The Imaging of Pancreatic Exocrine Solid Tumors: The Role of Computed Tomography and Positron Emission Tomography

Lucia Calculli¹, Raffaele Pezzilli², Riccardo Casadei³, Marta Fiscaletti¹, Carla Brindisi¹, Lorenzo Fantini², Giampaolo Gavelli¹

Departments of ¹Radiology, ²Internal Medicine, and ³Surgery, Sant’Orsola-Malpighi Hospital, University of Bologna. Bologna, Italy

Summary

The only potentially radical treatment for pancreatic cancer is the removal of the tumor which can be performed by total or subtotal surgical resection of the pancreas; this is possible in the early stages of the disease when the tumor is confined to the pancreatic gland without metastasis to the liver, lymph nodes and/or the peritoneum, or involvement of the vascular system such as the celiac trunk and its branches and the superior mesenteric artery. In this paper, we describe the accuracy of computed tomography and positron emission tomography in the diagnosis of exocrine pancreatic cancer.

Thus, it is important to evaluate the encasement of the portal mesenteric trunk in order to plan adequate treatment.

It is well-established that multidetector computed tomography (MDCT) is the gold standard option for diagnosing and staging exocrine pancreatic cancer [1, 2]. In the last few years, a new diagnostic imaging technique, positron emission tomography with CT (CT-PET) has been introduced in the clinical setting to better evaluate the presence of distal metastases, especially since it has the possibility of evaluating the entire human body [1, 2].

The aim of the present paper is to determine the clinical role of MDCT, CT-PET, in the diagnosis and staging of exocrine pancreatic solid tumors.

We would like to emphasize that, in our Institution, MDCT is the preferred imaging technique for studying the pancreatic gland and for confirming the clinical suspicion of pancreatic cancer. MDCT is carried out using a Siemens Somatom Sensation Cardiac (Siemens AG, Berlin, Germany) which uses SOMATOM Sensation Images (Siemens Medical Solutions, Siemens AG, Berlin, Germany) as software for acquisition imaging reconstruction in which ultrafast detector rotation and thin collimation can be combined to yield high-resolution, three-dimensional reconstructions of the pancreas and nearby structures.
We routinely use the following examination protocol. Before the examination, the patient drinks about 800 mL of water so that the stomach and the duodenum can be better visualized and the first acquisition is carried out. Then a contrast medium (Iomeron, Bracco S.p.A, Milan, Italy) is intravenously infused and three consecutive image acquisitions are carried out; the arterial phase is carried out after about 25 seconds of contrast medium infusion, the pancreatic phase is carried out with a 45-second delay and, finally, the venous phase is carried out with a 65-second delay.

The images acquired undergo post-processing via multiplanar reconstruction (MPR), angio-maximum intensity projection (MIP), InSpace, and volume rendering (VRT).

Using this image acquisition, we are able to diagnose a small pancreatic cancer less than 2 cm in diameter. An indirect sign seen during the arterial phase of MDCT called “black and white” which is characterized by a difference of enhancement between the normal pancreatic gland free of tumor involvement (white) and the edematous gland above the tumor (black) together with a dilated pancreatic duct, can be found when the pancreatic mass is not visualized (Figure 1). From a practical point of view, we also need to establish peripancreatic vascular involvement. The level of involvement of the

Figure 1. Multidetector computed tomography: the black and white sign visible during the arterial phase: normal appearance of the head of the pancreas and hypodense appearance of the body and tail of the gland (a-b). The arrows indicate the part of the gland which was found at surgery to be involved by the tumor.

Figure 2. Stage 0. Multidetector computed tomography: normal appearance of the pancreatic gland (a.) and normal peripancreatic vessels (a-b.)
peripancreatic vascular system is of particular interest when planning adequate surgical treatment and also in order to avoid unnecessary resection.

Five distinct stages of peripancreatic vascular involvement have been established:

- Stage 0: absence of vascular involvement with the fat plane conserved between the tumor and the vessels (Figure 2);
- Stage 1: loss of the fat plane between the tumor and the vessels (Figure 3);
- Stage 2: tangential invasion of the vessel (Figure 4);
- Stage 3: invasion of the vascular perimeter by up to two-thirds with a ribbon-like appearance of the vascular lumen (Figures 5 and 6);
- Stage 4: neoplastic thrombosis (Figure 7).

It has been reported that vascular involvement is very common in tumors involving the
pancreas head, having a frequency of 65% [3]. In the absence of lymph node and hepatic metastases and peritoneal carcinosis, the resectability of pancreatic tumors mainly depends on the level of vascular involvement [4]. Several authors [5, 6, 7, 8, 9, 10, 11] have suggested that CT is the best technique for evaluating vascular involvement and determining the viability of surgical resection of pancreatic tumors. Raptopoulos et al. [6] noted that CT is capable of establishing the non-resectability of tumors in 96% of cases which were demonstrated to be non-operable. Yosmini et al. [7] suggested that the presence and the level of portal mesenteric trunk invasion by the tumor needs to be established prior to surgery. O'Malley et al. [10] argued that demonstrating, with CT, the invasion of the circumference of a vascular structure by the tumor is vital for establishing which patients should undergo surgery. Howard et

**Figure 5.** Stage 3. Multidetector computed tomography: circumferential involvement of the superior mesenteric vein (a, multiplanar reconstruction). In panel b, the sign of the tear drop of the superior mesenteric vein is also visible (arrow).

**Figure 6.** Stage 3. Multidetector computed tomography: circumferential involvement of the peripancreatic artery (multiplanar reconstruction). Panel a, shows the involvement of the pancreatic-duodenal and hepatic arteries. In panel b, the involvement of the pancreatic-duodenal arteries is also visible (volume rendering tomography). In panel c, the circumferential involvement of the superior mesenteric artery (multiplanar reconstruction) is seen.
al. [9] found that the specificity, sensitivity and accuracy in determining the resectability of pancreatic tumors were 100%, 63% and 86%, respectively; the low level of sensitivity is due to the fact that CT is not always able to identify small peritoneal metastases and/or small hepatic metastases below the Glisson capsule (Figure 8). According to Lu et al. [5], the sensitivity, specificity, and the positive and negative predictive values for the non-resectability of pancreatic tumors are 84%, 98%, 95% and 93%, respectively. Bluemke et al. [11] found that the accuracy of CT was 70% in evaluating resectability. However, to evaluate the necessity of possible curative surgery, we need to know the possible local or distant malignant invasion (Figures 8 and 9). At present, three techniques capable of reaching this objective are available: CT-PET, magnetic resonance imaging (MRI), and echoendoscopy (EUS). The exact role of these techniques in the evaluation of local and distant metastatic disease is currently under investigation. A recent meta-analysis carried out by Orlando et al. [12], which evaluated 17 studies, found that CT-PET has a sensitivity of 71-100% and specificity of 53-100% in the detection of pancreatic cancer, and claimed

Figure 7. Stage 4. Multidetector computed tomography: thrombosis of the superior mesenteric vein (a. multiplanar reconstruction; b. angiography minimum intensity projection; c. InSpace; d. curvilinear multiplanar reconstruction).
that CT-PET might be an ideal method of distinguishing between benign and malignant lesions of the pancreatic gland [13]. However, another conclusion of this study was that the specificity of this imaging technique is of limited value because the hypermetabolic cell found in chronic pancreatitis or other inflammatory conditions may lead to false positive diagnoses [14]. Finally, CT-PET may be useful in monitoring disease recurrence or response to neoadjuvant therapy [15] (Figure 9).

In a recent interesting study, Sahani et al. [16] evaluated the comparative accuracy of MRI and CT-PET in assessing metastatic disease. The results are reported in Table 1. The authors found that the two techniques are equally useful in obtaining information on metastatic disease because there was no significant difference between MRI and 2-[F-18]-fluoro-2-deoxy-D-glucose (FDG) CT-PET in the detection of liver metastases on a patient-by-patient basis. However, for liver lesion detection, MRI detected significantly more and smaller metastases than FDG CT-PET and this observation was most significant for lesions which measured less than 1 cm. Finally, it has been reported [17] that, using MCDT and EUS, the sensitivity in assessing

| Table 1. Sensitivity, accuracy and positive predictive value (PPV) of magnetic resonance imaging (MRI) and positron emission tomography with computed tomography (CT-PET) in evaluating metastatic disease in patients with exocrine pancreatic cancer. |
|---------------------------------|-----------------|
| MRI                            | CT-PET          |
| Sensitivity                    | 96.6%           | 93.3%           |
| PPV                            | 100%            | 90.3%           |
| Accuracy                       | 97.1%           | 85.3%           |

Figure 8. Multidetector computed tomography (MDCT): small liver lesion (a. arrow). MRI: presence of the same liver lesion found at MDCT; the lesion appears to be larger than that seen at CT and Glisson’s capsule involvement (b.).

Figure 9. Positron emission tomography with computed tomography: pancreatic lesions (a.) and liver metastases (b.) at diagnosis. Disappearance of the liver lesion after neo-adjuvant therapy (c.).
the presence of a pancreatic neoplasm and local invasion was similar. The only superiority EUS has with respect to MDCT is in the detection and the biopsy of pancreatic lesions less than 2-3 mm in diameter, having a diagnostic sensitivity greater than 90% [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 16, 17, 18, 19, 20]. Finally, we would point out that the presence of lymph node metastases is high, ranging from 33 to 77% in patients with pancreatic cancer [18]; however no imaging techniques are capable of identifying metastatic lymph node involvement with a satisfactory degree of sensitivity. This is a drawback of the imaging assessment because Japanese authors have claimed that small metastases of lymph nodes and the extrapancreatic nerve plexus near the mesenteric superior artery are always present and this phenomenon is probably the cause of local and distant recurrence of the disease [19].

In conclusion, MDCT is the gold standard for diagnosing and staging more than 90% of pancreatic cancers; in the percentage remaining, MRI, CT-PET and EUS may play a role.

**Keywords** Diagnostic Imaging; Lymphatic Metastasis; Magnetic Resonance Imaging; Neoplasm Metastasis; Pancreatic Neoplasms; Positron Emission Tomography; Tomography; Ultrasonography

**Abbreviations** CT-PET: positron emission tomography with computed tomography; FDG: 2-[F-18]-fluoro-2-deoxy-D-glucose; MDCT: multidetector computed tomography; MIP: maximum intensity projection; MPR: multiplanar reconstruction; VRT: volume rendering

**Conflict of interest** The authors have no potential conflicts of interest

**Correspondence**
Lucia Calculli
Dipartimento di Radiologia
Azienda Ospedaliero-Universitaria
Policlinico Sant'Orsola-Malpighi
Via Massarenti, 9
40138 Bologna
Italy
Phone: +39-051.636.3383
Fax: +39-051.349.797
E-mail: lcalculli@aosp.bo.it

**References**


9. Howard TJ, Chin AC, Streib EW, Kopecky KK, Wiebke EA. Value of helical computed tomography,


