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Introduction

The key to the successful treatment of most patients with cancer is a delineation of the site of the primary tumor and demonstration of its local and regional spread. It is critical that the imaging used to demonstrate this is tailored precisely to answer the clinical questions so that the appropriate treatment modalities can be selected. Because of its high tissue contrast, magnetic resonance imaging (MRI) has become the gold-standard for imaging uterine malignancies where detailed disease assessment prior to implementing potentially curative treatments such as surgery and radical radiotherapy are required. For the surgeon and radiotherapist therefore, accurate and comprehensible anatomical information of disease within the uterus and pelvis is essential. Furthermore, new technologies such as minimally invasive organ conservation, telesurgery, robotics and intensity modulated radiation therapy techniques make such information particularly vital.

Uterine malignancy usually presents with vaginal bleeding (1). In the case of endometrial cancer, this is in a post menopausal age group and therefore is usually recognized and presents early (2). However, with an increasing use of hormone replacement therapy, irregular vaginal bleeding in a post-menopausal woman may be overlooked and investigation delayed. In cervical cancer, where the peak incidence of the disease is in pre-
menopausal women, irregular or heavy vaginal bleeding may be ignored. The cervical screening programme in these cases is crucial in early diagnosis and has dramatically reduced the mortality from cervical cancer (3).

**Technical Considerations**

*Patient Preparation:* Patient preparation is critical in order to obtain a good diagnostic examination. Bowel motion is one of the major reasons for image artefact particularly over the areas of interest of the endometrium and cervix. The use of anti peristaltic agents (4;5) is now routine in most Oncology centers and is essential to achieve good image quality. Hyoscine butyl bromide is readily available and safe to use. Glucagon is an alternative in patients with glaucoma or unstable angina. If administered intravenously these agents have a quick onset of action and last around 10 minutes. Their use in MRI via an intravenous route is therefore unhelpful. Oral administration is an alternative, but absorption is often erratic and it is difficult to predict the most effective time after administration for imaging. In our experience at least two hours is required if anti peristaltic agents are administered orally. A third route of administration is intramuscular, as absorption is relatively rapid and can be controlled, and the length of action of the agent is approximately 30 minutes, which suits most MRI examinations. Administration immediately prior to positioning the patient in the centre of the bore is optimal. At this point when the patient is set up in the pelvic array coil, injection into the deltoid muscle is simplest. In the rare instances of pediatric examination, oral mebeverine 135 mg may be used instead.
Coils: To examine the pelvis effectively a multi channel pelvic phased array coil is the preferred option. However in extremely large patients where the fill factor of the patient in the body receive coil of the scanner is maximal, the body coil may provide equally good pelvic images. The use of a multi channel array also allows parallel imaging which reduces scan time without a significant reduction in signal to noise ratio. A four channel array is the norm, but increasingly manufacturers are producing eight or larger numbers of coil arrays. Careful positioning of the patient in the coil is also important as coverage from the pelvic floor to the lower para aortic nodal chains is essential. Assessment of the abdominal nodes may be done by abdominal MRI or x-ray computerised tomography (CT). If the former, it is either necessary to reposition the patient in the pelvic array coil as for an abdominal examination, or to use the whole body multi-coil arrangement currently available on newer scanners.

For dedicated imaging of the cervix an endocavitary coil provides high spatial resolution images (6;7). Although coils may be sited in the rectum for this purpose, they are less comfortable than a vaginally sited coil. Balloon design shaped coils are available that are of single loop geometry. A solenoid design endovaginal coil that envelops the cervix provides a signal to noise advantage. The ring is 37 mm in diameter and is useful for delineating smaller tumors and early parametrial invasion (6). When an endocavitary coil is used, immobilisation of the coil is key to obtaining high quality images. Balloon coils use the balloon itself as an immobilisation device but it is important to place a sand bag over the coil handle to further reduce motion. With the ring design coil an external clamp is used to grasp the handle. The
endovaginal coil also may be combined with an external pelvic array in a multi-coil arrangement. Endovaginal coils are surprisingly well-tolerated even in patients with larger tumors and are a particular advantage in assessing patients prior to fertility-sparing surgery. This coil design is best suited to those cases in which a cervix is still present and the tumor is small (e.g. stage Ia or Ib). Breach of the fibrous ring of the stroma, or an abnormal pattern of enhancement may be features of early neoplasia that are more easily recognized with the improved resolution provided by this technique. In future, it may also prove more valuable in visualizing the mucosal-stromal junction in patients with severe cervical dysplasia and following them up after cone biopsy if they have persistently abnormal smears.

**Sequences:** The T2-weighted sequence forms the mainstay of assessment of the uterine body and cervix. The intermediate signal-intensity of tumor (either endometrial or cervical) is well delineated against the low signal-intensity of the junctional zone or the inner cervical stroma. Multiple planes for tumor assessment are required and it is usual to obtain three T2-weighted sequences in planes axial, coronal and sagittal to the uterine body or cervix as appropriate. T1-weighted images may be used to supplement T2-weighted images and are useful in cases of recent haemorrhage where the blood products are easily identified on T1-weighted imaging, but may be difficult to differentiate from other areas of low signal-intensity on T2-weighted imaging.

The use of dynamic contrast-enhanced imaging following a bolus of gadolinium is helpful to outline the tumor in cases where the zonal anatomy of the uterus is no longer evident or is disrupted. A 3-D or multi slice 2-D
acquisition is preferred, particularly as it may be difficult to identify a single slice of interest. Contrast between the highly perfused myometrium and the poorly enhancing tumor is maximal between 60 and 90 seconds, so a temporal resolution of at least 30 seconds is desirable. With carcinoma of the cervix intravenous contrast agent has limited value (8;9).

Normal Anatomy

The uterus is a pear-shaped structure with a triangular cavity with the cornua and the internal os as the corners. The cylindrical fibromuscular cervix with its central canal lined with epithelium extends into the vaginal vault. The uterus can be recognized in three distinct zones on T2-weighted images (10) - an inner high signal-intensity endometrial stripe, a middle layer of low signal-intensity representing the inner myometrium or “junctional zone”, and an outer intermediate signal-intensity layer of outer myometrium. With oral contraceptive pill usage, the junctional zone appears thinned. This zonal anatomy is not present pre-menarche or post-menopausally, but reappears after hormone replacement therapy.

Similarly T2-weighted images show the normal cervix to consist of two distinct stromal zones and the mucosa surrounding the central canal. The mucosa is relatively high signal-intensity on both T1- and T2-weighted images (11). Mucosal detail seen with a high spatial resolution endovaginal technique (pixel size < 0.5 mm) shows a smooth and regular outline in the nulliparous cervix (11) and a more irregular and indented outline in the parous cervix. In addition, dilated glands filled with secretions are sometimes seen in the latter group. The inner stromal zone is best identified on T2-weighted images as a
ring of low signal-intensity, whereas the outer stromal ring is intermediate signal-intensity on T1- and T2-weighted images. No obvious visible differences in the zonal anatomy are noted between women taking the oral contraceptive pill and women who are not, or between the follicular and luteal phases of the menstrual cycle. The presence of glandular retention (Nabothian) cysts within the cervical stroma is so common that it is considered a variation of the normal pattern.

Histologically, the myometrium and fibromuscular stroma of the cervix vary in cellularity between the inner region immediately surrounding the endometrium or endocervical mucosa and the outer more peripheral zone. In most instances, the transition from a tightly packed inner myometrial/stromal pattern to a more loosely packed outer myometrium/cervical stroma is gradual over 1-2 mm and subtle and the boundary between the two zones is difficult to define. Sometimes, the change is more abrupt. More peripherally, the extracellular space becomes more prominent and the cell nuclei fewer. The discrepancy between the MR findings and the histological appearances may in part reflect the differences in resolution of the two techniques: the cellular changes occur over one pixel (~0.5 mm) and appear to have a sharper boundary than the histological transition over one high power field (~1.5 mm).

The vascularity of the normal myometrium and cervix is easily demonstrable, with good correlation between ex vivo and in vivo appearances. The difference in vascularity between the inner and outer zones is borne out by their dynamic enhancement patterns. The outer zone is highly vascularized. Dynamic scanning done during and after a bolus injection of 0.1
mmol/kg body weight of gadopentetate dimeglumine shows brisk myometrial enhancement which peaks around 90 secs. The endometrium enhances more slowly (12). Conversely, in the cervix, mucosal enhancement commences at 30 sec and peaks at 120 sec after injection. The fibromuscular stroma enhances more slowly, making cervical zonal differentiation maximum at 90 sec (11).

The parametrium is optimally visualized in the transverse plane on both T1- and T2-weighted images. Adjacent rectosigmoid colon, obturator vessels, parametrial nodes and bladder can be easily identified.

**Endometrial carcinoma**

*Role of imaging:* Cancer of the uterine corpus is the second commonest gynaecological tumor with a reported incidence 19/100,000 women/year in the UK (Cancer Research UK Cancer Stats 2002) and 23/100,000 women/year in the USA (US Cancer statistics 2002). The majority are endometrial in origin. Endometrial cancers are predominantly adenocarcinomas. They are rarely diagnosed in the absence of abnormal bleeding but in the presence of post-menopausal bleeding it is mandatory to exclude them. The simplest and most convenient means of achieving this is transvaginal ultrasound. This has a negative predictive value of 96% (13) when the endometrial echo is ≤4 mm thick. An echo >4 mm indicates the need for a biopsy. Biopsy is obtained by D&C/hysteroscopy or by one of several devices such as Pipelle, Endocell, Vabra, Novak designed for the outpatient setting. When the diagnosis is confirmed histopathologically, additional imaging is recommended to help stage the disease.
Although ultrasound is an effective means of screening women with post-menopausal bleeding to exclude endometrial cancer, it is less accurate than MRI for delineating the extent of disease within the uterus. MRI (14) is superior for assessing both the extent of the tumor in terms of myometrial invasion and involvement of the cervix, as well as metastatic involvement of pelvic and para aortic lymph nodes. It is not a sensitive means of detecting micro-metastatic nodes but gross involvement can be identified (15). Formal staging of endometrial cancer however, as per the Federation International de Gynaecologie et Obstetrique (FIGO) classification is based on surgical staging and histopathology (Table 1). Full staging requires a pelvic and para aortic node dissection, but in the absence of obvious pelvic node involvement and palpable para aortic nodes, the latter need not be removed.

The principal benefit of pre-operative MRI in conjunction with histopathology is to confirm that disease is confined to the uterus prior to primary surgery. This consists of a total abdominal hysterectomy and bilateral salpingo-oophorectomy. The adnexae are removed because of the risk of their involvement with tumor. A vaginal hysterectomy offers less morbidity in an older population, and the adnexae may be removed either at open surgery or laparoscopically. When tumors are confined to the uterus it is the combination of differentiation and myometrial involvement that is used to estimate the risk of lymph node involvement. This can be exploited pre-operatively to triage tumors into low, medium and high risk based on endometrial biopsy and imaging. Well differentiated tumors and tumors only infiltrating superficially without enlarged nodes on MRI are unlikely to be associated with extrauterine disease and are at low risk of recurrence,
whereas patients with deep (>50%) myometrial invasion or cervical involvement or poorly differentiated tumors are at high risk of recurrence. Current practice in many centres is for high-risk patients to undergo pelvic lymphadenectomy at the time of primary surgery.

Although there are several studies showing the value of lymphadenectomy as a prognostic indicator (16;17), there is as yet no conclusive evidence that lymphadenectomy is itself effective in terms of surgical cure or even that it increases survival by incorporating adjuvant non-surgical treatment such as radiotherapy or chemotherapy (18). Some case control studies have suggested increased survival with lymphadenectomy but these may have been compounded by case mix. The only trial to assess the value of lymphadenectomy in endometrial cancer (ASTEC (19)) randomized women to have pelvic lymphadenectomy or no lymphadenectomy. Preliminary evidence from this study has shown no survival benefit (20) for those undergoing pelvic lymphadenectomy. Thus, the identification of patients at high risk of recurrence by differentiating <50% (Ib) from >50% (Ic) myometrial invasion, is for prognostic information, rather than for selecting patients for lymphadenectomy. Until an impact on surgical planning can be shown, the value of pre-operative imaging is in confirming that disease is confined to the uterus rather than in differentiating <50% from >50% myometrial invasion, as this information is readily available following hysterectomy. In patients unfit for surgery, a description of disease extent guides dose prescription and the use of brachytherapy.
The primary site: Eighty percent of endometrial cancers are found to be stage 1 and within stage 1 the majority are stages 1a and 1b. The endometrial lesion is usually well demonstrated on transvaginal ultrasound but establishment of a diagnosis of cancer and differentiation from adenomatous hyperplasia which may mimic endometrial cancer depends on histology. The sensitivity of detection of myometrial invasion on transvaginal ultrasound is highly operator dependent even with high frequency probes. Newer helical CT approaches do not provide any improvement in staging accuracy (21) and MRI is now the accepted gold-standard for assessing myometrial extension and extrauterine spread.

On a T2-weighted pulse sequence, the tumor is intermediate to high signal-intensity which contrasts with the low signal-intensity of the surrounding inner myometrium (Fig. 1). In a post-menopausal uterus however, it may be difficult to differentiate tumor from the high signal-intensity of normal postmenopausal myometrium. The use of dynamic contrast-enhanced T1-weighted MRI (Fig. 2) improves the ability to assess the depth of myometrial invasion (22;23). Overall, MRI has been found to have a sensitivity of 57% and a specificity of 96% for detecting tumor confined to the endometrium, a sensitivity and specificity of 74% for superficial invasion and a sensitivity and specificity of 88 and 85% respectively for deep invasion (24). However the degree of invasiveness may be overestimated for exophytic polypoid tumors with significant extraluminal extension (25;26). Powell et al (27) found the low-signal band of inner myometrium to be thinned or absent in those patients with deeply invasive tumors, and this correlated well with the pathological measurement of myometrial invasion.
Local spread: Around 10-15% of patients with endometrial cancer demonstrate microscopic or gross involvement of the cervix (28). The sagittal plane is most appropriate for imaging a patient with primary endometrial cancer, as this provides a longitudinal view of the uterus, which includes both corpus and cervix. Cervical involvement is usually better appreciated on the T2-weighted rather than the dynamic contrast-enhanced images because the intermediate to high signal-intensity tumor contrasts with the profound low signal-intensity of the normal cervical stroma (Fig. 3). Delineating endocervical mucosal involvement without stromal involvement can be difficult and ultimately relies on histopathology at hysterectomy. A sensitivity of 72%, specificity 93.2% has been shown for detection of any cervical involvement by MRI but when cervical stromal invasion was considered alone, the sensitivity was improved at 84.4%, specificity 87.4% (29). In cases of cervical involvement, radical hysterectomy followed by adjuvant pelvic and possibly para-aortic radiotherapy is usually employed. It must be noted however, that even when disease appears confined to the uterus on MRI, positive cytology on ascitic fluid, would stage the disease as Stage 3. This is not identifiable on imaging and emphasizes the importance of surgical staging.

In patients with more advanced disease clinically, use of the sagittal plane also provides the opportunity to assess anterior invasion of tumor into the bladder and posterior extension to the rectum.

Regional spread: Enlarged lymph nodes are best demonstrated on transverse T2-weighted images covering the pelvic lymph node chains from
aortic bifurcation to inguinal regions. Coronal T1-W and short tau inversion recovery (STIR) images may also be helpful to trace disease along the iliac chains. Iliac nodes >7mm short axis are regarded as positive (16). These techniques which rely on size criteria alone cannot differentiate between enlarged benign and metastatic nodes. Use of lymph node specific contrast agents have been advocated, but are not yet fully licensed for clinical use. Ultra small particles of iron oxide (USPIOs) can be administered intravenously to detect node metastases with MRI (30). The particles are normally taken up by macrophages in the reticuloendothelial system of normal lymph nodes (31). Uptake of USPIOs results in signal-intensity loss in normal lymph nodes in T2-weighted and T2*-weighted images due to the susceptibility artefact caused by iron. Metastatic tumor within the nodes does not take up the USPIO contrast agent and the nodes continue to show high signal-intensity.

When there is no lymphadenopathy detectable on preoperative imaging, assessment of nodal metastases relies on lymph node sampling or lymphadenectomy. The relatively low sensitivity of PET for detecting nodal disease in endometrial cancer does not warrant its routine use (32). In some advanced cases of endometrial cancer, peritoneal metastases are seen with a pattern indistinguishable from ovarian carcinoma (Fig. 4).

**Imaging in recurrent disease:** In cases where recurrent endometrial cancer is suspected, physical examination may be difficult because of postsurgical fibrosis. CT or MRI may be used to detect recurrent disease and metastatic carcinoma (33;34). Patterns of recurrence include central recurrence, often centered around the vaginal vault (Fig 5a), peripheral
recurrence with pelvic side-wall disease (Fig 5b) or distant metastases with lymphadenopathy above the pelvic radiation field or lung or liver metastases. MRI is preferred over CT for delineating pelvic recurrence as it provides better differentiation between post treatment fibrotic tissue and tumor (33).

Cervical cancer

Role of imaging: Cervical cancers occur in 9.4/100,000 women/year in the UK (Cancer Research UK Cancer Stats 2002), 8.7/100,000 women/year in the USA (US Cancer statistics 2002) and are usually squamous (~70%) or adeno carcinomas (~30%) arising from the cervical epithelium in a background of intraepithelial neoplasia. In cervical carcinoma, precise staging of the disease provides a prognosis, allows the institution of correct treatment and permits comparison of different treatment protocols.

Clinical staging, applied according to the system of FIGO (Table 2), is subjective and notoriously poor. The standard method of assessing cervical cancer, examination under anaesthesia, palpating the tumor and the parametria for assessing tumor size and parametrial invasion is often inaccurate (35). If the tumor is mainly exophytic, the findings from examination under anaesthesia give a reasonable indication of the size and extent of disease. However, in tumors with an endophytic component and in lesions located within the endocervical canal, the clinical assessment of disease volume is unreliable, usually resulting in substantial underestimation. While an experienced clinician can usually detect gross invasion of the parametria, early invasion invariably goes undetected.
Imaging with transabdominal ultrasound does not improve the accuracy of clinical staging (36) because of poor image quality and difficulty in interpretation. Transrectal ultrasound produces clearer views of the cervix but definition of tumor from normal cervix is still poor. The same difficulty limits the value of CT because the normal cervix and cervical carcinomas have similar attenuation values, so that the tumor can only be recognized if it alters the contour or size of the cervix (37).

MRI with a standard body coil has an accuracy of 76-85% (38-42) for detecting and staging cervical cancer and is therefore the modality of choice. Several studies have confirmed its staging accuracy in comparison to surgical staging (40;43). The primary tumor is best assessed using T2-weighted MRI which is superior to CT in detection (sensitivity 75 vs. 51%, p <0.005) and in staging (accuracy 75–77 vs. 32–69%, p <0.025) (44;45).

MRI is also able to provide an accurate tumor volume which is an important prognostic factor: the largest study using tumor volume measured this parameter in 1028 women with Stage Ib-IIb cervical cancer on the hysterectomy specimen (46). The 345 women with a tumor volume 2.5-10 cm³ had a 5 year survival of 79.2%; 330 women with a tumor volume 10-50 cm³ had a 5 year survival of 70.4%; and those with larger tumors had a 48% 5 year survival. It is not entirely clear whether the volume of the primary disease is the crucial factor or if it is simply an indication of the likelihood of spread. The correlation between tumor volume and the risk of lymph node metastases is well established using histological measurements obtained from Wertheim’s hysterectomy specimens (47;48). The tumor to cervix quotient has also been shown to predict the risk of nodal disease (49). Another important feature
detectable on MRI is parametrial spread. Parametrial invasion per se has been shown to be an important prognostic factor (50), but it is also an independent predictor of lymph node metastases (48): spread into the parametrium increases both the proportion of women with involved nodes and the extent of that involvement (47).

MRI therefore should be used routinely to define both tumor volume and parametrial extension. This enables a more rational and accurate choice of therapy, allowing some women with small lesions to be offered conservative surgical approaches and fertility-sparing procedures while, at the opposite extreme, selecting out those women with poor prognosis disease who might benefit from multimodality therapy (51). Pre-treatment MRI parameters may also be used to predict disease-free survival as they are better than clinical examination (52). Finally, treatment response to radiotherapy and neoadjuvant chemotherapy may be monitored with MRI. It is more accurate than clinical examination in predicting local control of disease (53).

The primary site: Cervical cancer is recognized as a high signal-intensity mass within the normally low signal-intensity cervix on T2-weighted images. Distortion of the low signal-intensity ring of inner cervical stroma may be apparent and any breaks in the ring representing tumor extension into the parametrium may be identified. MRI is also accurate in showing the relationship of the tumor to the internal os, and hence the patient’s suitability for fertility-sparing procedures such as trachelectomy (54). Tumor volumes are estimated by drawing regions of interest around the tumor image on
successive T2-weighted scans and then computing the tumor volume per slice from the product of the area and the slice thickness. Volumes obtained with MRI correlate well with those obtained by histomorphometric methods but only weakly with clinical stage (55): however the larger volumes on estimates from MRI are due to the hydration of the tissues in vivo prior to their fixation (56). Patients presenting because of abnormal smears tend to have tumor volumes of <1cm³ whereas patients who present with bleeding tend to have larger tumor volumes at presentation (57).

With an endovaginal MRI technique, the acquired in-plane resolution of ~0.4 mm means that very small cervical lesions with volumes as low as 0.2 cm³ and early spread to the parametrium can be demonstrated. Such precision makes this technique invaluable in the assessment of early cervical cancers prior to treatment (Fig 6). Trachelectomy (58) is often limited to ectocervical tumors because it has been impossible to accurately determine the extent of small endocervical lesions. Endovaginal MRI allows a precise definition of the size and location of small tumors and lends greater confidence to the selection of women for whom such conservative surgical treatment might be appropriate. Unfortunately, patients are often referred following positive cone biopsies when distortion of the cervix local haematoma or granulation tissue makes image interpretation difficult. Such appearances may result in false positives and radiologists must be aware of these potential pitfalls. In such cases, magnetic resonance proton spectroscopy used in conjunction with imaging may prove valuable (59;60) and developments may well emerge which address this issue. The sensitivity of endovaginal MRI compared to histology as the gold standard for detecting the presence of
Stage I tumors in our experience is 97.2%, specificity 80%, positive predictive value 97.2%, negative predictive value 80% (7). This compares well with quoted figures of 77% sensitivity 80% specificity for detecting Stage 1 cervical cancers using conventional MR techniques (61).

Following contrast enhancement a well-vascularized tumor like squamous carcinoma can be indistinguishable from the well-vascularized normal outer stroma of the cervix. However, in a rare, poorly vascularized tumor like oat-(small-) cell carcinoma, the use of contrast agent can be useful to delineate small foci of tumor in the more peripheral part of the cervix. The solid component of low grade tumors such as the rare adenoma malignum also are more apparent on gadolinium enhanced scans, although they may be recognized on the T2-weighted scans because of hyperintense cystic regions (62). Dynamic contrast enhancement has been reported by some as valuable in accurate assessment of cervical invasion by tumor (12) but there is general agreement that these images do not add to the information available on post-enhancement scans. Dynamic contrast enhanced studies have been used for assessment of tumor angiogenesis (63) and the rate of contrast uptake shown to correlate with microvessel density in the tumor. However, no correlation with tumor aggressiveness has been demonstrated (64).

Local Spread: Transrectal ultrasound, CT and MRI have all been used to assess parametrial spread. With ultrasound significant problems arise in distinguishing between inflammatory change and tumor invasion (65). Similarly, false-positive diagnoses may arise from misinterpreting inflammatory parametrial soft tissue strands associated with a tumor as actual
tumor invasion, on both CT and MRI (56). A comparison of the assessment by these modalities with histological findings after radical hysterectomy showed an accuracy rate for parametrial involvement of 87–90% for MRI, 55–80% for CT and 82.5% for examination under anaesthesia (44;45).

Extracervical extension on MRI is best defined using T2-weighted fast spin-echo sequences (Fig. 7). Fat suppression techniques do not provide additional benefits (66). Extracervical invasion may be assessed in three planes: the coronal and axial planes are used for determining parametrial invasion, the axial plane for determining extension into the bladder and rectum and the sagittal plane for extension into the uterine body, bladder and rectum (67). Where the low signal-intensity stripe of residual, normal stroma of the cervix is seen peripheral to the tumor mass on T2-weighted images, a diagnosis of no extracervical spread is made; a break indicates extension of tumor into the adjacent parametrium. Where there is extensive involvement with tumor, no residual normal stroma may be demonstrated. The intermediate signal-intensity of the tumor is seen extending into and blending with the high signal-intensity of parametrial fat, although tumor extension may be overestimated due to peri-tumoral inflammation.

Regional spread: Lymph node involvement in cervical cancer is often assessed with CT. The major drawback as in endometrial cancer, is that nodes must be enlarged to be detectable; >7mm short axis is usually regarded as positive. Some studies have shown an improvement in pelvic lymph node evaluation with MRI compared to CT (accuracy 88 vs. 83%, p<0.01) (45). However, like CT it relies on changes in the size of the lymph
nodes since the tumor deposits themselves are not highlighted. An in vitro study has shown that lymph nodes containing metastases have a significantly longer T2 than do normal or hyperplastic nodes (68), but in vivo tissue characterization based on relaxation times or signal intensities does not support this data. T1-weighted and T2-weighted sequences in the transverse plane and STIR sequences in the coronal plane are best for nodal detection and allow measurements of the long and short axes of any visualized lymph nodes. As with endometrial cancer, the routine use of USPIOs as a lymph node contrast agent may be useful in future.

**Assessing response and recurrence:** With the increased use of cytotoxic regimes for primary and recurrent tumor, accurate imaging techniques become more important. Serial MRI may be used before and after primary radiation therapy to assess tumor response (69). Primary tumors with a volume of >50cm$^3$ are likely to have a poor or delayed response (69). An early (2–3 months) and significant decrease in the signal-intensity and volume of tumor indicates a favourable response. However, it is often difficult to differentiate fibrosis after treatment from tumor recurrence. Although isolated reports promote MRI in distinguishing post-treatment fibrosis and recurrent pelvic neoplasm by measuring signal intensities from the different tissues on T2-weighted pulse sequences (33), in individual cases this differentiation is often impossible. Newer techniques such as diffusion weighted MRI may prove useful in this situation (70).
**Uterine Sarcomas**

Uterine sarcomas are rare and are reported to constitute between 1-3% of all uterine malignancies (71). They are characterised by their aggressive behaviour and early dissemination (72). The terminology of uterine sarcomas in the literature can be confusing. Uterine sarcomas are divided into pure sarcomas which contain only one sarcomatous element and mixed sarcomas which contain more than one element. They can be homologous (arising from tissues normally found in the uterus), heterologous (arising from elements not normally found in uterus) or mixed. Pure homologous uterine sarcomas include leiomyosarcoma, endometrial stromal sarcoma and fibrosarcoma. Rhabdomyosarcoma is included in the pure heterologous subset. Mixed homologous sarcomas may rarely be seen but most mixed sarcomas contain more than one heterologous component with or without a homologous element. This latter group is referred to as mixed mesodermal sarcomas or more properly as mixed heterologous sarcoma or malignant mixed mullerian tumor, heterologous type (71). Malignant mixed mullerian tumors are also called carcinosarcomas, referring to both their malignant epithelial and malignant mesenchymal elements (73;74).

MRI appearances of uterine sarcomas appear in the literature as case reports and small case series.

**Leiomyosarcoma:** Primary leiomyosarcoma of the uterus usually presents as a large mass replacing the normal architecture of the uterus (72) and may sometimes be misdiagnosed as leiomyoma (75). Leiomyosarcomas are
typically large solitary masses but may be associated with one or more typical leiomyomas. Leiomyosarcoma arising in a leiomyoma is rare (76).

The tumors are predominantly intermediate signal-intensity on T1- and T2-weighted images with scattered foci of high signal-intensity on T2-weighted images and high and low signal intensities on T1-weighted images, corresponding to areas of haemorrhage and cystic necrosis respectively. Leiomyosarcomas have been shown to involve endometrium (72) or to distort and dilate the endometrial cavity without endometrial invasion (77). In contrast to leiomyomas, which are sharply defined (78), leiomyosarcomas usually have an ill-defined irregular margin and avidly enhance following intravenous gadolinium.

Malignant Mixed Mullerian Tumor/ Carcinosarcoma: Malignant Mixed Mullerian tumors (MMMTs) or carcino-sarcomas are the most common of the uterine sarcomas (72;79). Like endometrial cancers, MMMTs usually expand the endometrial cavity (Fig. 8) and can lead to junctional zone disruption and myometrial invasion (72;79;80). Rarely these tumors can present as large masses replacing the normal uterine architecture (72;81). In advanced cases extension beyond the true pelvis with peritoneal deposits may be seen (79).

MMMTs are of mixed signal-intensity with areas corresponding to haemorrhage and necrosis (79;81). These signal characteristics are not unique and cannot differentiate MMMTs from endometrial carcinomas (79;80). However, size and extent may provide a clue to diagnosis as MMMTs tend to be larger with deep invasion at initial presentation in contrast to endometrial carcinomas which, in the majority, are confined to the endometrium or only
superficially invading the myometrium (79). MMMTs enhance following contrast (72;80), often heterogeneously, with areas of avid enhancement in the early phase, similar to that of myometrium, that persists into the delayed phase. This pattern is unusual for endometrial carcinomas and may be a differentiating feature (80).

_Endometrial Stromal Sarcoma:_ Endometrial stromal sarcomas (ESS) present as large uterine masses (82;83). They originate in the endometrium but often invade the myometrium so that predominantly endometrial or predominantly myometrial lesions (Fig. 9) are described (72;82-84). Rarely, tumors may be endometrial in location with no myometrial involvement (72;83) or lie within myometrium without any connection to the endometrium (85;86). The endometrial/myometrial border is irregular if there is myometrial invasion. ESS may be difficult to diagnose pre-operatively on curettage, as low-grade ESS cells may not be sufficiently atypical. ESS used to be subdivided into low-grade and high-grade tumors depending on mitotic rates. However, mitotic rates are no longer used and tumors previously designated as high-grade tumors are now classified as high-grade or undifferentiated ESS (76). The previously defined low-grade ESS tend to occur in a younger age group (82).

ESS lesions are high signal-intensity on T2-weighting (82;83) and low, heterogeneously, intermediate or high signal-intensity on T1-weighting (82-84). Bands of low signal-intensity running through the tumor on T2-weighted images have been described in some tumors with extensive myometrial involvement (82). These bands correlate with preserved myometrial bundles
separated by nodules and cords of tumor seen on pathological examination. When this feature is seen it suggests an ESS (82). Gross intravascular involvement is another feature of ESS with tubular masses extending from the uterus to the adnexal region resembling the intravascular extension seen in intravenous leiomyomatosis (82). Diffuse permeation of the tumor to the parametrium and fallopian tube walls has also been described and correlates to tumor infiltration within vessels and lymphatics (82;86).

Contrast enhancement within these tumors is seen much more often than in endometrial carcinoma (83). Heterogeneous enhancement has been described (84;86) as well as a pattern of peripheral enhancement with centripetal filling with persistence of enhancement (87). It may also be difficult to distinguish a myometrial ESS from a leiomyoma (82) particularly in a large leiomyoma undergoing cystic degeneration. However, lesion margins are important here as they are almost always sharp in a leiomyoma and frequently infiltrative in an ESS (82). Also contrast enhancement would be an unusual finding for a leiomyoma (85).

**Rhabdomyosarcoma:** Uterine rhabdomyosarcomas present as large uterine masses (72) of intermediate marbled signal-intensity with heterogenous areas high signal-intensity on T2-weighted scans. Homogeneous low signal-intensity is seen on T1-weighting. These cases are extremely rare and cannot be distinguished from other uterine sarcomas.
Unusual Uterine Malignancies

*Lymphoma:* Lymphoma of the uterus is rarely the initial site of disease (88;89). In most cases there is diffuse uterine enlargement with homogeneous low signal-intensity on T1-weighted and high signal-intensity on T2-weighted images (89-92). Lymphomatous infiltration of the uterine corpus may occur without destruction of uterine architecture (88), maintaining the appearance of a normal junctional zone (88;92). The zonal architecture of the cervix may also be preserved and the endometrium remain intact (90;91). However, loss of the junctional zone and involvement of the cervical stroma is also described (89). These diffuse lesions enhance homogenously (89;90). Uterine lymphoma also shows a nodular pattern: enlarged myometrial nodules may be either high or low signal intensity on T2-weighted images (91).

In cases of cervical lymphoma, cervical enlargement with hyperintense signal on T2-weighted and isointense signal on T1-weighted imaging is seen which is indistinguishable from cervical cancer (89;92). However, it may be possible to distinguish an intact cervical epithelium to help differentiate (89). There may be associated thickening of the vaginal walls (89;92).

*Small Cell Carcinoma:* Small cell carcinoma is rarely observed in the uterine corpus. When involved, the uterus may be uniformly enlarged, diffusely high signal intensity on T2-weighted and low signal intensity on T1-weighted images (resembling lymphoma) but with septal enhancement (93;94) and lobulation (94).
Uterine Metastases: The uterus may be involved with metastases, mainly from pelvic neoplasms. Metastases to the uterus from extrapelvic organs are rare. The most common primary tumours include breast and stomach though other sites have also been reported including melanoma (95;96).

Direct extension of tumor to the uterus from adjacent organs or peritoneal implants may be mass-like or infiltrative (Fig. 10) and involve the myometrium with or without endometrial invasion (97). In cases of direct tumor extension, the shape of the uterine body may be abnormal with loss of the junctional zone observed in some patients. In non-contiguous spread (haematogeneous, lymphatic and via fallopian tubes) the shape of the uterine body is preserved but again there is loss, at least in part, of the junctional zone on T2-weighted images. Infiltrative tumour may be low (97) or high signal-intensity (95) on T2-weighted images with heterogeneous enhancement. When the cervix is involved, a discernable mass and loss of the usual hypointense stroma on T2-weighting is usually seen (97).

CONCLUSION

Uterine cancers are clearly delineated on MRI, where T2-weighted contrast provides good definition of the primary lesion and its extrauterine extension. The key to a successful examination relies on good patient preparation, use of antiperistaltic agents and a meticulous scanning technique. With MRI, the multi-planar facility is invaluable for assessing disease margins and spread, with 3D techniques offering the advantages of increased coverage and high spatial resolution. Characteristic MRI features go a long way to refining the
differential diagnosis, but ultimately the management plan depends on a combination of clinical assessment, imaging and histology.

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Unpublished Work


Abstract


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FIGURES

Fig. 1: Endometrial cancer confined to the uterus: Sagittal (a) and transverse (b) T2-weighted fast spin echo (2500/90 msec [TR/TE]) images through the pelvis show an intermediate signal intensity polypoid mass filling and expanding the uterine cavity. There is discontinuity of the low signal-intensity stripe of the junctional zone (arrows) where early invasion of tumour into the myometrium is seen. A well-defined very low signal intensity leiomyoma is seen on the posterior myometrium in a.

Fig. 2: Endometrial cancer confined to the uterus: Sagittal dynamic contrast enhanced series (GRE 3.5/1.7 msec [TR/TE]) with fat saturation before (a), immediately after (b) and at 30 secs (c), 60 secs (d) and 5 mins (e) after intravenous administration of a bolus of 0.1 mg/kg Gadolinium DTPA. There is strong myometrial enhancement immediately following contrast injection. The irregularity at the endometrial-myometrial junction (arrows) showing early invasion of the low signal-intensity tumour into the enhancing myometrium is best seen at 30 secs. A poorly enhancing intramural leiomyoma is noted in the posterior myometrium.

Fig. 3: Endometrial cancer with cervical involvement: Sagittal T2-weighted fast spin echo (2455/90 msec [TR/TE]) image through the uterus showing replacement of the endometrium and myometrium with a homogenous intermediate signal-intensity mass. Tumour extends down the endocervical
canal (arrow) expanding it and involving the cervical stroma. Free fluid is noted in the pouch of Douglas.

Fig. 4: Peritoneal metastases from endometrial cancer: Sagittal (a) and transverse (b) T2-weighted fast spin echo (2500/90 msec [TR/TE]) images through the pelvis show extensive nodules and plaques of intermediate signal intensity tumour (arrows) on the pelvic peritoneum. High signal-intensity loculated cystic fluid collections are also part of this metastatic tumour.

Fig. 5: Recurrent endometrial cancer: Transverse T2-weighted fast spin-echo (FSE 2500/90 msec [TR/TE]) images showing central recurrence in the vagina (a) and peripheral recurrence on the right pelvic side wall (b). The tumour mass (arrows) is intermediate signal intensity in both cases with focal central necrosis. In a, there is adherence to the right puborectalis and anorectal junction. In b, the mass is adherent to the pelvic side wall fascia.

Fig. 6: Cervical cancer confined to the cervix: Sagittal (a) and transverse (b) T2-weighted FSE (2300/90 msec [TR/TE]) images through the cervix using an endovaginal coil (pixel size 0.2 mm, 3 mm slice thickness). The intermediate signal-intensity polypoid tumour mass (arrows) is clearly demarcated in the right anterior quadrant. The endovaginal coil frames the cervix and demonstrates a clear margin of normally appearing cervical tissue around the tumour without evidence of parametrial extension.
Fig. 7: Cervical cancer with parametrial extension: Transverse T2-weighted fast spin-echo (FSE 2000/90 msec [TR/TE]) image through the cervix showing a bulky tumour eccentrically within the right anterior quadrant of the cervix. There is extension of the tumour into the parametrial fat (arrows).

Fig. 8: Carcinosarcoma of the uterus: Sagittal (a) and transverse (b) T2-weighted fast spin-echo (FSE 2500/90 msec [TR/TE]) images through the uterus showing expansion of the endometrial cavity with a high-signal intensity, heterogenous polypoid mass (arrows). Tumour extends down into the endocervical canal expanding it. There is no evidence of disruption of the junctional zone. The high signal intensity of the tumour and its heterogenous appearance is suggestive of a carcinosarcoma.

Fig. 9: Endometrial stromal sarcoma of the uterus: Sagittal T2-weighted fast spin-echo (FSE 2500/90 msec [TR/TE]) image through the mid-uterus showing a bulky thickened myometrium of heterogenous signal intensity and loss of the normal zonal architecture (arrow). The endometrial stripe is preserved and the cervix appears normal. The appearances are those of an infiltrative tumour. Free fluid is noted in the pouch of Douglas.

Fig. 10: Ovarian metastases to the uterus: Sagittal (a) and transverse (b) T2-weighted fast spin-echo images (FSE 2500/90 msec [TR/TE]) images through the uterus showing diffuse high signal at the cervico-uterine junction (arrows). This diffuse infiltrative mass is causing uterine obstruction with a hydrometra.
At hysterectomy infiltration of the uterus with ovarian carcinoma was confirmed.