Diagnosis, Preoperative Evaluation, and Assessment of Resectability of Pancreatic and Periampullary Cancer

Ashish Verma¹ · Sunit Shukla² · Nimisha Verma³

Received: 24 September 2015 / Accepted: 30 September 2015 / Published online: 8 October 2015
© Association of Surgeons of India 2015

Abstract Periampullary region encircles a radius of 2 cm around the ampulla of Vater; accordingly, four distinct neoplasias with overlapping imaging features originate in the region. Each of these lesions has a different long-term prognosis; hence, imaging evaluation to characterize the lesion is important. Further certain specific features pertaining to the vascular invasion and systemic spread may decide about the treatment as well as surgical approach. An understanding of the advances in imaging and image processing technology as well as in the methods of image acquisition, for the purpose, is quite relevant towards etching out a rational pre-treatment evaluation protocol. Further, an evidence-based decision as to the choice of optimum modality for answering specific clinical question is of prime importance in achieving a reasonable post-treatment outcome. Pancreatic adenocarcinoma is the fourth most common cancer and a malignancy with one of the least 5-year survival rates (ranging from 6.8 to 15 % depending on peripancreatic extensions, dropping to 1.8 % for metastatic disease). A survival rate of 15–27 % can be achieved if the lesion is resectable but unfortunately, only 10–15 % of patients are eligible for resection. Cystic tumors of pancreas are a rarer variety of pancreatic neoplasia (5–15 % of pancreatic cysts and 1 % of all pancreatic cancers) which have a much better outcome and chances of resection. Being

mostly incidentalomas, a timely differentiation of this lesion from the much more common pseudocyst (which would mandate a medical management and a different surgical protocol) is the key for curability. Lastly, the neuroendocrine tumors of pancreas are equally rare (1 % of all pancreatic tumors), but importantly due to associated clinical syndromes and their capability to metastasize early in the course of disease, a timely detection may hence be the key for successful treatment of these lesions. Imaging plays a vital role in the initial detection and characterization as well as in determination of resectability of each of these pancreatic neoplasias. Further, the differentiation of pancreatic head tumors from other periampullary neoplasias is important; the fact that most recurrences are as a result of surgical intervention in an otherwise inoperable disease while most treatment failures are due to improper characterization of the lesion is notable.

Keywords Pancreatic cancer · Periampullary cancer · Resectability · Preoperative evaluation

Background

Periampullary tumors include neoplasias arising from the pancreatic head and uncus, lower common bile duct, ampulla of Vater, and periampullary duodenum. The emphasis of pre-treatment imaging evaluation remains on differentiating pancreatic from other periampullary cancers. Further imaging detects certain key features which may enable a decision about the treatment/surgical approach. Pancreatic tumors have been variously classified according to the histo-morphology [1–5] but a CT imaging-based classification system seems to be the most suitable for better differential diagnosis and treatment planning [6]. The system shows a good correlation between the histopathologic and the imaging features [6]. In routine

✉ Ashish Verma
drdnv5@gmail.com

¹ Department of Radiodiagnosis and Imaging, Institute of Medical Sciences, Banaras Hindu University, Varanasi 221005, India

² Department of Gastroenterology, Institute of Medical Sciences, Banaras Hindu University, Varanasi 221005, India

³ Department of Anesthesiology, Institute of Medical Sciences, Banaras Hindu University, Varanasi 221005, India

clinical practice, multi-detector computed tomography (MDCT) is the initial tool for detection and characterization of pancreatic and periampullary lesions. Subsequent differential diagnoses, if mandated, can be achieved by problem-solving tools like magnetic resonance imaging (MRI) and endoscopic ultrasound (EUS) [3, 4]. Both modalities are specifically useful in evaluation of complex and cystic lesions; the former offers excellent soft tissue contrast while the latter gives a precise depiction of internal architecture [5]. Periampullary neoplasias pose a formidable challenge in evaluation of pancreatic tumors and include ampullary adenocarcinomas and adenomas, as well as duodenal adenocarcinomas, and cholangiocarcinomas [5–7]. Apart from these, many non-neoplastic/hamartomatous conditions also form a diagnostic differential but are out of scope of the present review. Patient profile and laboratory findings play a prime role which is formation of the final impression as there is a considerable overlap in imaging features of certain lesions. As per the current evidence-based protocol, the focus of our institutional practice, and of the present review as such, remains on CT scan as the modality of choice for evaluation of pancreatic and periampullary tumors with other modalities considered in specific clinical situations.

Technical and Technological Aspects

The Pancreatic Protocol CT Scan

Imaging evaluation of periampullary cancers at most high-volume centers relies upon “pancreatic protocol CT scan” (Fig. 1). The technique has been shown to be superior to conventional CT and to routine abdominal scanning by MDCT for the evaluation of pancreatic tumors and differentiation from other periampullary cancers [8]. MDCT has the capability of acquiring isotropic volume data along the longitudinal axis of the patient and subsequently generating sections as thin as 0.1 mm, which can be reconstructed to multiplanar sections (MPR) of any required slice thickness, in any plane, without any loss of information or distortion of anatomy. Further 3-dimensional reconstruction of vascular anatomy depicting relation of tumor remains of prime importance in surgical planning [9]. Multiple acquisitions of the organ can be made in a single breath hold, enabling imaging of the gland and related pathology at many phases (passes) of passage of the injected high volume of iodinated contrast medium, hence showing a dynamic enhancement pattern. The latter capability has led to optimization of pancreatic imaging time at 30 to 40 s after intravenous injection (known as the “pancreatic phase” acquired with a small field of view [FOV] focused to the organ) as neither the pure arterial phase (15–30 s) nor the portal venous phase (45 s) has proved to be as sensitive for lesion detection. This is due to the fact that the

vascular supply to the pancreas is primarily arterial (pancreatic branches of splenic artery); hence, the pancreatic phase is a balance between the true arterial and the portal venous phases. Notably, the maximum difference in attenuation between the normal pancreas and most tumors is seen during the pancreatic phase, as a result of a combination of optimal enhancement of normal pancreatic parenchyma and poor enhancement of the tumor (reverse happens during the portal venous phase). Even the porto-mesenteric venous visualization is better during the pancreatic phase than the portal vein phase. The precise relationship of the tumor to surrounding critical venous structures is therefore better delineated during pancreatic phase. The pancreatic protocol includes “portal venous phase” for liver scanning (with extended field of view) to detect hepatic metastases as well. This phasing of intravenous contrast injection by an automated power injector, pre-synchronized to the scanning protocol, can be done using either a “test bolus” or a “smart prep” technique [8–10]. We perform all acquisitions with an extended field of view as scanners having 64 and above detector rows show insignificant difference in the spatial resolution due to FOV. Most studies advocating small FOV scanning during pancreatic phase were done on scanners having 16–32 detector rows [11]. The scanning initiates with an initial low-radiation planner/localizer to confirm the inclusion of relevant anatomy. Intravenous iodinated contrast media is injected (150 cc non-ionic contrast media) at a rate of 4 mL/s into an antecubital vein using a power injector. Scans are performed 15–20, 35–40, and 65 s (after initiation of the IV contrast injection) with a 3-mm collimation. We also include a delayed phase (at 120 s) to differentiate hepatic hemangiomas from metastases, a situation which remains quite common in clinical practice. In our personal unpublished data of about 242 cases over the duration of 5 years, we have been able to detect 36 metastatic lesions and differentiate 17 hepatic hemangiomas from metastasis.

Role of Magnetic Resonance Imaging

The use of magnetic resonance imaging (MRI) has been advocated as a problem-solving tool in certain specific situations. MRI with intravenous gadolinium injection has a superior contrast resolution than CT scan; this however comes at the cost of reduced spatial resolution; and hence, the modality is utilized when a better characterization of lesion architecture (especially the cystic tumors) is needed [12]. In routine practice, MRI offers minimal gain in sensitivity over contrast-enhanced CT (86 % for CT versus 84 % for MRI) [13], and in certain cases having an equivocal CT scan, tumors may be detected by MRI due to their natural contrast from the native tissue [14]. Enhancement pattern of lesions remain akin to that seen on dynamic CT scan and can be conveniently extrapolated from what has been mentioned above [13, 14]. With increased availability of high field superconducting magnets,

Fig. 1 Pancreatic protocol CT scan showing the early arterial (a), pancreatic parenchymal (b), portal venous (c), and delayed (d) phases. Note the maximum difference in attenuation (hence detectability) between the pancreatic parenchyma and the tumor (*solid black arrow*) is seen in the **b** as compared to other phases. The visualization of superior mesenteric artery (*straight black arrow*) is best in **a** while that of portal vein (*straight white arrow*) is best in **c**. Notably, all these structures are of prime importance for planning of surgery

having sub-second scan durations, similar protocol (as for dynamic CT scan) can be tailored even for MRI.

Role of Magnetic Resonance Cholangiopancreatogram Versus Endoscopic Retrograde Cholangiopancreatogram

Obstruction of the extrahepatic biliary tree is one of the prime sequel and clinical concern of periampullary cancers. Confirmation of the level of biliary block is a routine exercise and was done earlier by endoscopic retrograde cholangiopancreatogram (ERCP). Magnetic resonance cholangiopancreatogram (MRCP) is now an established technique performed by an MRI scanner using pulse sequences having a high T2 weighting; this suppresses the background soft tissue leaving only the fluid-filled structures for visualization [15]. Recently introduced respiratory gated 3-dimensional techniques provide excellent images without any motion degradation which can be evaluated in any plane of rotation to depict the finest details [15]. MRCP has emerged as the preoperative imaging procedure of choice for to evaluate the pancreaticobiliary tree as it can evaluate the bile ducts both above and below a stricture (as opposed to ERCP) with no loss of sensitivity [15, 16]. MRCP images may be more helpful in distinguishing between chronic pancreatitis and pancreatic adenocarcinoma especially if the “duct-penetrating sign” signifying a non-obstructed main pancreatic duct is present. The morbidity associated with endoscopic procedures

and intrabiliary contrast administration and the radiation risks are also obviated. The technique can be performed in those having a difficult or failed endoscopic cannulation [17]. However, MRCP has not yet completely replaced ERCP as the latter helps in achieving tissue diagnosis (by endoscopic brush cytology and forceps biopsy) where every percutaneous image-guided cytology remains inconclusive. Further biliary decompression achievable by ERCP remains helpful in inoperable cases and in those where a tumor down staging by chemotherapy can render the lesion operable [17, 18].

Role of Positron Emission Computed Tomography

Positron emission computed tomography (PET-CT) is a recently introduced fusion imaging technique, whereby CT scan (either contrast or non-contrast) images are co-registered with images acquired by a PET detector performed after injection of positron emitting the tracers like 18-fluorodeoxyglucose (FDG). The modality relies upon high metabolic activity of briskly proliferating lesions such as cancers, most of which are “avid” unlike benign lesions which accumulate a very low fraction of the metabolite. Inflammatory lesions such as chronic pancreatitis would show an intermediate response [18]. PET is utilized for staging evaluation of pancreatic cancers in terms of metastasis detection. In one study, the sensitivity and specificity after a positive CT was 87–95 and 51–81 %; after a negative CT, the corresponding values were 50–88 and 75–93 % [19]. The abovementioned results are

however focused for PET performed in isolation, and most centers now prefer using the fusion PET-CT. The sensitivity and specificity of PET-CT compared to MDCT, CT angiography, and EUS for tumor staging and detection of distant metastases were 89 versus 56 and 100 versus 95 %, respectively [20].

Role of Endoscopic Ultrasound

The evaluation of an equivocal case and confirmation of diagnosis can be done by a EUS and EUS-guided fine needle aspiration (EUS-FNA) (Fig. 2). The sensitivity of EUS-FNA for diagnosing pancreatic cancer is in the range of 80–95 % [21] which elevates to about 98.3 %, in the absence of obstructive jaundice but declines to about 92.5 % [22] in the presence of chronic pancreatitis. The modality has a T-stage accuracy of 78–94 % and N-stage accuracy of 64–82 % [22]. The main limitation of EUS is its operator dependence and limited availability of expert endosonographers. As with any invasive procedure, EUS carries a risk of complications like bleeding, tear, and anesthetic complications and a risk of pancreatitis (0.1–1 %) [23].

Role of Diagnostic Laparoscopy

CT scan suffers from poor sensitivity in detecting small-volume peritoneal surface metastases and hepatic metastases <1 cm. Staging laparoscopy with or without laparoscopic ultrasound can provide tissue diagnosis in such

situations. The same may be resorted to when primary tumor >3 cm, preoperative CA 19-9 level >1000 U/mL, and/ or equivocal findings of locally advanced or metastatic disease on CT scan. In the presence of these findings, the incidence of laparoscopic findings altering management is >10 % [24].

Current Evidence-Based Imaging

The focus of present day imaging is to offer an accurate comment on the factors governing resectability. The imaging modalities (especially CT scan) mentioned above and subsequently are accurate in providing this information which is vital to ensure a complete resection of tumor (R0 resection), even after neo-adjuvant chemotherapeutic down staging.

Initial Detection and Characterization

Pancreatic Tumors

Adenocarcinoma is a focal mass (with contour distortion) in the head of the pancreas (90–95 %) appearing hypoattenuating on CT scan in pancreatic phase. A smooth and homogenous dilatation of the upstream pancreatic and biliary ductal systems may be noted with a “sharp cutoff” at the mass [24]. These secondary signs and differential enhancement assist the diagnosis in event of a rare iso-attenuating mass [24,

Fig. 2 Pancreatic protocol CT scan (a, b) and endoscopic ultrasound (c, d) is a case of mixed-type IPMN. Multiple cystic lesions (straight black and white arrows) are seen in the pancreatic parenchyma with a dilated pancreatic duct (hollow arrow). These cysts however could not be characterized on CT scan as the internal architecture is not adequately seen. EUS shows the cysts with mural nodule within (curved arrow and solid white arrows), confirming the diagnosis. Communication of the cysts with dilated pancreatic duct (hollow arrow in d) is also confirmed

25] or a small totally inconspicuous tumor. The serous cystic pancreatic tumors consist of numerous fine hypoattenuating cysts (1 to 20 mm) with briskly enhancing walls (on arterial phase) clustered around a central fibrous stellate scar (“sunburst” calcification noted sometimes). The lesion usually has a “honeycomb” appearance on portal phase but may even appear solid due to the cysts being very fine; internal hemorrhage and hyperintense fluid seen on T2W MRI may be of help in such cases. These show no sign of local invasion or pancreaticobiliary obstruction and are mostly located in pancreatic head of older women. The mucinous cystic tumors consist of intraductal papillary mucinous tumors (IPMN) and mucinous cystic neoplasms (MCNs) both having larger (>20 mm), less numerous cysts (usually <6) appearing hypoattenuating on CT scan. Both arise from the pancreatic duct lining with the IPMN being more centrally and proximally located than MCN; focal pancreatic duct dilatation is a feature common to both groups. Depending on the duct of origin, IPMN may be main duct variety, side branch variety (mostly in head and uncinate process), and a combination; they may also be classified as diffuse or segmental, based on the extent of involvement. The compresses adjacent to the pancreatic parenchyma form the enhancing wall of IPMN which has a multiseptated appearance like serous tumors. However, as opposed to serous tumors, IPMN are common in older men, cause pancreatic atrophy, rarely calcify, and show poor enhancement in all phase. The “fish eye” appearance of the ampulla of Vater due to extruding out mucin can be seen on endoscopy, EUS, and MRI and remains confirmatory for the diagnosis (especially in combination type). MRCP is particularly useful to demonstrate the ductal proximity of these lesions; further, an intralesional enhancing nodule seen on MRI is indicative of malignant change, warranting surgical excision. A beaded irregular ductal dilatation seen on MRCP, with a delayed parenchymal enhancement (on portal venous phase of dynamic MRI), assists towards differentiation of chronic pancreatitis from IPMN. Unlike IPMN, MCN occurs mostly in middle-aged females and do not communicate with the pancreatic duct. Ranging from benign to frankly malignant cystadenocarcinoma, these lesions appear as well-defined smooth hypoattenuating exophytic lesions, which show moderate enhancement of the cyst wall, calcification being an uncommon feature. Usually unilocular, presence of thick septa or mural nodule is highly indicative of malignant change. Delayed phases of imaging play a vital role in demonstrating the relatively common hepatic metastasis which is isomorphic to the primary lesion. A broad division of these lesions into unilocular cysts (MCN, IPMN, oligocystic serous

cystadenoma, lymphoepithelial cyst, and cystic pancreatic neuroendocrine tumors (NET)), microcystic lesion (serous cystadenoma), macrocystic lesions (MCN, IPMN, and lymphoepithelial cyst), and cysts with solid components (malignant MCN, IPMN, cystic pancreatic neuroendocrine tumor, solid papillary neoplasm, adenocarcinoma) is a useful image-based classification [25].

Pancreatic NET are as rare but much less locally aggressive than cystic tumors, though a hepatic metastasis may be commonly picked up. Functional NET's secrete respective hormones (accordingly the nomenclature) causing specific clinical syndrome and hence are picked up when small while the non-functioning tumors (30–40 % of pancreatic NET) are usually large on the initial diagnosis. Pancreatic NET may be associated with inherited genetic syndromes like MEN-1 and VHL disease (when they can be multifocal). The arterial phase of MDCT has improved the detection of these briskly enhancing lesions by threefold (especially insulinomas), all becoming iso-attenuating in venous phase; MRI, EUS, and somatostatin receptor scintigraphy are useful as problem-solving tools. Insulinoma is mostly located in body/tail while a location in the “gastrinoma triangle” favors a diagnosis of gastrinomas. The latter is located in duodenal wall and may only be diagnosed by EUS. Delayed phase imaging is useful in glucagonoma, VIPoma, and non-functioning islet tumors to detect local invasion and metastases to the liver, adrenals, lymph nodes, bones, and lungs. Somatostatinoma are large bulky tumors appearing heterogeneous on imaging located in the head of the pancreas. Solid pseudopapillary neoplasms (SPEN/SPT) are tumors of young females having low malignant potential. They are usually larger than 3 cm in diameter, well-defined round encapsulated masses with a heterogeneous imaging appearance due to hemorrhagic (important feature) necrosis, cystic, and solid components. Peripheral calcifications may be present in more aggressive variants. Hematogenous metastases to pancreas present as localized lesions, multifocal masses, or a diffuse gland enlargement. Non-Hodgkin lymphoma of the pancreas presents as diffuse pancreatic enlargement with poor contrast uptake mimicking acute edematous pancreatitis; the absence of peripancreatic inflammation clinches the diagnosis. Peripancreatic adenopathy and hepatosplenomegaly are noted in lymphoma while ductal dilatation is absent. PET/CT is useful to demonstrate the multifocal/multiorgan involvement hence differentiating primary from secondary pancreatic lymphoma. Primary pancreatic squamous cell carcinoma is a rare diagnosis of exclusion with no specific imaging features [26].

Other Periapillary Tumors

This is a heterogeneous group of unrelated neoplastic and non-neoplastic pathologies; the present section shall include only the former. Though endoscopy is performed in all above

lesions, CT scan in addition is helpful in mapping the local invasion, potential complications such as obstruction, and nodal or distant metastases. All the lesions in this group show poor contrast uptake in arterial and pancreatic phase with slight delayed enhancement. Most are well-defined lobulated but infiltrative masses. Carcinoma of the ampulla of Vater is a high-grade epithelial malignancy and is picked up when small due to the early obstructive symptoms, hence the “double duct sign.” Duodenal adenocarcinoma usually presents at an advanced stage, as a short segment annular stenosing growth with overhanging edges, proximal gastroduodenal dilatation, and an occasional ulcer. Loss of gut signature, presence of metastases, and an occasional calcification are confirmatory towards diagnosis. Duodenal gastrointestinal stromal tumors (GIST) and adenoma are low-grade small round or ovoid endoluminal tumors with homogeneous enhancement. Hyper-enhancement on the arterial phase CT scan and invasion of the pancreas on the pancreatic phase are hallmarks of the malignant villous adenomas. Metastatic or infective pancreaticoduodenal lymphadenopathy is a common mimic of periampullary neoplasia [27]. In our center, we experience more numbers of tubercular peripancreatic adenopathy than due to other causes. Central hypoattenuation with peripheral enhancement due to necrosis seen on CT scan remains a useful way to characterize the pathological nodes; further, the intense periadenitis noted in tuberculosis closely mimics extranodal invasion due to metastasis, while the former shows delayed enhancement the latter enhances early. Quantitative measurement in diffusion-weighted MRI is proving to be another useful technique to differentiate malignant from benign adenopathy.

Preoperative Imaging Workup

Periampullary cancers need elaborate and exquisite imaging workup because the four members of this heterogeneous group, though having close imaging resemblance and surgical resection approach, have a widely different long-term prognosis. This is especially true for the pancreatic cancers, which need multifaceted evaluation for pre-treatment and pre-surgical planning as they have the worst prognosis of all. Emphasis has been laid down on a multidisciplinary team approach at a high-volume center and performance of advanced dedicated pancreatic imaging (even if a general scan is available) towards achieving a decision for diagnostic management and resectability of these tumors. Similar imaging algorithm and features are required for other periampullary cancers also. Pancreatic protocol CT/MRI remains the first step towards all such evaluation protocols followed by EUS assessment if required. In situations where CT scan fails to detect any pancreatic mass/metastasis and facilities/expertise for EUS is not available, MRCP or

ERCP may be resorted to. EUS has been included as an adjunct modality for staging; similarly, EUS-FNA may also be reserved for certain borderline cases only, as histological evidence is not essential for surgical management. However, in event of a requirement of sampling, the tumor EUS-FNA should be preferred over other modalities to prevent inadvertent upstaging. Arterial and portal venous phase imaging are accurate in assessing the vascular relations and invasion/encasement by the tumor, features which are prime towards assessment of resectability. Further, certain anatomical variations in the vascular tree that may alter the surgical approach may also be detected. These features form the basis of the TMN-AJCC classification and should be included in routine radiology reporting templates. Various nodal groups can be adequately assessed by CT scan, an emphasis is placed on the nodes located at the takeoff of the gastroduodenal artery as these are a part of the celiac drainage, and adenopathy is the region which is a poor prognostic indicator akin to presence of liver metastases [27].

Criteria for Resectability

The criterion for resectability favors specificity over sensitivity as potentially curative resection is feasible in only 10–15 % of patients. About 15–70 % patients staged as resectable on imaging are found unresectable at surgery or have a poor post-surgery survival. Most of the latter patients are those which have macroscopic major vessel involvement; hence, the target of present day dedicated imaging is to comment on the same with high level of accuracy. The two most important imaging maneuvers for the purpose include isotropic image manipulation (viz. multiplanar reconstruction (MPR), 3-dimensional maximum intensity projection (3D-MIP), and volume rendering (VR)) and phasing of intravenous contrast (as described above) to highlight the individual vessels. Further, the two most important features to categorize resectability include vascular proximity and presence of metastasis.

- (a) Vascular proximity—Arterial structures that should be included in routine evaluation include the celiac trunk (CA), common hepatic artery (CHA), superior mesenteric artery (SMA) with the first jejunal branch (J1), and aorta (Ao). A single vessel tumoral contact of $<180^\circ$, presence of adequate length stumps for reconstruction, absence of any variations in anatomy, and non-involvement of arterial bifurcations are features that indicate borderline resectability. The gastroduodenal artery (GDA) remains spareable as it is removed while resection, and still, it should be evaluated closely as it acts as a nodal trajectory for tumor extension. Contact to the Ao or J1 however preclude resectability. The spleno-portal

axis (SPA) including the gastrocolic trunk, inferior mesenteric vein, and first jejunal branch is best evaluated in the portal venous phase. A tumoral contact with SMV or PV of $<180^\circ$ or $\geq 180^\circ$ without vessel wall irregularity/luminal thrombosis and contact with IVC renders the lesion borderline resectable. Surgical discretion is mandated in such cases for availability of vascular stumps for reconstruction. The positive predictive value of MDCT for unresectability is 89–100 %, and for resectability is 45–79 %. Reconstructions are done perpendicular to the axis if a vessel carries a positive predictive value of 93 %, a negative predictive value of 86 %, and an accuracy of 88 % for commenting on circumferential contiguity; however, no definite advantage may be rendered while assessing the vascular luminal narrowing [28].

- (b) Detection of metastases—PET is the modality of choice for detection of systemic metastasis, with a sensitivity of about 61 % for the purpose. Acquisition of delayed phase in pancreatic protocol CT/MRI is done with the intent of detecting metastatic lesions in the region, but has a sensitivity of about 57 %. A combination of PET with CT however elevates the sensitivity to the order of 87 % and can alter the management in up to 11 % of cases. PET-CT is therefore complimentary to a good-quality CT/MRI but the latter should be replaced [29].

Though most lesions once detected and labeled resectable should be brought out, however, in cases of cystic pancreatic lesion, a risk (of surgery) versus benefit (of resection) analysis

helps. Features favoring surgery include a mural nodule or thick septa remains in cases of MCN while a size >4 cm in cases of serous tumors. Annual or biannual imaging surveillance may be done in cases where a more conservative approach is planned; the frequency of imaging also depends on the nature and growth rate of the tumor (more frequent scans if the tumor grows >1 cm per annum) [28, 29].

Evolving the Role of Image-Guided Interventions

A distressful disease indeed, inoperable pancreatic cancers mandate palliation of pain that may result from local infiltration of retroperitoneal neural plexus. Neurolytic blocks (using alcohol or phenol) to relieve visceral pain (while preserving somatic, motor and sensory functions) form the fourth step of the WHO analgesic ladder for cancer pain and is now routinely performed either under image or endoscopic guidance [29]. Further, the technique compliments the action of opioids thereby reducing the dose, reducing the incidence of opioid-induced immune-suppression. We follow the practice of targeting the plexus from an anterior approach under ultrasound guidance. In a subset of patients where celiac plexus block fails, splanchnic nerve block can be used to provide pain relief. Recently, radiofrequency neuro-thermoablation has been used to provide pain palliation in pancreatic carcinoma patients [30] (Fig. 3).

Fig. 3 Ultrasonography (a, c) and color Doppler (b, d) through the upper abdomen at the level of celiac trunk shows the origin of celiac trunk in sagittal (a, b) and axial (c, d) planes. Note the anatomy of celiac trunk (*curved arrow*), superior mesenteric artery (*hollow arrow*), and aorta (*straight arrow*) at this level. The injections for pain relieving celiac plexus block are given in axial plane guidance, in the fascia around the origin of celiac trunk (*straight black arrows*), which is the location of celiac plexus

Conclusion

MDCT is the preferred initial imaging modality in patients with clinical suspicion for pancreatic cancer. The role of MRI for use in pancreatic cancer diagnosis is evolving and is currently used interchangeably with MDCT for this purpose. MRCP seems promising in differentiating pancreatic cancer from chronic pancreatitis. PET scans can provide information on occult metastasis but its clinical benefit is not established. EUS is the most accurate examination for diagnosing pancreatic cancer and can be a useful adjunct to CT/MRI in determining resectability of pancreatic cancer. EUS/EUS-FNA can also provide a definite determination about the presence of pancreatic cancer in patients with non-specific findings suggestive of cancer on conventional imaging.

References

- Kim SY, Lee JM, Kim SH, Shin KS, Kim YJ, An SK et al (2006) Macrocystic neoplasms of the pancreas: CT differentiation of serous oligocystic adenoma from mucinous cystadenoma and intraductal papillary mucinous tumor. *AJR Am J Roentgenol* 187:1192–1198
- Park MS, Kim KW, Lim JS, Lee JH, Kim JH, Kim SY et al (2005) Unusual cystic neoplasms in the pancreas: radiologicpathologic correlation. *J Comput Assist Tomogr* 29:610–616
- Irie H, Honda H, Aibe H, Kuroiwa T, Yoshimitsu K, Shinozaki K et al (2000) MR cholangiopancreatographic differentiation of benign and malignant intraductal mucin-producing tumors of the pancreas. *AJR Am J Roentgenol* 174:1403–1408
- Song SJ, Lee JM, Kim YJ, Kim SH, Lee JY, Han JK et al (2007) Differentiation of intraductal papillary mucinous neoplasms from other pancreatic cystic masses: comparison of multirowdetector CT and MR imaging using ROC analysis. *J Magn Reson Imaging* 26:86–93
- Sahani DV, Kadavigere R, Saokar A, Fernandez-del Castillo C, Brugge WR, Hahn PF (2005) Cystic pancreatic lesions: a simple imaging-based classification system for guiding management. *Radiographics* 25:1471–1484
- Cho H-W, Choi J-Y, Kim M-J, Park M-S, Lim JS, Chung YE, Kim KW (2011) Pancreatic tumors: emphasis on CT findings and pathologic classification. *KJR* 12(6):731–739
- Nikolaidis P, Hammond NA, Day K, Yaghmai V, Wood CG 3rd, Mosbach DS, Harmath CB, Taffel MT, Horowitz JM, Berggruen SM, Miller FH (2014) Imaging features of benign and malignant ampullary and periampullary lesions. *Radiographics* 34(3):624–641
- Wiersema MJ, Wiersema LM (1996) Endosonography guided celiac plexus neurolysis. *Gastrointest Endosc* 44:656–662
- Wong GY, Schroeder DR, Carns PE, Wilson JL, Martin DP, Kinney MO, Carlos BM, Warner DO (2004) Effect of neurolytic celiac plexus block on pain relief, quality of life, and survival in patients with unresectable pancreatic cancer—a randomized controlled trial. *JAMA* 291(9):1092–1099
- Wyse JM, Chen YI, Sahai AV (2014) Celiac plexus neurolysis in the management of unresectable pancreatic cancer: when and how? *World J Gastroenterol* 20(9):2186–2192
- Papadopoulos D, Kostopanagiotou G, Batistaki C (2013) Bilateral thoracic splanchnic nerve radiofrequency thermocoagulation for the management of end-stage pancreatic abdominal cancer pain. *Pain Physician* 16:125–133
- Siegel R, Ma J, Zou Z, Jemal A (2014) Cancer statistics, 2014. *CA Cancer J Clin* 64(1):9–29
- Arnold LD, Patel AV, Yan Y, Jacobs EJ, Thun MJ, Calle EE, Colditz GA (2009) Are racial disparities in pancreatic cancer explained by smoking and overweight/obesity? *Cancer Epidemiol Biomarkers Prev* 18(9):2397–2405
- Simard EP, Ward EM, Siegel R, Jemal A (2012) Cancers with increasing incidence trends in the United States: 1999 through 2008. *CA Cancer J Clin* 62(2):118–128
- Smith BD, Smith GL, Hurria A, Hortobagyi GN, Buchholz TA (2009) Future of cancer incidence in the United States: burdens upon an aging, changing nation. *J Clin Oncol* 27(17):2758–2765
- Visser BC, Ma Y, Zak Y, Poultides GA, Norton JA, Rhoads KF (2012) Failure to comply with NCCN guidelines for the management of pancreatic cancer compromises outcomes. *HPB (Oxford)* 14(8):539–547
- Rijkers AP, Valkema R, Duivenvoorden HJ, van Eijck CH (2014) Usefulness of F-18-fluorodeoxyglucose positron emission tomography to confirm suspected pancreatic cancer: a meta-analysis. *Eur J Surg Oncol* 40(7):794–804
- Rösch T, Braig C, Gain T, Feuerbach S, Siewert JR, Schusdzianra V, Classen M (1992) Staging of pancreatic and ampullary carcinoma by endoscopic ultrasonography. Comparison with conventional sonography, computed tomography, and angiography. *Gastroenterology* 102(1):188–199
- Varadarajulu S, Wallace MB (2004) Applications of endoscopic ultrasonography in pancreatic cancer. *Cancer Control* 11(1):15–22
- Fuhrman GM, Charnsangavej C, Abbruzzese JL, Cleary KR, Martin RG, Fenoglio CJ, Evans DB (1994) Thin-section contrast-enhanced computed tomography accurately predicts the resectability of malignant pancreatic neoplasms. *Am J Surg* 167(1):104–111
- Horton KM, Fishman EK (2002) Adenocarcinoma of the pancreas: CT imaging. *Radiol Clin N Am* 40(6):1263–1272
- House MG, Yeo CJ, Cameron JL, Campbell KA, Schulick RD, Leach SD, Hruban RH, Horton KM, Fishman EK, Lillemoe KD (2004) Predicting resectability of periampullary cancer with three-dimensional computed tomography. *J Gastrointest Surg* 8(3):280–288
- Klauss M, Schöbinger M, Wolf I, Werner J, Meinzer HP, Kauczor HU, Grenacher L (2009) Value of three-dimensional reconstructions in pancreatic carcinoma using multidetector CT: initial results. *World J Gastroenterol* 15(46):5827–5832
- Günter S, Siveke JT, Eckel F, Schmid RM (2005) Pancreatic cancer: basic and clinical aspects. *Gastroenterology* 128: 1606–1625
- Schima W, Ba-Ssalamah A, Goetzinger P, Scharitzer M, Koellblinger C (2007) State-of-the-art magnetic resonance imaging of pancreatic cancer. *Top Magn Reson Imaging* 18(6):421–429
- Nallamothu G, Hilden K, Adler DG (2011) Endoscopic retrograde cholangiopancreatography for non-gastroenterologists: what you need to know. *Hosp Pract* (1995) 39(2):70–80
- Tirkes T, Sandrasegaran K, Sanyal R, Sherman S, Schmidt CM, Cote GA, Akisik F (2013) Secretin-enhanced MR cholangiopancreatography: spectrum of findings. *Radiographics* 33(7):1889–1906

28. Warshaw AL, Gu ZY, Wittenberg J, Waltman AC (1990) Preoperative staging and assessment of resectability of pancreatic cancer. *Arch Surg* 125(2):230–233
29. Andersson R, Vagianos CE, Williamson RC (2004) Preoperative staging and evaluation of resectability in pancreatic ductal adenocarcinoma. *HPB (Oxford)* 6(1):5–12
30. Varadachary GR, Wolff RA, Crane CH et al (2008) Preoperative gemcitabine and cisplatin followed by gemcitabine-based chemoradiation for resectable adenocarcinoma of the pancreatic head. *J Clin Oncol* 26:3487–3495