FOCUS ON: PANCREATIC NEOPLASMS

Wednesday 3 October 2007, 15:00–16:00

Pancreatic adenocarcinoma: diagnosis and staging using multidetector-row computed tomography (MDCT) and magnetic resonance imaging (MRI)

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Abstract

Pancreatic adenocarcinoma continues to be a leading cause of cancer death in the Western world and is amongst the leading gastrointestinal cancers. The incidence of pancreatic cancer has been stable or slowly rising in the past few decades. Overall the prognosis is poor with 5-year survival rates still under 5%. Therefore early detection and accurate staging of these tumors is crucial for optimal treatment.

Keywords: Pancreatic adenocarcinoma.

Introduction

Pancreatic adenocarcinoma continues to be a leading cause of cancer death in the Western world and is amongst the leading gastrointestinal cancers. The incidence of pancreatic cancer has been stable or slowly rising in the past few decades. Overall the prognosis is poor with 5-year survival rates still under 5%. Therefore early detection and accurate staging of these tumors is crucial for optimal treatment.

Pancreatic adenocarcinoma is the most common pancreatic exocrine neoplasm and accounts for 75–85% of all pancreatic malignancies. Common etiologies implicated are cigarette smoking, chronic pancreatitis and hereditary chronic pancreatitis.[1–6]

The majority of the tumors are located in the head of the pancreas[7,8]. Tumors located in the pancreatic head can obstruct the common bile duct leading to jaundice and tend therefore to be detected earlier, compared to tumors located in the body and tail which usually present in the late stages of the disease, often with distant metastases or locally advanced disease. However most tumors present late with advanced stages of the disease and so curative resection is possible only in about 10–15% of patients[1–6]. Therefore accurate staging is essential to differentiate the resectable patient from the unresectable and imaging plays a critical role in making this differentiation.

Contraindications to curative resection are the presence of liver or other distant metastases, peritoneal metastases, greater than half circumferential encasement of major mesenteric vascular structures (celiac, hepatic, superior mesenteric artery), and local infiltration into the peripancreatic fat, and mesentery of the jejunum or transverse mesocolon[6]. Mesenteric venous encasement (superior mesenteric vein and portal vein) is a relative contraindication for resection, as at some centers, en-bloc resection of tumor and the involved vein is performed with placement of a graft.

Imaging

While ultrasonography (US), computed tomography (CT) and magnetic resonance imaging (MRI) can all be used in the detection and staging of pancreatic carcinoma, CT is probably the most common modality used. As CT is the main diagnostic technique used in our
center for the detection and staging of pancreatic carcinoma, the following discussion focuses on the use of multidetector-row computed tomography (MDCT).

**MDCT**

MDCT enables evaluation of the pancreas during various phases of parenchymal enhancement during intravenous contrast administration. Several studies have shown that biphasic imaging of the pancreas is helpful in the detection and staging of pancreatic carcinoma and that the tumor-to-parenchymal differences are maximized during the pancreatic parenchymal phase of contrast enhancement\(^9,10\) (Fig. 1a,b). Using a 64-detector MDCT, we perform a biphasic protocol consisting of thin section (0.625 mm collimation) images obtained during the pancreatic parenchymal phase (50 s following commencement of intravenous contrast administration) followed by a hepatic parenchymal or portal venous phase at 65 s. A total of 125 ml of iodinated intravenous contrast (concentration 370 mg/ml of iodine) is injected at 4–5 ml/s followed by a 50 ml saline flush. Negative oral contrast is used to delineate and distend the stomach and duodenum permitting the rendering of 3D images (Fig. 2).

The thin-section images obtained with this technique are sent to the 3D laboratory for image processing and reformattting (curved planar, coronal and sagittal images) (Fig. 3)\(^11-15\). Some recent studies have shown that these 3D images may be more accurate in staging\(^13\).

Most often pancreatic adenocarcinomas are seen as hypoattenuating masses. Rarely they can be isodense to the normal pancreatic parenchyma, and difficult to detect. In these situations, indirect signs such as ‘upstream’ pancreatic duct dilation or the ‘double duct’

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**Figure 1** Contrast-enhanced axial CT images in pancreatic parenchymal (a) and portal venous phases of enhancement (b). Note the tumor (arrow) is best seen in the pancreatic parenchymal phase (a).

**Figure 2** Curved planar reformatted CT image through the pancreatic duct shows the relationship of the tumor (arrow) to the pancreatic duct.

**Figure 3** Coronal reformatted CT image depicts dilated pancreatic duct (arrowhead) due to obstructing tumor (arrow) in the pancreatic head.
sign due to pancreatic and common bile duct obstruction are helpful to diagnose the small isoattenuating tumors. The overall sensitivity for tumor detection by MDCT has been reported to be between 76 and 92%, but drops to between 63% and 77% when small tumors <2 cm in size are included in the analysis. The use of multiplanar reconstructions has improved the detection especially of small tumors.

**MRI**

Breath-hold sequences such as axial two dimensional (2D) spoiled gradient-recalled (SPGR), axial T1 spin echo (SE) with fat saturation, and axial three-dimensional (3D) gadolinium-enhanced SPGR images are combined with coronal single shot fast spin echo (SSFSE), and axial T2 fat saturated FSE images to provide excellent visualization of the pancreas and the adjacent structures thereby providing images that can detect, characterize and stage pancreatic carcinoma. Magnetic resonance cholangiopancreatography (MRCP) can be used in conjunction with pancreatic MRI for depiction of the pancreatobiliary system.

Most pancreatic carcinomas are seen as hypointense tumors compared to the normal pancreas on T1-weighted fat suppressed images, and as hypointense lesions on arterial phase gadolinium-enhanced images (Fig. 4), but can show progressive enhancement on delayed scans.

Most studies comparing MDCT and MRI for the detection and staging of pancreatic carcinoma have shown that both studies have similar accuracy, although recent studies have shown slight superiority for MDCT, in part due to the recent technical improvements in MDCT.

**Endoscopic ultrasound**

MDCT is inferior to endoscopic ultrasound (EUS) especially in the detection of small tumors. A recent study by DeWitt has shown that EUS had a sensitivity of 98% compared to 86% for MDCT. EUS has also been shown to have a high negative predictive value for excluding pancreatic cancer, and may therefore play a role in screening for pancreatic malignancies.

**Staging**

Although TNM staging is not widely used by radiologists, oncologists do use this staging system (Table 1). T stage is defined by tumor size, and local spread of the tumor, with T1 tumors being <2 cm in size and confined to the pancreas, with T2 tumors being ≥2 cm in size but still confined to the pancreas (Fig. 5). Tumor infiltration into the common bile duct, duodenum or peripancreatic tissues without associated major peripancreatic

**Table 1 TNM staging of pancreatic carcinoma**

| Stage | Definition |
|-------|------------|
| **Primary tumor** | |
| Tis  | Carcinoma in situ |
| T1  | Tumor limited to pancreas, ≤2 cm in any direction |
| T2  | Tumor limited to pancreas, ≥2 cm in any direction |
| T3  | Infiltration into peripancreatic tissue, duodenum and/or common bile duct |
| T4  | Infiltration into peripancreatic vessels, stomach, spleen, large bowel |
| **Regional lymph nodes** | |
| N0  | No lymph node metastases |
| N1  | Metastasis in peripancreatic lymph nodes |
| Nx  | Unknown |
| **Distant metastases** | |
| M0  | No distant metastases |
| M1  | Distant metastases present |
| Mx  | Unknown |

Adapted from ref. [29].
vascular infiltration is defined as T3 (Fig. 6); infiltration into the major peripancreatic vessels and contiguous organs such as the spleen, stomach or transverse colon is defined as T4. N stage is dependent on the presence of nodal metastasis, with N1 representing peripancreatic nodal metastases. Metastasis to more distant nodes such as para-aortic nodes is defined as M1 disease. Other sites of distant metastases are the liver and peritoneum.

While both MDCT and MRI are reasonably accurate in detecting local spread and distant visceral metastases\(^1,2,6,7,11,15,17,19,22,23\) from pancreatic cancer, both modalities are poor in detecting nodal metastases\(^30\).

### Perivascular tumor infiltration

The probability of tumor invasion of the major peripancreatic vasculature was studied by Lu et al.\(^{31}\) and O'Malley et al.\(^{32}\) with helical CT by measuring the degree and extent of tumor–vessel contact. Both these studies showed that when tumor–vessel contact was less than half the circumference of the vessel, the likelihood of tumor resectability was high (Fig. 7), whereas if it exceeded half the circumference, there was a high probability (80%) of unresectability (Fig. 8). These guidelines for vascular invasion are still in use today although no recent larger studies have been performed to further validate these criteria\(^{33–35}\).

**Figure 6** Contrast-enhanced axial CT image shows a mass in the body of the pancreas with peripancreatic invasion (arrows).

**Figure 7** Contrast-enhanced axial CT image shows a tumor in the body of the pancreas with less than 180 degrees of circumferential involvement (arrows) of the superior mesenteric vein. The tumor was resectable at surgery.

**Figure 8** Contrast-enhanced axial CT image shows a tumor in the head of the pancreas with more than 180 degrees of circumferential involvement (arrows) of the superior mesenteric vein, indicating unresectability.

**Figure 9** Contrast-enhanced axial CT image shows a mass in the tail of the pancreas (arrow), which at surgery proved to represent acute focal pancreatitis.
**References**

[1] Baci NC, Semelka RC. Radiologic diagnosis and staging of pancreatic ductal adenocarcinoma. Eur J Radiol 2001; 38: 105–112.

[2] Kilgir J, Pioepla T, Zajac A, Klek S, Kołodziejczyk P. The value of imaging techniques in the staging of pancreatic cancer. Surg Endose 2005; 19: 361–5.

[3] Takkar AS, Palaniappan P, Dhingra R, Lobo DN. Recent developments in diagnosis of pancreatic cancer. BMJ 2004; 329: 668–73.

[4] Clark DL, Thomson, SR, Madiba, TE, Sanyika C. Preoperative imaging of pancreatic cancer: a management-oriented approach. J Am Coll Surg 2003; 196: 119–29.

[5] Schima W, Ba-Ssalamah A, Kulinna-Cosentini C, Puespok A, Göttinger P. Pancreatic adenocarcinoma. Eur Radiol 2007; 17: 638–49.

[6] Freeny PC. Traverso LW, Ryan JA. Diagnosis and staging of pancreatic adenocarcinoma with dynamic computed tomography: Am J Surg 1993; 165: 600–6.

[7] Soin TA, Yeo CJ, Camron JL, et al. Resected adenocarcinoma of the pancreas: 616 patients: results, outcomes, and prognostic indications. J Gastrointest Surg 2000; 4: 567–79.

[8] Le DS, Vedantham S, Krasny J, et al. Two-phase helical CT for pancreatic tumors: pancreatic versus hepatic phase enhancement of tumor, pancreas and vascular structures. Radiology 1996; 199: 697–701.

[9] McNulty NJ, Francis IR, Platt JF, Cohan RH, Korobkin M, Gebramaniam A. Multidetector-row helical CT of the pancreas: effect of contrast-enhanced multiphasic imaging on enhancement of the pancreas, peripancreatic vasculature, and pancreatic adenocarcinoma. Radiology 2001; 220: 97–102.

[10] Fletcher JG, Wiersma MJ, Farrell MA, et al. Pancreatic malignancy: value of arterial, pancreatic parenchymal and hepatic phase imaging with multidetector-row CT. Radiology 2003; 229: 81–90.

[11] Pokesch RW, Chow LC, Beaulier CF, et al. Local staging of pancreatic carcinoma with multi-detector row CT: use of curved planar reformations-initial experience. Radiology 2002; 225: 759–65.

[12] Vargas R, Nino-Murica M, Trueblood W, Jeffery RB. MDCT in pancreatic adenocarcinoma: prediction of vascular invasion and resectability using a multiphasic technique with curved planar reformations. AJR 2004; 182: 419–25.

[13] Ichikawa T, Erturk WM, Sou H, et al. MDCT of pancreatic adenocarcinoma: optimal imaging phases and multplanar reformatting imaging. AJR 2006; 187: 1513–20.

[14] Fukushima H, Itoh S, Takada A, et al. Diagnostic value of curved multplanar reformatted images in multislice CT for the detection of resectable pancreatic ductal adenocarcinoma. Eur Radiol 2006; 16: 1709–18.

[15] Freeny PC. CT diagnosis and staging of pancreatic carcinoma. Eur Radiol 2005; 15: (Suppl 4): D96–9.

[16] Bronstein YL, Loyer EM, Kaur H, et al. Detection of small pancreatic tumors with multiphasic helical CT. AJR 2004; 182: 619–23.

[17] Smith SL, Basu A, Rae DM, Sinclair M. Preoperative staging accuracy of multidetector computed tomography in pancreatic head adenocarcinoma. Pancreas 2007; 34: 180–4.

[18] Sheridan MB, Ward J, Guthrie JA, et al. Dynamic contrast-enhanced MR imaging and dual-phase helical CT in the preoperative assessment of suspected pancreatic cancer: a comparative study with receiver operating characteristic analysis. AJR 1999; 173: 583–90.

[19] Spencer JA, Ward J, Guthrie JA, Guillou PJ, Robinson PJ. Assessment of resectability of pancreatic cancer with dynamic contrast-enhanced MR imaging: technique, surgical correlation and patient outcome. Eur Radiol 1998; 8: 23–9.

[20] Ly J, Miller GH. MR imaging of the pancreas: a practical approach. Radiol Clin North Am 2002; 40: 1289–306.

[21] Erturk SM, Ichikawa T, Sou H, et al. Pancreatic adenocarcinoma: MDCT versus MRI in the detection and assessment of locoregional extension. J Comput Assist Tomogr 2006; 30: 583–90.

[22] Lopez HE, Amthauer H, Hosten N, et al. Prospective evaluation of pancreatic tumors: accuracy of MR imaging with MR cholangiopancreatography and MR angiography. Radiology 2002; 224: 34–41.

[23] Schima W, Függer R, Schober E, et al. Diagnosis and staging of pancreatic cancer: comparison of mangafodipir trisodium-enhanced MR imaging and contrast-enhanced helical hydro-CT. AJR 2002; 179: 717–24.

[24] Obuz F, Dicle O, Coker A, Sagol O, Karademir S. Pancreatic adenocarcinoma: Detection and staging with dynamic MR imaging. Eur J Radiol 2001; 38: 146–50.

[25] Miller FH, Nini JK, Keppke AL. MRI of adenocarcinoma of the pancreas. AJR 2006; 187: W365–74.

[26] Dewitt J, Devereaux B, Chriswell M, et al. Comparison of endoscopic ultrasonography and multidetector computed tomography for detecting and staging pancreatic cancer. Ann Intern Med 2004; 141: 753–63.

[27] Soriano A, Castells A, Ayuso C, et al. Preoperative staging and tumor resectability assessment of pancreatic cancer: prospective study comparing endoscopic ultrasonography, helical computed tomography, magnetic resonance imaging, and angiography. Am J Gastroenterol 2004; 99: 492–501.

[28] DeWitt J, Devereaux B, Chriswell M, et al. Comparison of endoscopic ultrasonography and multidetector computed tomography for detecting and staging pancreatic cancer. Am Coll Phys 2004; 141: 753–63.

[29] Zeman RK, Cooper C, Zelberg AS, et al. TNM staging of pancreatic carcinoma using helical CT. AJR 1997; 169: 459–64.

[30] Roche CJ, Hughes ML, Garvey CJ, et al. Local staging of pancreatic cancer: criteria for unresectability of major vessels as revealed by endoscopic ultrasonography and MR angiography. Radiology 2002; 224: 173: 583–90.

[31] Bronstein YL, Loyer EM, Kaur H, et al. Detection of small pancreatic tumors with multiphasic helical CT. AJR 2004; 182: 619–23.

[32] Smith SL, Basu A, Rae DM, Sinclair M. Preoperative staging accuracy of multidetector computed tomography in pancreatic head adenocarcinoma. Pancreas 2007; 34: 180–4.

[33] Sheridan MB, Ward J, Guthrie JA, et al. Dynamic contrast-enhanced MR imaging and dual-phase helical CT in the preoperative assessment of suspected pancreatic cancer: a comparative study with receiver operating characteristic analysis. AJR 1999; 173: 583–90.

[34] Spencer JA, Ward J, Guthrie JA, Guillou PJ, Robinson PJ. Assessment of resectability of pancreatic cancer with dynamic contrast-enhanced MR imaging: technique, surgical correlation and patient outcome. Eur Radiol 1998; 8: 23–9.

[35] Ly J, Miller GH. MR imaging of the pancreas: a practical approach. Radiol Clin North Am 2002; 40: 1289–306.

[36] Erturk SM, Ichikawa T, Sou H, et al. Pancreatic adenocarcinoma: MDCT versus MRI in the detection and assessment of locoregional extension. J Comput Assist Tomogr 2006; 30: 583–90.

[37] Lopez HE, Amthauer H, Hosten N, et al. Prospective evaluation of pancreatic tumors: accuracy of MR imaging with MR cholangiopancreatography and MR angiography. Radiology 2002; 224: 34–41.

[38] Schima W, Függer R, Schober E, et al. Diagnosis and staging of pancreatic cancer: comparison of mangafodipir trisodium-enhanced MR imaging and contrast-enhanced helical hydro-CT. AJR 2002; 179: 717–24.
Horton KM, Fishman EK. Multidetector CT angiography of pancreatic carcinoma: Part II, Evaluation of arterial involvement. AJR 2002; 178: 833–6.

Balthazar EJ. Pancreatitis associated with pancreatic carcinoma. Preoperative diagnosis: role of CT imaging in detection and evaluation. Pancreatology 2005; 5: 330–44.

Oto A, Eltorky MA, Dave A, et al. Mimicks of pancreatic malignancy in patients with chronic pancreatitis: Correlation of computed tomography imaging features with histopathologic findings. Curr Probl Diagn Radiol 2006; 35: 199–205.

Johnson PT, Outwater EK. Pancreatic carcinoma versus chronic pancreatitis: dynamic MR imaging. Radiology 1999; 212: 213–18.