REVIEW ARTICLE

Imaging Modalities in Gynecology

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Abstract

Although ultrasound is the primary imaging modality for most gynecologic diagnoses and conditions, knowledge of other diagnostic imaging procedures is important to gynecologists, emergency room physicians and radiologists who care for women of all ages. Since the early 1960s when ultrasound was introduced for the use in obstetrics and gynecology, other imaging techniques have rapidly come into play due to the tremendous advances in computer technology and in the field of engineering. It behooves us to become familiar and knowledgeable about the differences in these imaging techniques in order to gather the most information in the shortest amount of time to care for patients in the most efficient and cost-effective way. This review is meant for the use of most practicing physicians that are exposed to common as well as uncommon gynecologic conditions; therefore the primary imaging modalities discussed in this paper are limited to ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI).

Objectives
- Understanding of the strengths and limitations of ultrasound, MRI and CT
- Obtaining knowledge of when to apply the most appropriate imaging technique for a certain clinical situations

Keywords: Transvaginal ultrasound (TVS), computed tomography (CT), magnetic resonance imaging (MRI), gynecologic diseases.

ULTRASOUND

Transabdominal gynecologic ultrasound combined with transvaginal scanning is a technique that was initially introduced in the early 1980's and quickly became a "must-have" procedure for gynecologists and emergency room physicians for assistance in diagnosing many gynecologic conditions. Rapid advances in the quality of the equipment, techniques used to obtain best images, and research designed to help physicians interpret their findings have contributed to ultrasound's quick rise in use and popularity. It is ubiquitous that ultrasound is the imaging modality of choice for gynecologic conditions.

The advantages of ultrasound are numerous. It is fast, easy to obtain, has a high patient tolerance and is relatively inexpensive when compared to CT and MRI. Many physicians' offices have ultrasound machines that are more than sufficient to make common diagnoses thereby alleviating patient anxiety and physician concerns if an abnormality is found during a physical exam. Appropriate referrals and treatments can be initiated in a timely manner at minimum expense. The ability to use the transvaginal ultrasound as an extension of a pelvic exam is extremely useful, particularly when the source of pain is uncertain during bimanual exam or if a mass is found of uterine or ovarian origin. An obvious advantage, especially when compared to CT, is that no radiation exposure occurs. As will be

discussed in more detail, pelvic ultrasound has been shown, in numerous studies, to have a high negative predictive value and offers excellent resolution of the uterus and adnexal structures, especially when compared to CT and MRI.

There are disadvantages; however, that should be addressed. Even with routine use of transabdominal scanning which utilizes the acoustic window of a full bladder, the field of view is very limited, especially, compared to CT and MRI. Transvaginal sonography limits the field; however, it is effective in obtaining excellent resolution of the uterus, endometrium and adnexal structures. Ultrasound visualizes the bowel poorly and it is well-known that bowel gas corrupts the ultrasound signal allowing for potential "missed" masses not visible under the bowel. An additional drawback is that poor contrast occurs between dissimilar tissues (i.e. blood and fat) making it difficult to characterize certain ovarian masses accurately.

Ultrasound characterizes gynecologic pathology extremely well. Fibroids, endometriomas, dermoids, masses that are suspicious for malignancy, uterine anomalies, IUD complications, ectopic pregnancies, and endometrial pathology (with the help of transvaginal saline infusion sonography) are diagnoses that are detected with high accuracy. The following will give illustrations of the clinical utility of diagnostic gynecologic ultrasound for specific clinical conditions.

PELVIC PAIN OF UNDETERMINED ORIGIN

Reproductive aged women presenting with pelvic pain require immediate evaluation to rule out ectopic pregnancy or other pregnancy complication. Should these conditions be ruled out by a negative serum beta-hCG, other possibilities of the cause of pelvic pain can be investigated. Nonobstetrical presentations of acute and chronic pelvic pain account for 10% of all gynecologic visits.[1] Identifying ovarian cysts and their complications, ovarian torsion, endometriosis, tubo-ovarian abscesses, degenerating fibroids, and IUD complications are a few added beneficial uses of transvaginal sonography.

OVARIAN/ADNEXAL CYSTS

The incidence of ovarian cysts resulting in pelvic pain has not been reported; but in reproductive-aged women, it is the most common cause of pelvic pain that presents in emergency rooms. It is also the most common finding in asymptomatic women during routine pelvic exams that present for US. There are many types of ovarian cysts ranging from simple cysts (>2.5 cm),[2] endometrial cysts, cystadenomas and cystadenocarcinomas as well as paraovarian cysts. It should also be noted that not all observed cysts are the source of pelvic pain. The vaginal probe is able to achieve close proximity to the ovaries which aids in the determination of a cyst being the probable source of pain or if pain is external to the "incidental" cyst finding.

Beyond identifying a cyst or ovarian mass as the cause of the pain; the perennial dilemma is assessing the risk of malignancy in a mass. Many morphologic criteria are used to differentiate between benign *vs* malignant masses and transvaginal ultrasound has shown to have a sensitivity between 88 to 100% and a specificity between 62 to 92%.[3] Improvements to this risk assessment are assisted by Doppler flow studies and measurements and most recently, 3D imaging of power Doppler patterns.[4] Morphologic scoring systems use ultrasound findings such as presence of septations, thickness of septations, fluid density, wall excrescences and other parameters in scoring a mass to determine, if there is a high-risk of malignancy, or most commonly, a cyst that is benign. These morphologic scoring systems consistently show a high negative predictive value and high sensitivity.[5-8] Besides the benefit of assessing the risk of cysts or masses to be malignant, ultrasound is very
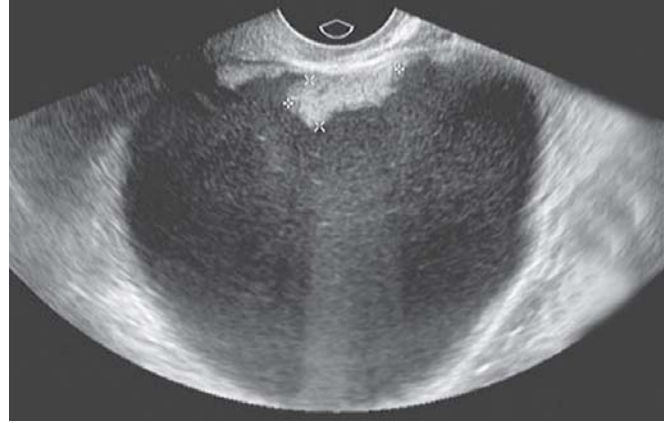

Figure 1: Borderline endometrioid tumor

efficient in determining if pelvic pain is the result of a rupture or an acute hemorrhage into the ovary. Temporal assessment can further assist in definitive a diagnosis, especially, if the cyst resolution is coincident with pain resolution (Figure 1).

OVARIAN TORSION

Ovarian torsion is the cause of 3% of patients presenting with acute pelvic pain and is a surgical emergency that may result in the loss of an ovary in young children to women of reproductive age. In 50% of cases, an ovarian mass is associated with the torsion.[9] Ultrasound is considered the imaging modality of choice for this diagnosis although its accuracy is far from perfect. Classic findings of ovarian enlargement (edema), multiple peripheral follicles and absence of Doppler venous and/or arterial flow, free fluid in the pelvis are not seen in the majority of the cases. Diagnoses often times are elusive and should be based on clinical presentation and suspicion. The possibility of torsion is certainly increased in an ovarian mass (particularly a large follicular cyst, cystic teratoma or a hemorrhagic cyst)[10] that is tender with pressure from the US vaginal transducer. As far as duplex and color Doppler flow studies are concerned, the studies have been "confusing and inconsistent".[9] The most predictive use of color Doppler has been the visualization of a "twisted pedicle as a whirlpool sign" described by Lee[11] in 1998 with a diagnostic accuracy of 88% for torsion (Figure 2).

In conclusion, there is no highly specific test to diagnose an ovarian and/or adnexal torsion. Also focusing on Doppler studies is flawed due to the dual arterial blood supply to the

Figure 2: Peripheral follicles in an enlarged, torsed ovary

ovary from the aorta to the main ovarian artery and from branches of the uterine artery. The venous system is similarly complex.[12]

PELVIC INFLAMMATORY DISEASE/ TUBO-OVARIAN ABSCESS

Acute PID is estimated to affect 1 million women per year and also causes 100,000 women to become infertile per year. It is also a significant factor in a number of ectopic pregnancies per year.[13] If any one of the following criteria are found, PID may be suspected in a reproductive-aged woman: pelvic pain, cervical motion tenderness and uterine or adnexal tenderness.[14] Although imaging is not indicated in every suspected case of PID, women with more severe symptoms or those with a high possibility of having a pelvic mass will require imaging or more specific diagnostic tests as management may need to altered based on these findings. Ultrasound is excellent for visualizing uterine enlargement, endometrial thickening or presence of fluid, increased ovarian size (with or without evidence of abscesses), hydrosalpinx as well as pyosalpinx[15] Thick-walled, tubular adnexal masses (with or without free fluid in the pelvis) have been reported to have a sensitivity or 85% and specificity of 100% for the diagnosis of PID.[16] As PID becomes more severe, other imaging modalities (MRI/CT) may be more beneficial in distinguishing soft tissue structures better than US (Figure 3).

DEGENERATING FIBROIDS

Uterine fibroids are the most common benign tumor of the female reproductive tract and their incidence is not known precisely, but ranges from 30 to 70% in premenopausal women and their incidence increases with age, particularly in the 5th decade of life.[17] Pelvic pain due to
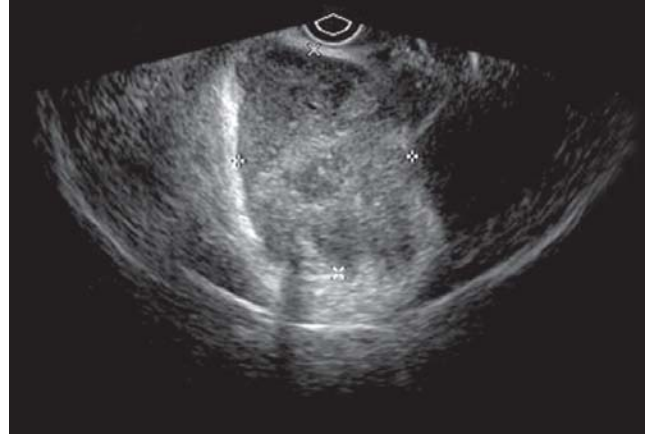

Figure 3: Tubo-ovarian abscess with complex mixed echogenic contents, diffuse borders and extreme tenderness during US examination

Figure 4: Cystic degeneration in a subserosal fibroid

fibroids is most commonly due to degenerating fibroids as they outgrow their blood supply.[18] Although, there are many forms of degeneration (hyaline, calcific, cystic, and hemorrhagic), there are characteristic US findings for each. Other imaging modalities discussed later in this article may be more useful in unclear cases related to pelvic pain and fibroids (Figure 4).

ENDOMETRIOSIS

Endometriosis, which is a pathologic condition of endometrial glands and stroma present in extrauterine locations is found in 10% of reproductive-aged women and is more common in infertile women. It is also commonly found in women with acute and chronic pelvic pain.[19] Since

Figure 5: "Classic" endometrioma with "ground glass" dense fluid contents with thickened walls

Figure 6: Transvaginal sonohysterography image with multiple endometrial polyps

80% of all pelvic endometriosis is found in the ovaries, US is the optimal method to diagnose this condition. Studies by Mais et al[20] and Kurjak et al,[21] and numerous others, have shown high sensitivities of 75 to 99% and specificities of 99% using US criteria. This development was particularly significant for those women who were to be followed conservatively, without surgery or to those who had limited, conservative surgery (i.e. laparoscopy). It was therefore important to attempt to determine the degree of risk for malignancy in these complex masses. Again, temporal imaging may be optimal in confirming a diagnosis without the need of a surgical confirmation due to ability to observe their characteristic appearance over time. Other imaging modalities may best determine extent of disease (MRI) as will be discussed later in this paper (Figure 5).

ENDOMETRIAL PATHOLOGY

Ultrasound is the imaging modality of choice for detecting endometrial abnormalities such as polyps, submucosal fibroids, thickening of the lining in postmenopausal patients and uterine anomalies. Again, the ability of the high frequency transducer in close proximity to the anatomic structures in question allows for excellent visualization of the endometrium as it relates to the myometrium and cervix. The addition of saline infusion sonography (SIS), with or without 3-dimensional sonography, greatly enhances the ability to detect pathology. In fact, SIS, when compared to the "gold standard" of hysteroscopy or hysterectomy, has a high sensitivity (87-96%) and even higher specificity (91-100%) when performed for abnormal bleeding[22,23] (Figures 6 and 7).

Transvaginal sonography in the evaluation of postmenopausal bleeding has been extensively studied,

Figure 7: Submucosal fibroid with > 50% exposure into the uterine cavity

resulting in an excellent review of US's role in a recent American College of Obstetricians and Gynecologists Committee Opinion[24] which states that postmenopausal bleeding may be assessed initially with either endometrial biopsy or transvaginal ultrasound. There is no need to utilize both tests. Transvaginal ultrasound may be used to "triage" patients to determine which patient may forego endometrial biopsy (i.e. if their endometrial thickness is less than or equal to 4 mm) and those who may require further evaluation, as transvaginal sonography has a very high negative predictive value as determined by several multicenter trials.

IUD COMPLICATIONS

Sonography plays a crucial role in the visualization of an intrauterine device (IUD). When checking for proper
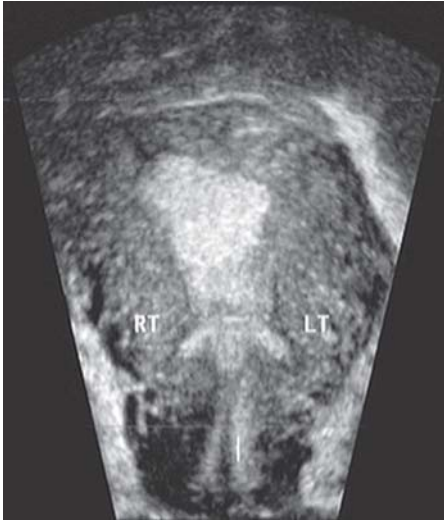
Figure 8: Three-dimensional rendering of the uterus in the coronal plane illustrating an IUD in endocervical canal

Figure 9: Three-dimensional rendering of the uterus in the coronal plane is a misplaced arm of an IUD

intrauterine location, sonography is the best method of detection in clinical cases of an IUD string no longer felt or seen on exam, or for detecting an absent or malpositioned IUD. Further imaging may be necessary in the case of a suspected uterine perforation; but for the most part, two dimensional imaging suffices in this regard.[25] Most recently however, three-dimensional imaging in visualizing the uterus in the coronal plane has been found to be superior in cases of malpositioned IUDs[26] (Figures 8 and 9).

COMPUTED TOMOGRAPHY

CT came into clinical practice in the early 1970s as the first imaging modlality that could acquire a view of anatomy in multiple "slices". It has improved much since then and CT technology has enjoyed a resurgence of popularity due to more rapid acquisition technology called spiral CT that not only acquires sliced images, but also obtains volume images. CT scanners are now widely available in most hospital settings and in many outpatient facilities as well. Images are now acquired with the use of multidetector machines that complete their acquisitions within seconds, and they can be displayed in multiple planes via reconstruction of data and images. The spatial resolution is excellent and different circulatory phases can be obtained allowing better interpretation of images.[27]

The optional, yet common use of IV contrast helps with differentiation of tissues such as blood vessels, lymph nodes, and the presence of tumors. The IV contrast also opacifies the ureters and the bladder. Oral and rectal contrast opacifies the bowel and aids in differentiating these anatomic markers from gynecologic structures. A large field of view is presented and total body CT scanning can be accomplished quickly and easily. The Z-axis (or coronal axis) is obtained automatically, resulting in excellent spatial resolution. This method is also less costly than MRI; however much more expensive than the alternative, US.

The disadvantages include radiation exposure, relative lack of soft tissue discrimination and the risks of IV contrast exposure. Exposure to ionizing radiation should always be in question when a decision is being made to order this imaging technique, especially as the use of this rapid acquisition modality has become more available in hospitals. A recent article by Fazel[28] observed nearly 1 million non-elderly adults over a 3 years period and found nearly 70% of them had at least one imaging procedure associated with radiation exposure. He also found that the cumulative effective doses of radiation from imaging procedures increased with advancing age and that they were higher in women than in men. CT and nuclear imaging accounted for 75% of cumulative effective dose with 82% of the total procedures were conducted in outpatient settings. The acceptable and appropriate dose of radiation follows the ALARA (As Low As Reasonably Achievable) principal which applies to radiation as well as ultrasound exposure and is universally accepted as a guiding principle in the practice of diagnostic imaging.[29] The relative level of radiation exposure in US and MRI is zero compared to a pelvic or abdominal

CT, where it is estimated to be 5 to 10 mSv, which is considered medium exposure. If abdominal or pelvic CT is done with and without contrast, the exposure can be in the range of greater than 10 mSv, which is considered as beng high exposure.[30] It is well-known that radiation exposure to a developing fetus can have damaging and long-term effects. Although the true risk of carcinogenesis in the use of "low-level radiation" in adults is not as clear; it cannot be stated to be zero.[31]

Additionally, there are relative contraindications to CT scanning and the use of contrast. CT should be used with extreme caution for diagnostic purposes in pregnancy, especially in the first trimester, in patients who are either allergic to contrast, those with renal compromise, those who are at high-risk for acute radiocontrast nephrotoxicity and those in renal failure. Despite these concerns, a recent paper by Hunt[32] in the American Journal of Roentgenology reported a very low incidence (0.15%) of adverse events with the use of low-osmolar iodinated contrast among nearly 300,000 administered doses. Although, there are clear disadvantages, CT imaging has defined and important uses in gynecology, particularly when the results of US imaging are unclear or ill-defined. Due to the larger field of view with CT evaluations, large masses are best characterized with this modality. CT imaging can be utilized to further evaluate pelvic masses following inconclusive US exams, to better characterize and delineate advanced pelvic diseases such as PID, to aid in the preoperative staging of ovarian, uterine and cervical malignancies, to assess treatment response of gynecologic malignancies and to assess for tumor recurrence. Evaluation of postoperative complications such as abscesses, fistulas, subfascial hematomas, ureteral injuries and retroperitoneal complications are also best diagnosed with CT imaging. Additionally, CT-guided biopsies and drainage procedures of pelvic fluid collections are possible.[33]

Women frequently have CT imaging performed as a first step in the evaluation of pelvic or abdominal pain. The question often arises whether to reimage with US or not after CT imaging. An excellent paper addressing this issue by Patel et al[34] suggests that a CT scan can stand alone in certain situations. He lists the situations as follows: Normal gynecologic structures seen on CT, CT demonstrated gynecologic pathology has a limited differential diagnosis that can be monitored by US or otherwise over time (i.e. hemorrhagic cyst), CT demonstrated gynecologic

abnormality has a characteristic diagnostic appearance (i.e. dermoid), CT demonstrated finding is clearly seen in the myometrium (i.e. fibroids) and in cases where US would be unable to add more information in the CT-detected abnormality. The following section covers gynecologic conditions whereby CT is superior to US.

PELVIC INFLAMMATORY DISEASE

CT scans are useful in cases of vague abdominal or pelvic pain, severely ill patients that can't tolerate or cooperate with transvaginal sonography, patients with equivocal US findings and patients in whom PID shows no improvement in initial treatment with antibiotics. Infections that are limited to the uterus can be visualized on CT as fat stranding in the parapelvic fat planes, fluid in the endometrium and loss of uterine border definition. As the disease ascends, CT can detect thickening of the fallopian tubes and enlargement of the ovaries.[35] Coronal reconstruction can assist in the detection of the tubal aspect of this disease. The most complicated cases of PID have tubo-ovarian abscesses (TOA) and when extensive, should be distinguishable from other causes of abscesses by the presence of anterior displacement of the mesosalpinx.[36] Reactive lymphadeno-pathy and perihepatic inflammation (Fitz-Hugh-Curtis symdrome) can also be seen in severe cases of PID/TOA[37] (Figure 10).

Figure 10: CT of tubo-ovarian abscess. Long arrows show the left thick-walled tubo-ovarian abscess and the short arrow shows a normal right ovary (Source: http://RiTradiology.com)

CYSTIC TERATOMA (DERMOID)

Benign cystic teratomas or dermoids are found in 10 to 15% of all ovarian tumors.[38] CT scan detection of dermoid tumors are commonly seen as an incidental finding in women who are scanned for other reasons and have characteristic features that do not necessitate additional US imaging. Dermoid tumors are also frequently seen in cases of ovarian torsion; therefore a CT scan could be performed as first line imaging for the diagnosing of acute pelvic pain. Certain cases of dermoids are not clearly seen on ultrasound and are sometimes confused with an endometrioma or other neoplasm. CT imaging reveals fat densities much better than US so that an ovarian mass with fat densities, with or without calcifications is diagnostic of a cystic teratomas[39] (Figure 11).

OVARIAN VEIN THROMBOSIS (OVT)

Ovarian vein thrombosis is a serious postpartum complication, estimated to occur in 1 in 3000 deliveries and can result in pulmonary embolism.[40] OVT may also occur after any gynecologic surgery, especially in gynecologic oncology cases or as a complication of PID, chemotherapy or trauma.[41,42] CT scans are particularly beneficial in the diagnosis of ovarian vein thrombosis and has been cited in a few papers as being the modality of choice.[43,44] CT findings are conclusive when a dilated pelvic vein is seen with enhancing walls containing a central low-attenuation (thrombus). The right ovarian vein is involved in 80 to
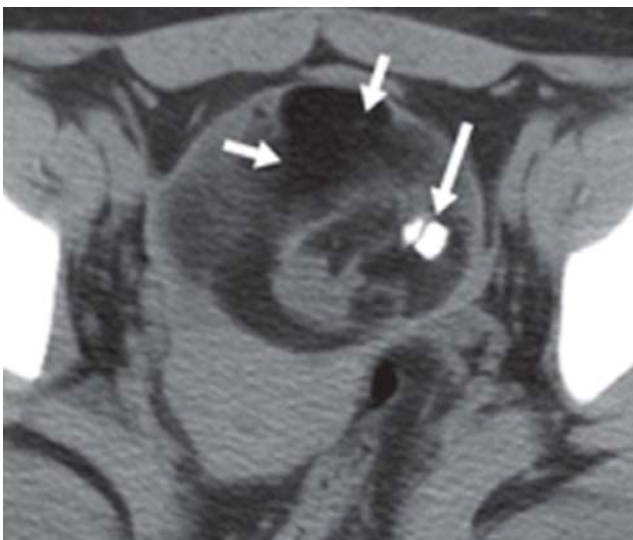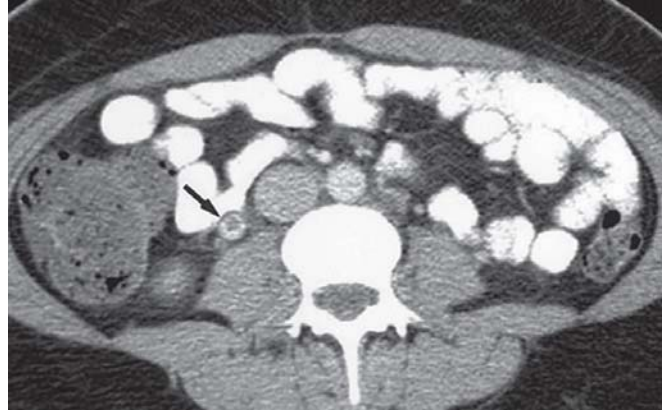

Figure 12: Right ovarian vein thrombosis (arrow) diagnosed by CT scan (Used with permission, Bennett GC, et al. Radiographics 2002;22:785-801, Figure 24)

90% of cases, with 10% of cases being bilateral[45] Multiplanar reconstruction may be crucial in the aid of distinguishing a dilated ureter or an inflamed appendix from a dilated ovarian vein with a thrombus. A comparison study by Twickler et al,[46] CT and MRI was shown to have greater sensitivity and specificity than Doppler US in the detection of OVT (Figure 12).

POSTPARTUM AND POSTSURGICAL COMPLICATIONS

CT imaging is the primary imaging modality for postoperative and postpartum complications. It provides an excellent field of view with anatomic localization. The ureters, the bladder and the bowel are clearly visible, aiding in the detection of postoperative complications. Examples of this may be seen in cases where poor response to antibiotics for suspected postpartum endometritis occurs. CT scan is capable of confirming a confined endometritis, endometritis with accompanying retained placental products as opposed to one that is an extending infection into the parametrial tissues.[47,48] Intra-abdominal, retroperitoneal or subfascial abscesses and hematomas can be visualized and localized with greater accuracy using CT imaging and may be used to assist in the drainage of these fluid collections as indicated.[49,50] The ability to differentiate between fluid types with CT-contrast is much easier compared to US. This is illustrated in cases of postsurgical urologic injuries which occur in 0.1 to 1.3% of all gynecologic surgeries.[50] These should be diagnosed with expediency to minimize further adverse sequelae. Contrast-enhanced CT with delayed imaging, CT cystography, and retrograde urethrography are the diagnostic imaging studies of choice for these

Figure 11: CT imaging of a mature cystic teratoma (Used with permission: Park SB, et al. Radiographics. 2008;28:969-983, Figure 1b)

injuries.[51] CT cystography with retrograde filling of the bladder followed by helical CT acquisitions is reported to have a 97% sensitivity and 100% specificity for intraperitoneal leakage and 78% sensitivity and 99% specificity for intraperitoneal leakage. Fistulas can also be diagnosed with this method.[52,53] Bladder injuries and bowel complications with intravenous and/or oral or rectal contrast assists in these areas as well. CT is also found to be superior to traditional radiology and barium studies in the diagnosis of small bowel obstruction.[54]

MAGNETIC RESONANCE IMAGING

MRI technology was first introduced into medical practices in the 1980s and it is the latest development in the three modalities covered in this article. It demonstrated the highest potential for diagnostic capabilities in a host of clinical situations. The distinct advantage that this modality has over both US and CT concerns soft tissue delineation. There is no risk of radiation exposure along with the advantages of high contrast resolution and it offers the option of non-ionizing contrast (gadolinium). Like CT and most recently, US; MRI has multiplanar reconstruction images. Similar to CT, MRI displays a wide field of view of structures outside of the pelvis and the adjacent areas.

High cost and limited availability of MRI are distinct disadvantages relative to US and CT. Contraindications occur as a result of the MRI's strong magnetic field in patients with pacemakers, ICDs (implantable cardioverter defibrillators), certain types of implanted intracranial aneurysm clips, cochlear implants and other medical devices. The use of IV contrast is frequently required; however, the risks of (noniodinated) gadolinium are less severe when compared to CT's iodinated contrast. MRI acquisitions are generally more time consuming than CT and US and a higher incidence of claustrophobia and motion artifact may occur. Scan times have been reduced with more modern scanners. The following section illustrates gynecologic conditions which are best visualized with MRI technology.

ADENOMYOSIS AND LEIOMYOMATA

Due to MRI's excellent soft tissue delineation, in part due to absence of degradation of images from calcified tissue (bone), MRI has been shown to be the most accurate imaging tool to diagnose and locate uterine fibroids.[55] This may be particularly important in women who wish to retain their reproductive function. Adenomyosis accompanies fibroids in 35 to 55% of women. Planning surgical

Figure 13: MR images of adenomyosis (Used with permission. Byun JY, et al. Radiographics. 1999;19:S161-S170, Figure 8)

management or the administration of GnRH analogs may be less successful where adenomyosis is present. Diagnosing the presence of adenomyosis is extremely relevant in clinical situations such as these.[56] MRI imaging has a greater specificity in this matter as it can demonstrate the diffuse thickening of the junctional zone (>12 mm) which is a hallmark of adenomyosis.[57] In another study by Dueholm et al[58] MRI is superior to US in the diagnosis of adenomyosis with a higher specificity and superior diagnostic accuracy especially when the uterine volume exceeds 400 cc (Figure 13).

ENDOMETRIOSIS

Endometriosis affects 5 to 10% of women of reproductive age and it is a contributing cause in many cases of chronic pelvic pain and infertility.[59] A characteristic MRI finding for the diagnosis of endometriosis is hyperintense T1-weighted images with hypointense T2-weighted images. MRI is able to obtain a much larger field of view when compared with US, and it able to detect extrapelvic implants assisting in preoperative staging.[60] MRI's role in the diagnosis and management of endometriosis and the detection of deep endometriosis is superior and results in higher accuracy than CT or US.[61,62]

UTERINE ANOMALIES

A discussion of MRI technology and gynecology without the mention of uterine anomalies would not be complete.

Traditionally, US and sonohysterography or hystero-salpingogram that involves radiation exposure are used as a first step in cases of suspected uterine anomalies. The gold standard has been laparoscopy or laparotomy with hysteroscopy to solidify the diagnosis. The surgical process may be better planned with the proper surgical specialists if a more accurate preoperative assessment is done. Due to MRI's ability to detect subtle soft tissue differences, MRI has been considered to be the best imaging method available because of its superior ability to reliably visualize complex uterovaginal anatomy.[63] Other recent studies and reviews have also come to this same conclusion.[64,65] An excellent approach to MRI interpretation and accurate diagnosis of types of uterovaginal anomalies can be found in Saleem's article from 2003 Radiographics[66] which illustrates a 5-step approach for diagnosing these anomalies. Cases that require surgical management can be readily identified as well as cases not amenable to surgical correction. Another advantage of MRI's wide field of view it that other associated anomalies (i.e. renal) can be detected.

GYNECOLOGIC MALIGNANCIES

Staging of gynecologic malignancies varies by anatomic location. Cervical cancer is staged through clinical exams and endometrial and ovarian cancers are surgically staged by FIGO (International Federation of Gynecology and Obstetrics classifications). MRI has been proven to be a beneficial and accurate tool in the preoperative or pretreatment phase of gynecologic cancer evaluations.

It is estimated that more than 11,000 women will be diagnosed with invasive cervical cancer in 2009 and more than 4,000 women will succumb to this cancer.[67] Although, cervical cancer is staged by clinical exam that does not include the use of MRI, CT or US, contrast-enhanced MRI has been shown to have similar accuracy to spiral CT in the evaluation of lymph node metastases.[68] Others have shown that MRI staging accuracy is significantly higher than CT (up to 77% *vs* up to 69%).[69,70] MRI is felt to be the imaging modality of choice in locating and characterizing tumor invasion. Contrast-enhanced MRI has a 95% negative predictive value for stage IIB cervical cancer (parametrial invasion) that may help identify patients who are candidates for surgical treatment. MRI also has a 98% predictive value in excluding pelvic side wall invasion.[71] Perhaps with time, the optimal method in the staging of cervical cancer will be the result of the addition of this rapidly expanding imaging modality to the clinical examination protocol.

Endometrial cancer is the most common gynecologic malignancy accounting for 6% of all female cancers.[72] MRI has been shown to have a 92% accuracy in staging endometrial cancer which can assist in preoperative counseling as well as appropriate referrals to tertiary care centers as necessary.[73] Another study has shown MRI to be the best imaging modality in determining the depth of myometrial invasion when compared to visual inspection.[74] A Bayesian and meta-analysis demonstrated that contrast-enhanced MRI was clinically useful for diagnosing deep myometrial invasion, not only in women with grade 3 cancers, but also in patients with grade 1 or 2 cancers.[75]

Ovarian cancer is the 9th most common cancer in women but ranks fifth in the cause of death in women diagnosed with cancer. It is estimated to be the cause of death in over 14,000 in 2009.[76] Ovarian cancer staging involves surgical staging but preoperative assessment in planning surgery and patient counseling may be crucial for an optimal outcome. Preoperative visualization of areas where the potential spread of ovarian cancer to local areas such as the colon, bladder, uterus, liver and diaphragm can be detected with MRI. Some studies have found MRI to be more accurate in this regard, especially for lymph node metastases and tumor resectability.[77,78] Contrast-enhanced MRI have been found to have a 92% sensitivity in detecting small peritoneal disease such as those that can be found in the omentum, in the mesentery of the small and large bowel, on the anterior abdominal peritoneal surface, under the diaphragm, and in the paracolic gutters.[77] Prolonged survival after ovarian cancer diagnosis and the success of chemotherapy depends on optimal debulking at the time of the initial surgery, yet less than 50% of ovarian cancer patients acquire a gynecologic oncologist to be involved in their care.[79]

CONCLUSION

Gynecologic imaging has advanced in both the technical aspects and knowledge base over the last four to five decades due to engineering feats and great volumes of research. In a very short period of time, the use of gynecologic ultrasound has become standard in physician's offices, emergency departments and ancillary facilities to best serve women for the diagnoses of a variety of gynecologic conditions. This fact has oftentimes led to a knee-jerk reflex to order an ultrasound for every female condition, which has a positive diagnostic result most of the times; but can be nondiagnostic and disappointing at other times.

Consideration of other imaging modalities as a possible first choice should always be considered. Time factors, cost-effectiveness and availability of different imaging techniques should influence a clinician's ultimate decision on the type of test to pursue.

Undoubtedly, most ovarian lesions, endometrial pathology and uterine lesions are best detected with ultrasound. CT imaging offers better diagnostic capabilities for large pelvic masses, tubo-ovarian abscesses, post-operative and postpartum complications; but this needs to be balanced with the concerns of radiations exposure. MRI imaging is superior with adenomyosis, complicated endometriosis and gynecologic malignancies; but cost concerns may make this more prohibitive than using less accurate but none-the-less decent alternatives. In some cases, both ultrasound and CT or ultrasound and MRI techniques are employed to achieve optimal differential diagnoses to determine the clinical pathway to follow. Knowledge of what each imaging modality's strengths and weaknesses are will help the clinician choose the best test to pursue first. Future research and technological advances will continue to offer additional advantages that ultimately will improve the overall care for our patients.

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