lymphoma	solid, homogeneous mass, mostly bilateral, no ascites	Intermediate to low	Intermediate
Secondary tumor (metastasis)	Krukenberg tumor: oval to kidneylike shape, solid, central necrosis or cystic, contains mucinous mass, bilateral	Heterogeneously, low to intermediate	Intermediate

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