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

Part 1

Kerstin A. Brocker[1], Celine D. Alt[2], Michael Eichbaum[1], Christof Sohn[1], Hans-Ulrich Kauczor[2], Peter Hallscheidt[2]

Aim: The goal of this article is to provide an overview of diagnostic standard operating procedures for both clinical and imaging assessment of cervical and endometrial carcinoma, sarcoma of the uterus, and primary pelvic non-Hodgkin's lymphoma.
Methods: The literature was reviewed for methods used to diagnose malignancies in the female pelvis with a special focus on the role of MRI as the imaging method of choice. Furthermore, CT findings and staging criteria for the mentioned malignancies are also provided.
Conclusion: Whereas ultrasound still remains the imaging modality of choice in clinical practice for the early diagnosis of female pelvic malignancies, MRI is more frequently recognized as a diagnostic tool for its accuracy in tumor identification. MRI also plays a crucial role in the 3D pretreatment planning for brachytherapy especially in cervical cancer. In the future, PET/CT might achieve an important role for staging lymph nodes or distant metastases as well as tumor recurrence.

Key Words: Cervical carcinoma • Endometrial carcinoma • Uterine sarcoma • Pelvic non-Hodgkin lymphoma • MRI • CT • PET/CT

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Bildgebung weiblicher Beckentumoren unter Berücksichtigung von MRT, CT und PET/CT: Teil 1

Ziel: Überblick über den aktuellen Stand der bildgebenden Diagnostik des Zervix- und des Endometriumkarzinoms, des Uterussarkoms und des primären Non-Hodgkin-Lymphoms des Beckens.
Methodik: 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: Im klinischen Alltag ist der Ultraschall für die Primärdiagnostik weiblicher Beckentumoren bildgebendes Verfahren der Wahl, wobei die MRT durch den hohen Weichteilkontrast einen zunehmenden Stellenwert als bildgebendes Verfahren zur Tumordetektion besitzt. Auch für die prätherapeutische 3D-Bestrahlungsplanung insbesondere des Zervixkarzinomes spielt die MRT eine wichtige Rolle. Die PET/CT erscheint zunehmend relevanter im Lymphknotenstaging sowie in der Detektion von Fernmetastasen und in der Rezidivdiagnostik.

Schlüsselwörter: Zervixkarzinom • Endometriumkarzinom • Uterussarkom • Non-Hodgkin-Lymphom des Beckens • MRT • CT • PET/CT

Introduction

The prognosis in women with gynecologic malignancies, e.g., cervical or endometrial cancer or uterine sarcomas, 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 [38, 47]. Positron emission tomography (PET), especially if combined with CT (PET/CT), might have a benefit in staging and restaging gyne-

[1]Department of Obstetrics and Gynecology, Medical School, University of Heidelberg, Heidelberg, Germany,
[2]Department of Diagnostic and Interventional Radiology, Medical School, University of Heidelberg, Heidelberg, Germany.

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cological malignancies, especially regarding lymph node metastases or recurrent tumor due to the simultaneous availability of functional and anatomical information [9, 14, 29, 32, 35, 42]. 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. For example, it plays a crucial role in systemic imaging of ovarian malignancies [6, 19, 30, 31, 36, 41, 42]. However, CT is not only limited by lower soft tissue contrast compared to MRI, but there is notable radiation exposure for patients. Because differentiation of recurrent tumor and radiation fibrosis is also challenging on CT, MRI has become the most valuable imaging tool for diagnosing pelvic tumors in women [31]. Due to a wide variety of possible imaging sequences, high spatial resolution, and superior soft tissue contrast, non-enhanced MRI can often 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 intravenous antiperistaltic agent (i.e., butylscopolamine) and by distending the vagina with sterile ultrasound contact gel [3, 4, 11, 53].

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 an intravenous contrast agent is crucial.

An additional diagnostic imaging tool in MRI is an endorectal coil, which is custom designed for MRI of uterine and cervical structures. Due to its positioning inside the rectum in direct contact with the cervix, the endorectal cervix coil provides more reliable tissue differentiation due to the high spatial resolution in a smaller field of view (FOV) at 1.5 T [20, 34, 40, 44].

For three-dimensional (3D) radiation planning, both CT and MRI are used to 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, the MRI has, due to its good soft tissue differentiation, advantages in defining the tissue volume needing radiation (gross tumor volume (GTV), clinical target volume (CTV), and planning target volume (PTV)) [45].

Around the GTV, which is defined by three planes in the MRI, a safety margin is added to define the clinical target volume. 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 an identical patient position was kept [45]. Brachytherapy is used in patients with cervical cancer, but is seldom used in patients with primary endometrial cancer.

Becoming increasingly more interesting is positron emission tomography (PET), a molecular imaging technique that can be used to 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 ^{18}F-fluordeoxyglucose i.e., (^{18}F-FDG)-PET, is used,. Unfortunately, it has its limitation in the difficulty of depicting tumor lesions precisely due to accumulation, also in normal tissues or inflammatory lesions [42].

Operating procedures and MRI findings are described in detail in the following, while complementary information about CT and PET/CT findings are also mentioned.

Cervical Cancer

General Information

The incidence of cervical cancer varies between 3.6–45/100,000 women each year. The incidence of cervical precancerous lesions is about 100-times higher. According to the Robert-Koch-Institut, about 6,500 women in Germany were diagnosed with an invasive cervical cancer in the year 2002 and more than 1,700 women died, leading to a mortality of 30%. The mean age was 52.2 years with a peak between 35–54 years and a second peak at 65 years of age [2].

Diagnostic Standard Operating Procedure

Clinical vaginal and colposcopical examinations of the cervix, including the bimanual palpation of the parametrial area in addition to cytological smears and biopsies are state of the art in diagnosing cervical cancer. The transvaginal and abdominal ultrasound is the imaging modality of choice for further staging information. AWMF and DGGG guidelines recommend the use of MRI in staging a cervical tumor at a clinical FIGO stage IB2 or higher for the assessment of local tumor spread and infiltration of surrounding tissue (Table 1) [2].

Radiological Findings

In diagnosing cervical cancer, the recommended standard protocol in MRI includes T2-weighted turbo spin echo (TSE) sequences with high spatial resolution (matrix 512) in the sagittal and transversal oblique (short cervical axis) planes in addition to a T1-weighted TSE sequence in the transversal plane. No intravenous contrast agent is needed (Table 2) [6, 17, 50, 53].

The cervical structure is well demonstrated on a high resolution T2-weighted sequence. The endocervical mucosa is hyperintense, the cervical stroma is hypointense, and the adjacent tissue layer shows a myometrium-like signal intensity. In order to correctly identify an interruption of the hypointense cervical stroma and diagnose parametrial infiltration, the transversal slices should be parallel to the short axis of the cervix [30, 53]. In the T2-weighted sequence, cervical cancers often appear as hyperintense masses in comparison to the healthy surrounding hypointense tissue, which makes them easy to detect. The detection of tumors originating from muscular structures, which are often isointense to surrounding muscle tissue, can be

Table 1. The TNM staging for cervical cancer is analogous to the FIGO stage. FIGO: International Federation of Gynecologists and Obstetricians staging system, TNM: Tumor, Nodes, Metastasis classification system.

Tabelle 1. Die TNM-Klassifikation des Zervixkarzinoms entspricht der aktuellen FIGO-Klassifikation. FIGO: International Federation of Gynecologists and Obstetricians, TNM: Tumor, Nodes, Metastasis.

Cervical cancer	FIGO	TNM
The carcinoma is strictly confined to the cervix (extension to the corpus would be disregarded)	I	T1
Invasive carcinoma which can be diagnosed only by microscopy, with deepest invasion ≤ 5.0 mm and largest extension ≤ 7.0 mm	Ia	T1a
a) Measured stromal invasion of ≤ 3.0 mm in depth and horizontal extension of ≤ 7.0 mm	Ia1	T1a1
b) Measured stromal invasion of > 3.0 mm and not > 5.0 mm with an extension of not > 7.0 mm	Ia2	T1a2
Clinically visible lesions limited to the cervix uteri or pre-clinical cancers greater than stage IA	Ib	T1b
Clinically visible lesion ≤ 4.0 cm in greatest dimension	Ib1	T1b1
Clinically visible lesion > 4.0 cm in greatest dimension	Ib2	T1b2
Cervical carcinoma invades beyond the uterus, but not to the pelvic wall or to the lower third of the vagina	II	T2
Without parametrial invasion	IIa	T2a
a) Clinically visible lesion ≤ 4.0 cm in greatest dimension	IIa1	T2a1
b) Clinically visible lesion > 4.0 cm in greatest dimension	IIa2	T2a2
With obvious parametrial invasion	IIb	T2b
The tumor extends to the pelvic wall and/or involves lower third of the vagina and/or causes hydronephrosis or non-functioning kidney	III	T3
Tumor involves lower third of the vagina, with no extension to the pelvic wall	IIIa	T3a
Extension to the pelvic wall and/or hydronephrosis or non-functioning kidney	IIIb	T3b
The carcinoma has extended beyond the true pelvis or has involved (biopsy proven) the mucosa of the bladder or rectum. A bullous edema, as such, does not permit a case to be allotted to Stage IV	IV	T4
Spread of the growth to adjacent organs	IVa	T4a
Spread to distant organs	IVb	M1

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

Tabelle 2. Empfohlene MR-Sequenzen zur Diagnostik des Zervixkarzinoms (1) und des Endometriumkarzinoms (2). Abhängig von der Tumorentität müssen die Sequenzen speziell gekippt werden. T2w: T2-gewichtet, T1w: T1-gewichtet, fs: Fettsättigung, TR: Repetitionszeit, TE: Echozeit, FOV: Field of View, tra: transversal, sag: sagittal, cor: koronal, 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 cervix 2) short axis of the uterus
Incoherent gradient echo (gradient spoiled) 2D nonenhanced	T1w	tra oblique	+	128	4.76	350	6	256	1) short axis of the cervix 2) short axis of the uterus
Turbo spin echo	T2w	cor oblique	/	3,950	92	300	4	512	1) long axis of the cervix 2) long axis of the uterus
Turbo spin echo Gd i.v.	T1w	tra oblique	+	470	12	350	4	384	1) short axis of the cervix 2) short axis of the uterus

more challenging, and only the mass aspect may indicate their presence (Figures 1–3) [30].

Contrast-enhanced T1-weighted images might be used as a complement [53]. They may help to distinguish healthy cervical tissue from vital tumor tissue and necrotic parts of the tumor. In the T1-weighted contrast-enhanced fat-saturated sequence (T1-weighted fs KM), the tumor presents as a hyperintense lesion, which is of great value for diagnosing small tumors. However, microscopic metastatic areas may still be difficult to detect, while ascites can be a helpful indicator [3, 12].

Contrast-enhanced CT can give additional information about systemic tumor spread in higher tumor stages (especially liver, lung, and lymph node metastases), but local extension can only be visualized as a hypodense cervical mass or an eccentric thickening of the cervix [31].

In several studies, ^{18}F-FDG-PET was shown to be more sensitive than CT or MRI in detecting lymph node metastases in cervical carcinoma, but, so far, it is neither specific for primary tumor imaging nor effective for detecting parametrial tumor extension [15, 21, 29].

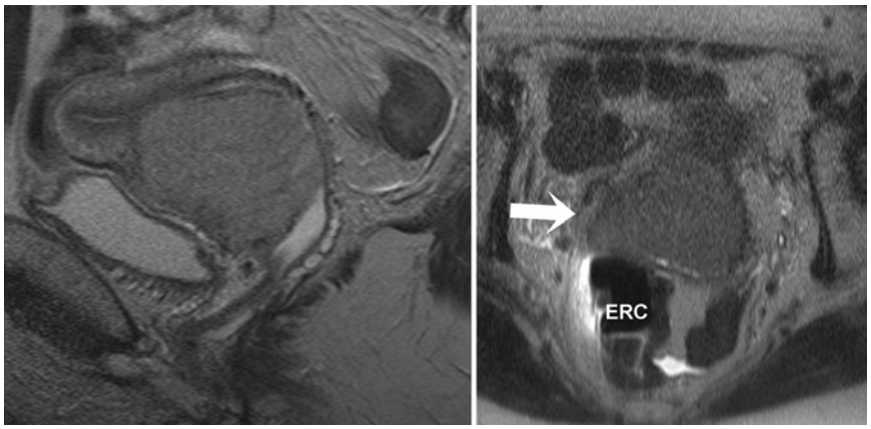

Figure 1. Huge solid mass originating in the anterior part of the cervix and infiltrating the corpus uteri in a T2-weighted sequence in the sagittal plane. No infiltration of the vagina or the bladder wall. In the transversal plane of the T2-weighted sequence, the hypointense ring of the cervix stroma is intact on the left side, but disrupted on the right side (*white arrow*). Histopathological result was cervical carcinoma T2b. ERC: endorectal coil.

Abbildung 1. In der sagittalen T2-gewichteten Sequenz große solide Raumforderung, von der vorderen Muttermundslippe ausgehend und das Corpus uteri infiltrierend. Vagina und hintere Blasenwand frei. In der transversalen T2-gewichteten Sequenz ist der hypointense Stromaring der Zervix links intakt und rechts unterbrochen (*weißer Pfeil*). Histologisch gesichertes Zervixkarzinom im Stadium T2b. ERC: Endorektalspule.

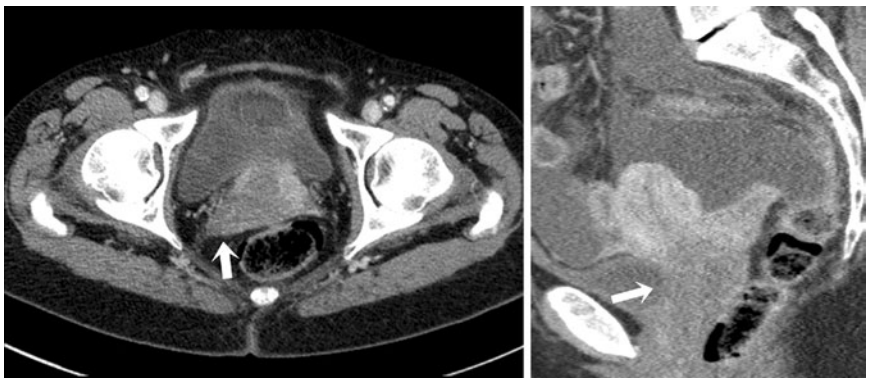

Figure 2. CT scan with iodine i.v. in the axial and sagittal planes. An irregular mass in the cervix; right parametrium might be involved (*white arrows*). Histopathological result was cervical carcinoma stage T2b.

Abbildung 2. Kontrastmittelgestützte CT in axialer und sagittaler Orientierung. Von der Zervix ausgehende irreguläre Gewebsvermehrung mit Erreichen des rechten Parametriums (*weiße Pfeile*). Histologisch gesichertes Zervixkarzinom im Stadium T2b.

In case of brachytherapy procedure planning, MRI is more reliable and more appropriately assesses, compared to CT or clinical examination, size, configuration, and topography of the tumor, which leads to accurate delineation of the GTV and can facilitate dose optimization [7, 10, 16, 39, 51].

Endometrial Cancer

General Information

The incidence of endometrial cancer is about 142,000 cases per year worldwide, yet it shows regional variations and rises with increasing age. There is a peak at about 75–80 years of age. In Germany, about 11,300 women are diagnosed with endometrial cancer annually [1].

Diagnostic Standard Operating Procedure

A transvaginal ultrasound is recommended to obtain an impression of the endometrial layer or suspicious lesions in the female pelvis, for example, in case of vaginal bleeding. Further investigations, such as hysteroscopy and curettage, are necessary in case of adenocancerous cells on the PAP smear. Further imaging modalities, e.g., CT, PET, or MRI, are not recommended by recent guidelines for staging endometrial cancer, since they have not been proven to be beneficial, although the extent of myomentrial infiltration can be estimated with MRI (Table 3) [1].

Radiological Findings

Again, MRI is a superior imaging modality compared to CT in staging endometrial cancer. T2-weighted turbo spin echo (TSE) sequences with high spatial resolution (matrix 512) in the sagittal, transversal oblique (short uterine axis) and coronal oblique (long uterine axis) planes are recommended for the staging of endometrial cancer. Contrast-enhanced T1-weighted TSE images are mandatory to assess myometrial infiltration (Table 2) [11, 18, 23].

The endometrium appears as a hyperintense layer in the MRI. The junctional zone – the innermost myometrial layer directly attached to the endometrial layer – is hypointense in a T2-weighted sequence. The outermost myometrial layer displays intermediate signal intensity. In order to correctly identify myometrial infiltration depth of more than 50% and consequently correctly distinguish between a local tumor stage T1a and T1b, the transversal slices should be parallel to the short axis of the uterus (Figures 4 and 5) [23, 43].

Comparable to cervical carcinoma, contrast-enhanced CT can give additional information about systemic tumor spread (especially liver, lung, and lymph node metastases). The local tumor exhibits a hypodense mass in the dilated corpus lumen or intramural location. The assessment of myometrial invasion is difficult [31].

In addition, recent studies have shown that in case of restaging for recurrence of endometrial carcinoma, PET/CT might be beneficial [8, 24]. In some cases of primary endometrial cancer

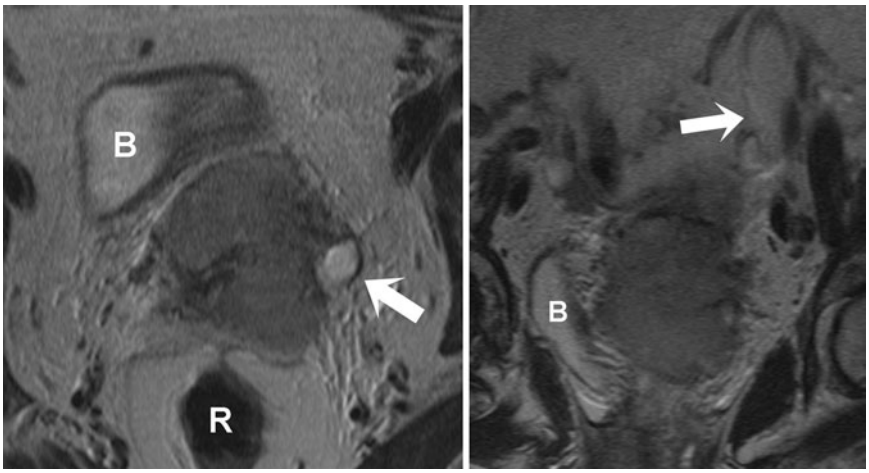

Figure 3. Cervical mass with parametrial infiltration and obstruction of the left ureter (*white arrow*) in a T2-weighted sequence with high spatial resolution in the transversal and coronal planes. Cervical carcinoma stage T3b. B: bladder, R: rectum.

Abbildung 3. In der hochaufgelösten T2-gewichteten Sequnez in transversaler und koronaler Orientierung dargestellter Zervixtumor, der die Parametrien infiltriert und den linken Ureter komprimiert (*weißer Pfeil*). Zervixkarzinom im Stadium T3b. B: Blase, R: Rektum.

Table 3. Staging of endometrial cancer. FIGO: International Federation of Gynecologists and Obstetricians staging system, TNM: Tumor, Nodes, Metastasis classification system.

Tabelle 3. Staging des Endometriumkarzinoms. FIGO: International Federation of Gynecologists and Obstetricians, TNM: Tumor, Nodes, Metastasis.

Endometrial cancer	FIGO	TNM
Tumor confined to the corpus uteri	I	T1
No or less than half myometrial invasion	Ia	T1a
Invasion equal to or more than half of the myometrium	Ib	T1b
Tumor invades cervical stroma, but does not extend beyond the uterus	II	T2
Local and/or regional spread of the tumor	III	T3
Tumor invades the serosa of the corpus uteri and/or adnexae	IIIa	T3a
Vaginal and/or parametrial involvement	IIIb	T3b
Metastases to pelvic and/or para-aortic lymph nodes	IIIc	N1
a) Positive pelvic nodes	IIIc1	
b) Positive para-aortic lymph nodes with or without positive pelvic lymph nodes	IIIc2	
Tumor invades bladder and/or bowel mucosa, and/or distant metastases	IV	
Tumor invasion of bladder and/or bowel mucosa	IVa	T4
Distant metastases, including intra-abdominal metastases and/or inguinal lymph nodes	IVb	M1

(patients with a severe acute or chronic medical illness), brachytherapy might be the treatment of choice – if the tumor is confined to the uterus. For pretreatment planning, CT and MRI give 3D information about tumor size, configuration, and topography and can, therefore, influence dose adaption [11, 52].

Sarcoma of the Uterus

General Information

Sarcomas of the uterus are often located in the corpus or the isthmus of the uterus and originate in endometrial or myometrial tissue. The uterine sarcoma is rather rare (2–3%), and it may evolve from various tissue origins [30, 33]. Malignant sarcoma of the stroma, mixed cell tumors, e.g., osteochondrorhabdomyosarcoma or mesodermal tumors, e.g., muellerian adenocarcinoma, derive from endometrial tissue, whereas leiomyosarcomas often derive from the myometrium [46].

Diagnostic Standard Operating Procedure

The malignant endometrial sarcoma is often a coincidental diagnosis in women with simple hysterectomies, since most patients are asymptomatic. Symptomatic patients present with uncharacteristic spotting or postmenopausal vaginal bleeding and pelvic pain. Hysteroscopy and curettage are generally recommended, whereas in case of tumor mass extruding the cervix, a biopsy leads to diagnosis (Tables 4 and 5). [25, 33].

Radiological Findings

Transvaginal ultrasound is the standard imaging technique [25]. Unfortunately, differentiation of leiomyosarcoma from leiomyoma is challenging in MRI. Smooth muscle cell tumors with fuzzy margins, more than 50% of hyperintense signal volume in a tumor on T2-weighted images or any small hyperintense signal volume on T1-weighted images are findings which might suggest leiomyosarcoma. Another characteristic of leiomyosarcoma is rapid growth. The differentiation between other malignant tumors can be challenging and often requires consultation with a pathologist [28]. Muellerian adenosarcoma frequently presents as a large, multiseptate, cystic mass with heterogeneous solid components filling the endometrial cavity in the MRI. The solid part has low signal intensity on T2-weighted images and hyperintensity on contrast-enhanced T1-weighted images [37]. However, MRI can only differentiate sarcoma of the uterus from endometrial cancer with combined findings of irregular tumor margins and marginal nodular lesions which might not be possible in all cases [25].

Contrast-enhanced CT can provide an overview of infiltrated surrounding structures, distant metastases, ascites, renal obstruction or peritoneal spread, while a local tumor is uncharacteristic despite of its rapid growth [26, 31]. Finally, PET/CT

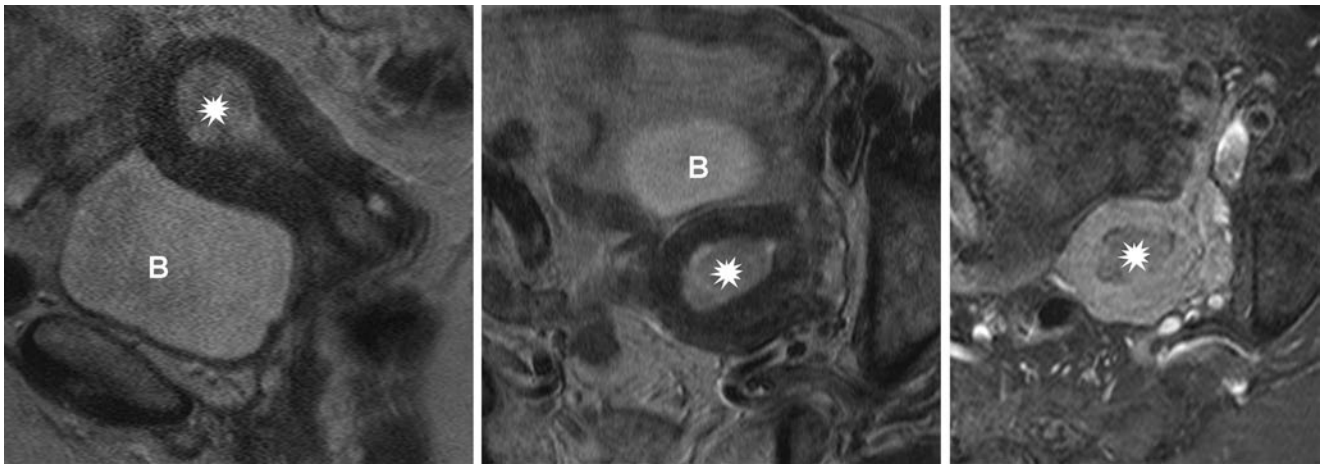

Figure 4. T2-weighted sequences in the sagittal and transversal planes show a moderate hyperintense mass in the lumen of the corpus uteri (*). Contrast-enhanced T1-weighted sequence in transversal plane delineates the tumor from the myometrium. Histopathological result was endometrial carcinoma stage T1a. B: bladder.

Abbildung 4. In der sagittalen und transversalen T2-gewichteten Sequenz Nachweis einer moderat hyperintensen Gewebsvermehrung im Korpuslumen (*). In der kontrastmittelgestützten transversalen T1-gewichteten Sequenz Demaskierung des Tumors vom umgebenden Myometrium. Histologisch gesichertes Endometriumkarzinom im Stadium T1a. B: Blase.

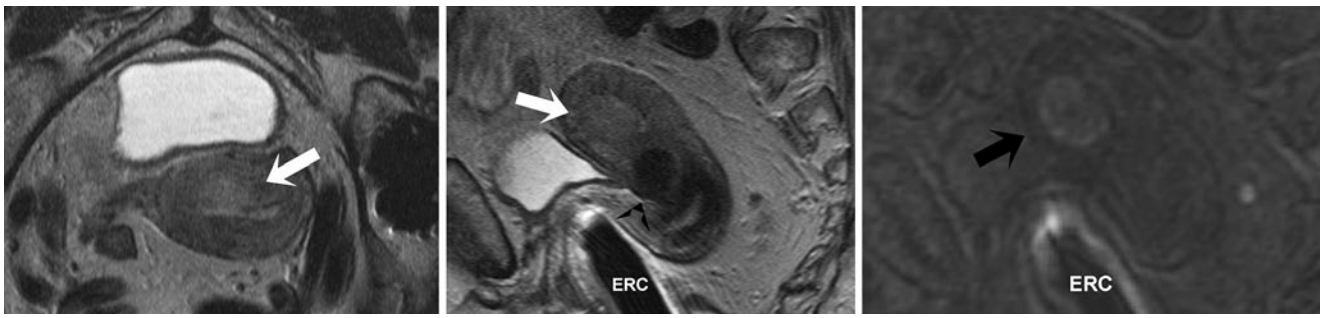

Figure 5. MRI with high spatial resolution at T2-weighted sequences in the sagittal and transversal planes show an oval mass originating in the endometrium (*white arrow*). After intravenous Gd administration, the infiltration of more than 50% of the myometrial layer is visible (*black arrow*). Histopathological result was endometrial cancer stage T1b. *Short black arrow*: intramural leiomyoma, ERC: endorectal coil.

Abbildung 5. Die hochaufgelöste T2-gewichtete Sequnz in sagittaler und transversaler Ebene zeigt eine ovaläre Gewebsvermehrung des Endometriums (*weißer Pfeil*). Nach i.v. Kontrastmittelgabe zeigt sich eine myometrane Infiltrationstiefe von mehr als 50% (*schwarzer Pfeil*). Histologisch gesichertes Endometriumkarzinom im Stadium T1b. *Kurzer schwarzer Pfeil*: intramurales Myom, ERC: Endorektalspule.

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

Primary Pelvic Non-Hodgkin's Lymphoma

General information

Malignant lymphoma of the uterus or cervix is a very rare entity (incidence > 1%). Patients of nearly all ages between 20 and 80 have been reported [27, 49]. Only 1% of all cases of primary extranodal lymphoma are cases of vaginal lymphoma [13].

A secondary affection of lymph nodes is far more frequent (40%) with most patients between 19 and 65 years of age (mean 42 years). In the clinical examination, patients may either show no symptoms at all or present with pelvic pain, vaginal bleeding, or tumor mass discharge [37].

Diagnostic Standard Operating Procedure

For diagnosing lymphomas of the female genital tract, no gynecological guidelines have been published recently. However, contrast-enhanced, whole-body CT may be performed for therapy planning and follow-up after treatment every 3 or 6 months [48].

Radiological Findings

In MRI, cervical lymphoma is best seen in a T2-weighted or contrast-enhanced T1-weighted sequence. They often appear as homogeneously hyperintense masses without a clear margin to the surrounding healthy tissue, which is why their differentiation from degenerative benign leiomyomas, endometrial cancer, or a large cervical cancer is difficult [22]. Vaginal lym-

Table 4. Staging of leiomyosarcoma of the uterus is comparable to staging of adenosarcoma, except for stage T1. FIGO: International Federation of Gynecologists and Obstetricians staging system, TNM: Tumor, Nodes, Metastasis classification system.

Tabelle 4. Das Staging des uterinen Leiomyosarkoms ist außer im Stadium T1 mit dem Staging des uterinen Adenosarkoms identisch. FIGO: International Federation of Gynecologists and Obstetricians, TNM: Tumor, Nodes, Metastasis.

Leiomyosarcoma, endometrioid stromal sarcoma	FIGO	TNM
Tumor confined to uterus	I	T1
Greatest extension of the tumor ≤ 5 cm	Ia	T1a
Greatest extension of the tumor > 5 cm	Ib	T1b
Tumor invasion beyond uterus	II	T2
Tumor invades adnexa	IIa	T2a
Tumor invades other structures of the pelvis	IIb	T2b
Tumor extends to abdominal structures	III	T3
Extension to one location	IIIa	T3a
Extension to more than one location	IIIb	T3b
Metastasis to local lymph nodes	IIIc	N1
Tumor invades mucosa of the bladder and/or rectum	IVa	T4
Distant metastases	IVb	M1

Table 5. Staging of adenosarcoma of the uterus is comparable to staging of leiomyosarcoma, except for stage T1. FIGO: International Federation of Gynecologists and Obstetricians staging system, TNM: Tumor, Nodes, Metastasis classification system.

Tabelle 5. Das Staging des uterinen Adenosarkoms ist außer im Stadium T1 mit dem Staging des uterinen Leiomyosarkoms identisch. FIGO: International Federation of Gynecologists and Obstetricians, TNM: Tumor, Nodes, Metastasis.

Adenosarcoma	FIGO	TNM
Tumor is limited to the uterus	I	T1
Tumor is limited to the endometrium	Ia	T1a
Invasion of less than half the myometrium (< 50%)	Ib	T1b
Invasion of more than half the myometrium (≥ 50%)	Ic	T1c
Tumor invasion exceeds the uterus and infiltrates other organs of the pelvis	II	T2
Tumor invades adnexa	IIa	T2a
Tumor invades other structures of the pelvis	IIb	T2b
Tumor extends to abdominal structures	III	T3
Extension to one location	IIIa	T3a
Extension to more than one location	IIIb	T3b
Metastasis to local lymph nodes	IIIc	N1
Tumor invades mucosa of the bladder and/or rectum	IVa	T4
Distant metastases	IVb	M1

phoma presents either with an infiltrative or a lobular growth pattern in the MRI. In the T1-weighted sequence, vaginal lymphoma appears as a homogeneously hypointense lesion, which is moderately hyperintense in a T2-weighted sequence and presents with high signal intensity post contrast. Typically, the mucosal layer is not affected [13].

Regarding CT and PET/CT for diagnosing involvement of abdominal lymphatic pathways, contrast enhancement leads to better diagnosis comparable to nonenhanced examination. Whereas PET is the indicated modality in identifying and localizing lymphatic lesions with non-Hodgkin lymphoma showing high FDG accumulation [29, 42], even for small lesions, the spatial resolution of PET/CT is still not sufficient [48].

Conclusions

For visualizing female pelvic tumors, MRI has become appreciated as the cross-sectional imaging modality of choice, whereas ultrasound still remains the gold standard in early diagnosis due to its widespread availability and cost effectiveness. Advantages of MRI are better tumor delineation in the entire pelvis, superior tissue contrast, and additional information concerning accompanying pathologies which can be helpful for further therapy planning. As a consequence, MRI is more frequently applied for pretreatment disease staging. Nonetheless, it has, up to now, only been explicitly listed in the guidelines for cervical cancer.

Although, CT has poor soft tissue contrast, which is a major drawback in the pelvis, it provides important information about peritoneal implants, lymph nodes, ascites, and distant metastases (e.g., of the lung and the liver).

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

Brachytherapy can be the treatment of choice in patients with locally progressed cervical cancer and in occasional cases of endometrial cancer. For optimal pretreatment radiation planning, MRI allows precise identification of the GTV and CTV in three planes.

References

1. Diagnostik und Therapie des Endometriumkarzinoms. In: Düsseldorf: Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften, 2008.
2. Diagnostik und Therapie des Zervixkarzinoms. In: Düsseldorf: Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaft, 2008.
3. Alt C, Gebauer G. Uterus. In: Hallscheidt P, Haferkamp A (eds). Urogenitale Bildgebung. Berlin: Springer, 2011:231–301.
4. Alt C, Gebauer G. Vulva, Vagina. In: Hallscheidt P, Haferkamp A (eds). Urogenitale Bildgebung. Berlin: Springer, 2011:347–97.
5. Benz MR, Tchekmedyian N, Eilber FC et al. Utilization of positron emission tomography in the management of patients with sarcoma. Curr Opin Oncol 2009;21:345–51.
6. Boss EA, Barentsz JO, Massuger LF et al. The role of MR imaging in invasive cervical carcinoma. Eur Radiol 2000;10:256–70.
7. Chargari C, Magne N, Dumas I et al. Physics contributions and clinical outcome with 3D-MRI-based pulsed-dose-rate intracavitary brachytherapy in cervical cancer patients. Int J Radiat Oncol Biol Phys 2009;74:133–9.
8. Chung HH, Kang WJ, Kim JW et al. The clinical impact of [(18)F]FDG PET/CT for the management of recurrent endometrial cancer: correlation with clinical and histological findings. Eur J Nucl Med Mol Imaging 2008;35:1081–8.
9. De Iaco P, Musto A, Orazi L et al. FDG-PET/CT in advanced ovarian cancer staging: value and pitfalls in detecting lesions in different abdominal and pelvic quadrants compared with laparoscopy. Eur J Radiol 2010 (Epub ahead of print).

10. Dimopoulos JC, Schirl G, Baldinger A et al. MRI assessment of cervical cancer for adaptive radiotherapy. Strahlenther Onkol 2009;185:282–7.
11. Frei Bonel KA, Kinkel K. Endometrial carcioma. In: Hamm B, Forstner R (eds) MRI and CT of the female pelvis. Berlin: Springer, 2007:101–19.
12. Fujii S, Matsusue E, Kanasaki Y et al. Detection of peritoneal dissemination in gynecological malignancy: evaluation by diffusion-weighted MR imaging. Eur Radiol 2008;18:18–23.
13. Griffin N, Grant LA, Sala E. Magnetic resonance imaging of vaginal and vulval pathology. Eur Radiol 2008;18:1269–80.
14. Gruen A, Musik T, Kohler C et al. Adjuvant chemoradiation after laparoscopically assisted vaginal radical hysterectomy (LARVH) in patients with cervical cancer: oncologic outcome and morbidity. Strahlenther Onkol 2011;187:344–9.
15. Haie-Meder C, Mazeron R, Magne N. Clinical evidence on PET-CT for radiation therapy planning in cervix and endometrial cancers. Radiother Oncol 2010;96:351–5.
16. Haie-Meder C, Potter R, Van Limbergen E et al. Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group (I): concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV. Radiother Oncol 2005;74: 235–45.
17. Hauth EA, Kimmig R, Forsting M. [Magnetic resonance imaging (MRI) of the pelvis in the diagnosis of cervical carcinoma – review]. Zentralbl Gynakol 2006;128:60–7.
18. Heuck A, Lukas P. Gynäkologie. In: Reiser M, Semmler W (eds) .Magnetresonanztomographie. 3rd ed. Berlin: Springer, 2002:781–803.
19. Hricak H, Yu KK. Radiology in invasive cervical cancer. Am J Roentgenol 1996;167:1101–8.
20. Kaji Y, Sugimura K, Kitao M et al. Histopathology of uterine cervical carcinoma: diagnostic comparison of endorectal surface coil and standard body coil MRI. J Comput Assist Tomogr 1994;18:785–92.
21. Kim SK, Choi HJ, Park SY et al. Additional value of MR/PET fusion compared with PET/CT in the detection of lymph node metastases in cervical cancer patients. Eur J Cancer 2009;45:2103–9.
22. Kim YS, Koh BH, Cho OK et al. MR imaging of primary uterine lymphoma. Abdom Imaging 1997;22:441–4.
23. Kinkel K, Forstner R, Danza FM et al. Staging of endometrial cancer with MRI: guidelines of the European Society of Urogenital Imaging. Eur Radiol 2009;19:1565–74.
24. Kitajima K, Suzuki K, Nakamoto Y et al. Low-dose non-enhanced CT versus full-dose contrast-enhanced CT in integrated PET/CT studies for the diagnosis of uterine cancer recurrence. Eur J Nucl Med Mol Imaging 2010;37:1490–8.
25. Köhler G, Evert M. Uterine Sarkome und Mischtumoren. 1st ed. Berlin: De Gruyter 2009:7–120.
26. Kortmann B, Reimer T, Gerber B et al. Concurrent radiochemotherapy of locally recurrent or advanced sarcomas of the uterus. Strahlenther Onkol 2006;182:318–24.
27. Kosari F, Daneshbod Y, Parwaresch R et al. Lymphomas of the female genital tract: a study of 186 cases and review of the literature. Am J Surg Pathol 2005;29:1512–20.
28. Kubik-Huch RA, Semelka RC, Michel SCA et al. Uterus and cervix. In: Semelka RC (ed). Abdominal-Pelvic MRI. New York: Wiley-Liss, 2002:1049–122.
29. Lammering G, De Ruysscher D, van Baardwijk A et al. The use of FDG-PET to target tumors by radiotherapy. Strahlenther Onkol 2010;186:471–81.
30. Lehmann KJ. [Malignant neoplasms of the female pelvis]. Radiologe 2009;49:753–64; quiz 65–6.
31. Lehmann KJ, van der Molen AJ, Keberle M. Weibliches Becken. In: Prokop M (ed). Ganzkörper-Computertomographie: Spiral- und Multislice-CT. Stuttgart: Georg Thieme, 2006:737–64.
32. Lemke U, Hamm B. [Pretreatment diagnostic evaluation of cervical cancer]. Rofo 2009;181:433–40.
33. Leung F, Terzibachian JJ, Aouar Z et al. [Uterine sarcomas: clinical and histopathological aspects. Report on 15 cases]. Gynecol Obstet Fertil 2008; 36:628–35.
34. Milestone BN, Schnall MD, Lenkinski RE et al. Cervical carcinoma: MR imaging with an endorectal surface coil. Radiology 1991;180:91–5.
35. Minamimoto R, Senda M, Terauchi T et al. Analysis of various malignant neoplasms detected by FDG-PET cancer screening program: based on a Japanese Nationwide Survey. Ann Nucl Med 2011;25:45–54.
36. Mitchell DG, Snyder B, Coakley F et al. Early invasive cervical cancer: tumor delineation by magnetic resonance imaging, computed tomography, and clinical examination, verified by pathologic results, in the ACRIN 6651/GOG 183 Intergroup Study. J Clin Oncol 2006;24:5687–94.
37. Nucci M, Oliva E. Gynecological Pathology. Oxford: Churchill Livingston, 2009.
38. Pecorelli S. Revised FIGO staging for carcinoma of the vulva, cervix, and endometrium. Int J Gynaecol Obstet 2009;105:103–4.
39. Potter R, Dimopoulos J, Georg P et al. Clinical impact of MRI assisted dose volume adaptation and dose escalation in brachytherapy of locally advanced cervix cancer. Radiother Oncol 2007;83:148–55.
40. Preidler KW, Tamussino K, Szolar DM et al. Staging of cervical carcinomas. Comparison of body-coil magnetic resonance imaging and endorectal surface coil magnetic resonance imaging with histopathologic correlation. Invest Radiol 1996;31:458–62.
41. Radeleff B. Ovarien. In: Hallscheidt P, Haferkamp A (eds). Urogenitale Bildgebung. Berlin: Springer, 2011:303–46.
42. Saif MW, Tzannou I, Makrilia N et al. Role and cost effectiveness of PET/CT in management of patients with cancer. Yale J Biol Med 2010;83:53–65.
43. Sala E, Wakely S, Senior E et al. MRI of malignant neoplasms of the uterine corpus and cervix. AJR Am J Roentgenol 2007;188:1577–87.
44. Scheidler J, Heuck AF. Imaging of cancer of the cervix. Radiol Clin North Am 2002;40:577–90, vii.
45. Schlegel W, Schad L, Herfarth KK. Computerunterstützte 3D Bestrahlungsplanung im MRT. In: Reiser M, Semmler W (eds). Magnetresonanztomographie. 3rd ed. Berlin: Springer, 2002:1047–61.
46. Scully RE Kurmann R, Bonfiglio TA. Histological typing of female genital tract tumors. World Health Organisation – International Histological Classification of Tumours. 2nd ed. Berlin: Springer, 1994:14–8.
47. Sobin LH, Compton CC. TNM seventh edition: what's new, what's changed: communication from the International Union Against Cancer and the American Joint Committee on Cancer. Cancer 2010;116:5336–9.
48. Tateishi U, Terauchi T, Inoue T et al. Nodal status of malignant lymphoma in pelvic and retroperitoneal lymphatic pathways: PET/CT. Abdom Imaging 2010;35:232–40.
49. Thyagarajan MS, Dobson MJ, Biswas A. Case report: appearance of uterine cervical lymphoma on MRI: a case report and review of the literature. Br J Radiol 2004;77:512–5.
50. Vandecasteele K, De Neve W, De Gersem W et al. Intensity-modulated arc therapy with simultaneous integrated boost in the treatment of primary irresectable cervical cancer. Treatment planning, quality control, and clinical implementation. Strahlenther Onkol 2009;185:799–807.
51. Wachter-Gerstner N, Wachter S, Reinstadler E et al. Bladder and rectum dose defined from MRI based treatment planning for cervix cancer brachytherapy: comparison of dose-volume histograms for organ contours and organ wall, comparison with ICRU rectum and bladder reference point. Radiother Oncol 2003;68:269–76.
52. Weitmann HD, Potter R, Waldhausl C et al. Pilot study in the treatment of endometrial carcinoma with 3D image-based high-dose-rate brachytherapy using modified Heyman packing: clinical experience and dose-volume histogram analysis. Int J Radiat Oncol Biol Phys 2005;62:468–78.
53. Zaspel U, Hamm B. Vagina. In: Hamm B, Forstner R (eds). MRI and CT of the Female Pelvis. Berlin: Springer 2007:275–91.

Address for Correspondence
Kerstin A. Brocker, MD, MSc
Department of Gynecology and Obstetrics
Medical School
University of Heidelberg
Vossstraße 9
69115 Heidelberg
Germany
Phone (+49/6221) 56-7856, Fax -4328
e-mail: kerstin.brocker@med.uni-heidelberg.de