Imaging Neoplasms of the Abdomen and Pelvis

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Technological innovations in computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography have greatly improved our ability to diagnose abdominopelvic neoplasms and monitor treatment efficacy. Although plain films and air contrast techniques remain fundamental to our imaging armamentarium, they have largely been supplanted by cross-sectional imaging. Endoscopic ultrasonography and functional MRI along with positron emission tomography (PET) are new approaches whose role is increasing in scope. The choice of technique is determined by the organ being studied, the suspected pathology, the patient’s clinical condition, and the experience of the radiologist and endoscopist.

Conventional ultrasonography is often the initial screening examination but has overall a limited role in the diagnosis and staging of abdominopelvic neoplasm. Both endoscopic and transvaginal ultrasonography, however, have become important adjuncts in the evaluation of gastrointestinal and pancreatic malignancies, and gynecologic malignancies, respectively.

CT has now become the primary diagnostic modality used in oncologic radiology. The development of multislice CT (MSCT) has dramatically improved the examination speed, enabling one to image with very thin slices and during multiple phases of contrast administration. This has resulted in expanded roles for CT to the point that relatively invasive studies such as CT arteriogram, CT arterial portography (CTAP), or certain vascular studies can now be replaced by noninvasive evaluations with MSCT. Gastrointestinal, as well as intravenous, contrast administration is required in most cases, assuming that renal function is normal and there is no history of allergy to iodine. Intravenous (IV) contrast should be given through an adequate bore needle using an injector to achieve a rate of injection of 3 to 5 cc/s depending upon the specific CT protocol. With such injection rates, helical (spiral) CT allows the acquisition of multiphasic images of an organ or mass, which help to characterize the disease and to more easily define its stage. In selected cases, three-dimensional (3D) reconstructions assist radiologists in more confidently staging neoplastic disease (Figure 36d-1). Three-dimensional imaging with CT also provides a roadmap to guide surgical intervention.

MRI is superior to CT when improved soft-tissue contrast or direct multiplanar images are needed such as in the evaluation of large abdominopelvic masses. In the case of soft-tissue tumors involving the extremities, MRI is widely accepted as a superior examination. In the pelvis, MRI is used to assess rectal tumors and gynecologic malignancies. The application of phased-array or endorectal coils improves signal-to-noise ratio, translating into improved resolution in evaluating cervical, uterine, and prostate cancers. MR angiography (MRA) can also be readily performed in conjunction with MRI and plays a role in local staging of renal and pancreatic carcinomas.

PET using (18F)-fluorodeoxy-d-glucose (FDG) is an emerging imaging technique based on the increased signal from glucose metabolism in the tissues of tumors. The technique benefits by its “whole-body imaging” ability, allowing detection of the primary tumor and metastases. It is useful in differentiating malignant neoplasm from a benign process although a significant crossover of uptake exists with benign lesions. It is also used to monitor tumor response to treatment. In lymphoma, the use of PET might detect more sites of disease than CT but larger studies are needed to confirm the accuracy of PET in staging lymphoma. PET has also shown to be helpful in the evaluation of response to treatment and assessment of residual masses. The role of PET in gastrointestinal tumors is primarily to detect metastasis or recurrence particularly in the setting of elevated tumor markers. Clinical utility in primary liver tumors and pancreas is still being investigated. Normal uptake of radiotracer in the kidney, bladder, and bowel limits the use of PET to evaluating the primary neoplasms in these organs. Application in prostate carcinomas has been discouraging because of the low metabolic rate of prostate carcinoma and the proximity of pelvic nodes to the bladder which can detrimentally impact on the detection of increased uptake.

Figure 36d-1  Pancreatic adenocarcinoma. A, A contrast-enhanced CT image during the pancreatic phase demonstrates a hypodense mass (large arrows) in the head of the pancreas, completely encasing the hepatoduodenal artery (small arrow), and compressing the main portal vein (arrowheads). B, A reconstructed coronal image depicts the mass (arrow) that involves the hepatoduodenal artery (small arrows) as well as the common hepatic artery and celiac trunk (arrowheads).
GASTROINTESTINAL TRACT

Detection of gastrointestinal (GI) tumors relies primarily on luminal contrast techniques and endoscopy. Both techniques are used to assess the mucosa of the upper GI tract and of the colon. Air-contrast barium studies of the esophagus, stomach, and colon require a degree of technical skill and an optimized approach to be diagnostic. This implies a fasting status for studies of the upper GI tract and an excellent preparation of the colon for barium enema.10 Under these conditions subtle mucosal abnormalities representing early neoplasms can be detected. A sensitivity of 81% is achieved for the detection of colonic polyp larger than 1 cm. CT colonography or “virtual colonoscopy” has emerged as a sensitive method for the detection of clinically relevant polyps and adenoma. Early results are encouraging, although multicenter trials are needed.14

Endoscopy, because it allows direct visualization and the ability to provide tissue by means of biopsy of a mucosal tumor, tends to supersede air-contrast studies. Colonoscopy has been advocated as the screening modality for colon cancer, although significant controversy exists on the optimal screening program in light of recent technological developments in MSCT and CT colonography.15 Endoscopic ultrasonography provides an adjunctive study for local staging to evaluate the depth of penetration through the wall (T stage) in the esophagus, stomach, and rectum, with an accuracy of 85% and a sensitivity of 67% to 97%16 It also has the capability to detect nodal spread, although with less accuracy.

Small bowel tumors are, for the time being, not accessible to endoscopy. Evaluation is performed using a barium examination with graded compression of the opacified loops. This study requires the patient to drink a significant volume of contrast material. Depending on individual transit time, the duration of the examination can exceed 2 h. Small bowel enteroclysis (SBE) is another, more sensitive technique for detecting abnormalities of the small bowel. Unfortunately, it involves invasive intubation of the proximal jejunum and infusion of barium alone or barium and methylcellulose for a double-contrast effect. The technique also has a significant dependence on the expertise of the radiologists and technologist. Multiple images of the distended loops are obtained. Although the distention aids in detection of abnormalities, this must be weighted against the patient’s discomfort with nasojejunal intubation.17,18

While the visualization of mural and extramural involvement is possible with CT, the technique has not been used for tumor detection mainly because of the difficult-to-control bowel distention and opacification to assess the mucosa. CT colonography, however, combining the air-contrast enema technique and helical CT, may provide a screening tool.14 Stromal tumors and lymphoma, which tend to grow exophytically, are more readily demonstrated with CT. Small bowel tumors (such as carcinoid tumors) may be diagnosed on CT by the detection of the mesenteric involvement, as well as local and distant metastatic disease. CT is the best modality to stage these tumors. Locally, the extent of the mass can be grossly assessed for extension into the peritoneal fat or to adjacent organs. Nodal, peritoneal, and hepatic metastases are best assessed with CT.20-22 As described above, endoscopic ultrasonography is used to define the T stage of the tumor.

The role of MRI in gastrointestinal tumors is very limited with the exception of the rectum. MRI has shown its superior capability in local staging at the time of diagnosis and in monitoring these tumors after treatment.23

THE LIVER

Radiographic evaluation of liver disease relies on ultrasonography, CT, and MRI.24 These techniques enable detection, and often characterization, of focal and diffuse hepatic processes. Ultrasonography is inexpensive and readily available, but its value compared to single-slice helical CT (SSCT), MSCT, and MRI is limited as a consequence of reduced sensitivity and specificity. Recent advances in Doppler technique and ultrasonography contrast material can aid in the characterization of the lesion. Intraoperative ultrasonography is widely used prior to hepatic resection because of its high sensitivity.25

The initial evaluation of primary and metastatic liver tumors is usually done with CT, although MRI is as appropriate and relies on similar morphologic and vascular criteria. With the introduction of helical CT, a biphasic hepatic acquisition has become a standard method to evaluate primary hepatic neoplasms because it provides morphologic and physiologic information, which helps to characterize the tumor. The pattern of enhancement defined with the multiphasic technique, provides key information for diagnosis.26 Hypervascular tumors have a rapid and brief uptake of contrast while cholangiocarcinoma or adenocarcinoma in general have a less intense, more delayed, and persistent contrast uptake (Figures 36d-2 and 36d-3).27 Specific patterns of enhancement have also been defined for hemangioendothelioma and, to a lesser extent, focal nodular hyperplasia (FNH).26,28,29 Multiphasic technique is used for the evaluation of hypervascular tumors, primary hepatocellular carcinoma (HCC), and metastasis (neuroendocrine, carcinoid, and choriocarcinoma) because it improves lesion detection. Paulson and colleagues evaluated metastases from carcinoid tumor and showed that one-third of the lesions were most conspicuous on the arterial phase and one-sixth were seen only on the arterial phase.30 Similarly, additional tumor nodules are seen on the arterial phase in patients with HCC.31

In contrast, hypovascular tumors (such as metastases from lung and gastrointestinal neoplasms) require imaging in the hepatic venous phase (HVP) only. A sensitivity of 85.1% was achieved with helical CT in the detection of hepatic metastases from colorectal carcinoma.32

Figure 36d-2 Multifocal hepatocellular carcinoma. A. A late arterial phase image of enhanced CT demonstrates three hypervascular lesions (arrows). B. Two of these become isodense to hepatic parenchyma during the portal venous phase and the third becomes hypodense with an enhancing rim (arrow).
MRI, as a first-line oncologic imaging approach, is mainly used as a problem solving modality or in patients who are allergic to iodine. The dynamic technique is essential in both CT and MRI. Focal areas of fatty infiltration can be easily differentiated from a mass lesion using in- and out-of-phase sequences. Hypervascular metastasis and benign hypervascular neoplasms such as focal nodular hyperplasia or adenoma, can be differentiated on MRI by using a liverspecific contrast in addition to traditional gadolinium (Gd) compound. For example, focal nodular hyperplasia is typically highly vascular in early arterial phase on Gd-enhanced MRI (as with enhanced CT) and is also enhanced by liver-specific contrasts, while the metastasis is not. Use of liver-specific contrast agents can be helpful to differentiate the adenoma from FNH. FNH is enhanced by both iron oxide and manganese compound, but adenoma is only enhanced by manganese compound. Use of liver-specific contrasts also maximizes lesion detectability and is often used prior to resection of the metastasis. MRI can be particularly useful in the presence of discrepant clinical and CT findings and to monitor recurrent tumors.

CT or ultrasonography guidance is generally employed for needle biopsies of liver lesions. Either can be used and the lesion itself (accessibility, visualization, etc) will dictate the choice by the availability of the equipment and expertise of the radiologist.

**BILIARY DUCT**

Ultrasoundography, CT, and MRI are all used in the exploration of a jaundiced patient. Conventional ultrasonography easily identifies bile duct obstruction as the origin for the jaundice, as well as the level of the obstruction, but may not be able to determine its cause, often because of gaseous interpositions. Endoscopic ultrasonography, however, is used to explore the distal common bile duct and the pancreatic head.

CT is currently the primary imaging modality used to identify the cause of bile duct obstruction. SSCT and MSCT can provide thin section from the level of the porta hepatis to the pancreatic head to display the extra hepatic bile ducts and pancreas. With this technique, the site of obstruction is defined and assessed for the presence of stone, soft-tissue mass arising from the biliary tree or pancreas, and/or extrinsic involvement by adenopathy or adjacent neoplasm. In general, the cause of the obstruction can be classified into one of these categories, although the differentiation of a benign inflammatory process from a malignant obstruction is not always possible before surgical exploration.

Cholangiocarcinoma, involving the hilum of the liver, and gallbladder carcinoma are often large at the time of diagnosis because of the lack of symptoms associated with the early stage of the disease. Tumors arising in the common hepatic duct and common bile duct tend to be small and are more difficult to detect. A biliary stent placed to relieve the jaundice may limit the quality of the imaging studies by the artifacts created by the stent and inflammatory process. Ideally, diagnostic CT should be done before stent placement. Helical CT allows detection of small tumors limited to subtle wall thickening. These tumors are usually hypovascular although papillary tumors or tumors with a neuroendocrine differentiation are hypervascular and best seen during the arterial phase. Assessment of the extent of the tumor along the biliary tree, involvement of adjacent organs, portal vein, and hepatic artery, and the detection of distant metastasis is done with CT but with a variable accuracy.

**CARCINOMA OF THE PANCREAS**

Detection of small pancreatic tumors with CT is primarily based on the difference in enhancement between tumor and normal parenchyma. Most ductal adenocarcinomas enhance less than the surrounding normal parenchyma. Additional findings show a focal change in texture or an abrupt change in the caliber of the pancreatic and/or bile duct. By using a dedicated technique, tumors as small as 5 mm can be detected.

Accurate definition of the relationship of the tumor with the superior mesenteric artery, celiac axis, superior mesenteric portal venous confluence, and the detection of extrapancreatic disease will determine whether the tumor is potentially resectable (see Figure 36d-1). The accuracy for CT to predict unresectability is well established.

If a diagnosis is not achieved with CT, MRCP or cholangiography, such as ERCP or percutaneous transhepatic cholangiography, is used to define the obstruction. Cholangiography also allows brushing for cytologic evaluation. Endoscopic ultrasonography (EUS) is used to explore a distal duct obstruction. It is used to explore the ampullary region of the pancreas. EUS-guided biopsy provides a cytologic diagnosis when a mass is identified.

Fast and ultrafast dynamic MRI using the paramagnetic contrast agents and fat-suppression technique have improved the ability of MRI to image the pancreas. While some studies suggest that helical CT is superior to MRI in staging and detection of pancreatic cancer, another study has found that MRI can detect more small tumors than CT.

**IMAGING OF RENAL AND ADRENAL TUMORS**

In cancer patients with an adrenal lesion the most common diagnostic dilemma is distinguishing an adrenal adenoma from metastasis. This can be done with either noncontrast CT or chemical-shift MRI (Figure 36d-4). Both these techniques rely on the presence of intracellular lipids to characterize adenomas. In noncontrast CT, a low attenuation value mass provides a reliable means of discriminating benign adenoma from metastatic disease. A threshold value of 10 Hounsfield units (HU) gives a sensitivity of 71% and a specificity of 98%. This is comparable to results obtained with chemical shift MRI. In the identification of lipid poor adenomas, delayed contrast-enhanced CT is more valuable. Threshold attenuation values of 30 to 40 HU or percentage of enhancement washout of 60% at 15 min are equally efficacious. In a study combining noncontrast and delayed contrast-enhanced CT, 96% of adenomas were correctly characterized. The most common primary tumor of the adrenal gland is adrenal carcinoma, which usually presents as characteristic large heterogeneous masses with areas of necrosis.

In the radiologic characterization of renal masses the objective is distinguishing solid malignant lesions requiring surgical intervention from benign conditions (complex cysts, abscesses, pseudotumors and angiomyolipomas). Ultrasoundography is excellent at identifying and characterizing simple cysts. The limitations are large body habitus and lesion size, as only 25% of masses between 10 and 15 mm are detected by ultrasonography. Thin-section CT can correctly characterize most lesions greater than 1 cm in size. Enhancement indicates vascularity and favors a malignant process. MRI is comparable to CT in evaluating renal masses and can be used in case of contrast reactions or compromised renal function. CT and MRI are both used in the staging of renal cell carcinoma. The
multiplanar capability of MRI assists in the evaluation of the relationship of large renal cell tumors to adjacent structures. Transitional cell carcinoma of the upper and lower urinary tract is best diagnosed by intravenous pyelogram (IVP) or retrograde pyelogram; CT and MRI are used primarily in staging.

**TUMORS OF THE FEMALE REPRODUCTIVE TRACT**

Ultrasonography is usually the initial imaging modality in the evaluation of adnexal masses. A combination of gray scale imaging, color, and duplex Doppler have a high accuracy in the detection and characterization of ovarian masses. MRI can be used to identify the site origin and characterize certain ovarian masses, such as dermoid with fat element, or hemorrhagic cyst and masses that are indeterminate by ultrasonography. Once the diagnosis is made, CT is the primary imaging modality in staging and monitoring ovarian cancers. Peritoneal carcinomatosis is best identified on CT. When the tumor is large which is often the case in ovarian cancers, MRI plays an important role in surgical planning.

MRI is superior to CT and ultrasonography in the staging of cervical and endometrial cancer. The excellent soft-tissue resolution of this technique enables definition of uterine and cervical zonal anatomy. When supplemented by the use of dynamic contrast scans this technique has a high accuracy in the definition of small tumors and evaluation of depth of stromal and myometrial invasion. Cervical tumors can be accurately identified in 91% of invasive lesions (Figure 36d-5). MRI provides the most accurate noninvasive pretreatment evaluation of tumor size, parametrial invasion, and depth of stromal invasion, criteria that are important prognostic determinants in cervical cancer. In endometrial cancer, tumor grade and depth of myometrial invasion are the most important prognostic factors. MRI provides the most accurate preoperative assessment of depth of myometrial invasion (see Figure 36d-2). CT and MRI have comparable accuracies in the evaluation of nodal involvement, as both techniques rely on nodal size and shape as the criteria for presence of metastasis. Lymphangiography permits evaluation of nodal architecture but is invasive. Helical CT, MRI, and lymphangiography are comparable in the detection of nodal metastasis. The use of PET scanning in nodal disease has the potential to improve sensitivity and specificity; however, its use remains limited in nodes less than 1 cm in size. CT is the most efficient and widely used screening modality in the follow-up of ovarian, cervical and uterine cancers. MRI, however, is superior in the evaluation of locally recurrent disease within the pelvis and should be used in cervical cancer.

**PROSTATE**

Transrectal ultrasonography (TRUS) is currently an initial imaging modality in patients with suspected prostate carcinomas. The role of ultrasonography in staging prostatic cancer is still limited. The benefit of TRUS is to provide an access for a biopsy for a confirmative diagnosis. MRI is at least as sensitive as, or more sensitive than, ultrasonography in detecting the tumors and probably the most accurate imaging modality in T3 and T4 staging (eg, extracapsular extension or seminal vesicle involvement, etc), but it does not allow biopsy. Pelvic phased-array coil or endorectal coil should be used to optimize the diagnostic and staging accuracy of MRI. It is advised to wait at least 6 to 8 weeks following biopsy to optimize its accuracy. The benefit of MRI is having the capability of evaluating pelvic lymph nodes and bones simultaneously.

Either CT or MRI can be used to evaluate the retroperitoneal and pelvic lymphadenopathy and distant metastasis; however, CT is the primary imaging modality because of availability. While CT or MRI can detect bone metastasis, a bone scan is the most sensitive modality to evaluate bone disease.

Imaging has a limited role in monitoring prostate carcinoma after treatment. Posttreatment surveillance is done clinically. CT is the primary screening modality for suspected recurrent disease. In monitoring locally advanced disease or suspected local recurrence, MRI may be superior to CT. Imaging of the prostate is continuously evolving. PET has not yet been proven useful in detecting prostate carcinomas however, magnetic resonance spectroscopy, based on high choline levels in prostate carcinoma tissue, is under extensive clinical investigation with promising results. The technique may contribute to identifying patients with clinically significant prostate carcinoma. It may also aid in monitoring local disease and in the detection of local recurrence.

**CONCLUSION**

In summary, CT, MRI, and ultrasonography are the major imaging modalities fundamental to the diagnosis and staging of abdominopelvic neoplasms. The technological advances in MSCT have brought the technique to the forefront of oncologic imaging.