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ORIGINAL ARTICLE

Preoperative Imaging for Resectable Periampullary Cancer: Clinicopathologic Implications of Reported Radiographic Findings

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Abstract

Background High-resolution, multiphase, computed tomography (CT) is a standard preoperative test prior to pancreatectomy, yet the clinical significance of routinely reported findings remains unknown.

Methods We identified patients who underwent a pancreaticoduodenectomy for a periampullary adenocarcinoma (PA) over the previous 5 years and had a pancreas protocol CT at our institution. Clinicopathologic implications of reported CT findings were evaluated.

Results There were 155 pancreatic ductal adenocarcinomas (PDA) and 47 non-pancreatic PAs. No mass was visualized on CT in 6 % of PDAs and 23 % of non-pancreatic PA. A size discrepancy of ≥1 cm between radiographic and pathologic tumor diameters was observed in 40 % of PAs, with CT underestimating the size in most instances (75 %). Radiographically enlarged lymph nodes were not associated with true lymph node metastases in PDAs (70 % lymph node positive cases were enlarged on CT vs 74 % lymph node negative, $p = 0.5$), but were associated with a preoperatively placed biliary endoprosthesis (63 % with endoprosthesis were enlarged vs 37 % no endoprosthesis, $p = 0.013$). Major visceral vessel involvement on CT was not associated with a vascular resection (3 % with CT vessel involvement vs 2 % without, $p = 0.8$) or a positive uncinate resection margin (24 vs 20 %, respectively, $p = 0.6$).

Discussion While dedicated pancreas protocol CT provides unprecedented detail, the test may lead to overinterpretation of the extent of disease in some instances. A radiographic suggestion of enlarged lymph nodes and vascular involvement does not necessarily preclude exploration with curative intent. CTs with local disease should be reported in an objective template and carefully reviewed by a multidisciplinary group of surgeons, radiologists, and oncologists to avoid missing an opportunity for neoadjuvant therapy or cure by resection.

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Introduction

Multi-detector computed tomography (CT) with 3-D reconstruction is the imaging modality of choice for the preoperative evaluation of periampullary cancer.[1–4] Technical improvements in CT imaging, particularly over the past decade, have substantially improved acquisition speed and image quality.[5,6] The modern-day 64-slice scanner has an acquisition time of less than 30 s (as compared to more than 20 min in the 1980s)[5] for studies of the liver and pancreas, and reliably detects sub-centimeter lesions with isotropic resolution (i.e., equal resolution throughout).[7–9]

These improvements provide certain tangible benefits in patient care. For instance, on occasion CT may incidentally identify asymptomatic pancreatic cancers at an early stage.[10] Perhaps more commonly, low-volume metastatic disease is detected, thereby avoiding an unnecessary laparotomy. Indirect evidence of improved preoperative staging with modern-day imaging is suggested by decreased 1-year cancer-specific mortality rates after resection for pancreatic cancer, which likely relates to improved patient selection for resection.[11] Increased image resolution provides greater detail along the tumor borders with respect to nearby major visceral blood vessels, which facilitates careful assessment of local resectability.[8,9,12–15] CT may also help identify patients with questionably resectable (borderline) cancers and identify a subset that may benefit from neoadjuvant treatments.[4,16–18] In addition, the anatomic information provided by high-quality, modern-day CT images allows pancreatic surgeons to better plan surgery and anticipate relevant vascular anomalies and anatomic challenges.

Despite the aforementioned advantages of modern-day imaging, studies that objectively assess the accuracy or true benefit of modern-day, high-resolution, multi-slice CT are sparse. Some studies have highlighted inaccuracies in the assessment of borderline resectable periampullary cancers;[12,19,20] others have questioned the significance of enlarged lymph nodes.[19,21] While certain radiographic findings from high-quality imaging add invaluable insights for surgical planning, other more subtle observations are subjected to over- or underinterpretation. This is particularly relevant in light of a recent study that found a national failure to operate on localized pancreatic cancer in over 2/3 of patients with apparent stage I disease.[22] It is unknown if misinterpreted radiographic data contributed to this problem. Few studies have thoroughly examined the clinicopathologic implications of radiographic findings. In this study, we examine our institutional experience in order to determine if routinely reported CT findings correlate with relevant operative findings and pathological data.

Methods

A retrospective review of the prospectively established Thomas Jefferson University (TJU) pancreatic surgery database was performed. The study was approved by the Institutional Review Board. Patients with a periampullary adenocarcinoma (including pancreatic ductal adenocarcinoma, distal bile duct adenocarcinoma, ampullary adenocarcinoma, or duodenal adenocarcinoma) resected by a pancreaticoduodenectomy (PD) at TJU between 2005 and 2011 were included. They were all surgically explored with a curative intent. In order to best determine the clinical and pathologic significance of reported radiographic findings, we limited the study to patients who had a preoperative pancreas protocol staging CT scan performed at our institution, and interpreted by a TJU radiologist with expertise in pancreatic imaging. While imaging studies performed and read at other institutions are frequently sufficient for operative planning, their inclusion into the present study would confound the analysis. Overall, there were 202 patients identified who met the study criteria.

Difficult cases are reviewed and interpreted at a multidisciplinary meeting which consists of a working group of pancreatic surgeons, radiologists, pathologists, medical and radiation oncologists to determine whether or not the patients were appropriate for exploration and attempt at resection with a curative intent. Typically, patients with resectable disease (based on the MD Anderson definition[23] and the criteria set by Evans et al.[24]) were offered resection, while those with borderline (particularly those with segmental occlusion of the SMV or PV) or locally advanced cancers were referred for neoadjuvant treatment. Relevant clinical data included perioperative clinicopathologic information routinely captured in our PD database, and described in previous studies.[25,26] With regard to margin processing, the uncinate margin is assessed perpendicularly. The resected specimen is inked on its uncinate reflection, and margins are considered positive if gross or microscopic tumor is present on ink.

Radiographic details not routinely collected in the aforementioned database were added through a retrospective review of radiographic reports. Gallbladder distension on CT was defined as any mention of gallbladder distension in the original CT report. Lymphadenopathy found on CT was defined as any mention in the radiology report of "lymphadenopathy," "enlarged lymph nodes," or a description of a lymph node with a diameter over 0.9 cm. Bile duct (BD) and pancreatic duct (PD) dilatation on CT were defined as any mention of a dilated duct, or duct sizes above 8 mm[27] and 4 mm[28] in naïve ducts before they were stented, respectively. Major visceral vessel involvement was determined at the discretion of the radiologists. Since the CT reports were performed for routine clinical care, and not research purposes, terms such as "abutment," "encasement," and "involvement" were occasionally not based on standard definitions, but the subjective judgement of the radiologist.

The CT scan variables were then analyzed with respect to clinicopathologic variables. This is not a systematic study analyzing CT variables using standard definitions, but rather an analysis of the clinical and pathologic significance of reported radiographic findings using common interpretation by experienced radiologists in the field.

Pancreas Protocol CT Examination

All included patients (n=202) underwent a dedicated 64-channel, multi-phase, pancreas protocol CT examination with water given orally. Patients underwent injection at a rate of 4 ml/s of 100–120 ml non-ionic iodinated (300–320 mg I/ml) contrast material (Optiray 320, Covidien, Mansfield, MA or Ultravist 300, Bayer Healthcare, Wayne, NJ). Acquisition phases in chronological order included unenhanced, early arterial (arteriogram), late arterial (pancreatic parenchymal), and venous phases. Post-contrast phases were acquired at 0, 10, and 35 s after bolus arrival to the aorta at the mid-liver level. For all phases, 0.6–0.75-mm-thick axial images were obtained. Images were reconstructed at: 5 mm for the unenhanced phase, 3 mm for the early arterial phase, 3 and 1.5 mm for the later arterial phase, and 3 mm for the venous phase. Early arterial and venous phase images were reconstructed at the scanner consoles using multi-planar reformatting and 3D surface rendering for enhanced vascular anatomy visualization.

Statistical Analysis

Statistical analyses were performed using Intercooled Stata software, version 12.0 (StataCorp, College Station, TX). Percentages were calculated using denominators that reflect the number of patients with available data for each specific variable. Categorical variables were analyzed using the Chi-squared test or logistic regression. Continuous variables were compared using the Mann–Whitney rank sum test. Averages were reported as medians, and statistical significance was accepted at the $p<0.05$ level.

Results

A total of 1,684 patients were evaluated for pancreatic or periampullary pathology in the outpatient clinic at the Jefferson Pancreas, Biliary, and Related Cancer Center during the study interval. One hundred and sixty-one patients were denied surgery because of obvious unresectability of cancer (obvious invasion of major visceral vessel, metastatic disease). A total of 1,123 patients were explored for a possible resection, of which 140 patients (9.2 %) were deemed unresectable intraoperatively and underwent double bypasses. There were 983 patients who had a pancreatic resection, with 585 PDs. Out of these patients, 325 (56 % of PDs) were for a periampullary adenocarcinoma. Preoperative imaging was obtained at an outside hospital (OSH) in 123 (38 %) of these cases (excluded from this analysis), while 202 patients (62 % of periampullary adenocarcinomas) had a staging CT scan performed at TJU using the described pancreas protocol. The pathologic distribution of the 202 periampullary adenocarcinomas included 155 (77 %) pancreatic ductal adenocarcinomas (PDA), 21 (10 %) ampullary adenocarcinomas (AA), 15 (7 %) distal bile duct adenocarcinomas (BDA), and 11 (6 %) duodenal adenocarcinomas (DA).

Mass Detection and Size Estimation

A primary tumor mass was detected in 146 (94 %) PDAs, 18 (86 %) AA, 8 (53 %) BDA, and 10 (90 %) DA (Table 1). As compared to PDAs, a significantly smaller proportion of masses were visualized for BDAs (p=0.0001). Pathologic size as measured by a pathologist did not strictly account for the detectability of the primary tumor by CT. Specifically, the median pathologic tumor sizes of periampullary adenocarcinomas with detectable masses on CT were 3.0 cm for PDAs (n=146), 2.2 cm for AAs (n=18), 1.9 cm for BDAs (n=8), and 3.8 cm for DAs (n=10). The median pathologic tumor sizes for undetectable masses were 2.5 cm for PDAs (n=9, p=0.5), 1.8 cm for AAs (n=3, p=0.5), and 1.8 cm for BDAs (n=7, p=0.4), respectively. The pathologic tumor size of the single undetectable DA was not available for comparison.

In the periampullary adenocarcinomas group with radiographically detectable masses, size discrepancies between measured radiographic and pathologic diameters were compared, with data available for 186 patients. An inaccurate measurement was defined as a size discrepancy of ≥1 cm between radiographic and pathologic measurements. Pancreatic and non-pancreatic periampullary adenocarcinomas were analyzed separately, and the results summarized in Table 2. The sizes were concordant in 54.2 % of the PDAs (n=71) and 40.9 % of the non-pancreatic periampullary adenocarcinomas (n=9, p=0.26 >vs PDAs). For PDAs, when CT scan misrepresented tumor size (n=60), it underestimated the tumor size (n=44, 73 %) more often than it overestimated the size (n=16, 27 %). Similarly, in the non-pancreatic periampullary adenocarcinomas group (n=13), CT underestimated tumor size in 11 (85 %) patients and overestimated tumor size in 2 patients (15 %, p=0.4 vs PDAs).

Pancreatic and Bile Duct Dilatation

PD and BD sizes in the various periampullary adenocarcinomas subtypes are summarized in Table 3. PD dilatation was observed on CT in 66 % of PDAs, 57 % of AAs (p=0.47 vs PDA), 25 % of BDAs (p=0.001), and 46 % of DAs (p=0.201; Table 3). BD dilatation was observed in 66 % of PDAs, 90 % of AAs (p≥0.001 vs PDA), 67 % of BDAs (p=0.588), and 50 % of DAs (p=1.000). A double duct sign was observed in 49 % of PDAs, 22 % of BDAs (p=0.172 vs PDA), 52 % of

Table 1 CT detection rates of periampullary cancer, $n=202$

	Mass detected on CT, *n* (%)	Mass not detected on CT, *n* (%)	*p* value
Pancreatic ductal adenocarcinoma	146 (94.2)	9 (5.8)	–
Ampullary adenocarcinoma	18 (85.7)	3 (14.3)	0.1584
Distal bile duct adenocarcinoma	8 (53.3)	7 (46.7)	0.0001
Duodenal adenocarcinoma	10 (90.9)	1 (9.1)	0.5062
All periampullary adenocarcinomas	182 (90.1)	20 (9.9)	–

p values reflect comparisons between non-pancreatic periampullary adenocarcinomas and PDAs

CT computed tomography

AAs ($p=0.814$), and 30 % of DAs ($p=0.331$). Gallbladder distension was observed in 25 (16 %) PDAs, and a comparable proportion of patients with non-pancreatic periampullary adenocarcinomas (15 %, $p=1.000$).

Lymphadenopathy

Enlarged lymph nodes were reported in 66 (35.3 %) patients with periampullary adenocarcinomas. Out of these cases, they were described as peripancreatic ($n=36$, 54.5 %), periportal ($n=33$, 50.0 %), portocaval ($n=26$, 39.4 %), periceliac ($n=12$, 18.2 %), gastrohepatic ($n=10$, 15.2 %), and aortocaval ($n=3$, 4.5 %). Radiographic lymphadenopathy was not associated with the presence of true lymph node metastases for either PDA or non-pancreatic periampullary adenocarcinoma groups (Table 4). Regional lymph node metastases were observed on final pathology in 69.6 % of patients in the PDA group with radiographic lymphadenopathy, and 74.4 % of patients without lymphadenopathy ($p=0.527$). Similarly, 50.0 % of patients with non-pancreatic periampullary adenocarcinoma with radiographic lymphadenopathy had regional lymph node metastases, as compared to 61.3 % of patients without lymphadenopathy on imaging ($p=0.529$). The median number of lymph nodes harvested in the resection specimen in the study cohort was 15±7.1. Statistical measures of performance for a finding of lymphadenopathy, with regard to true lymph node metastases, are as follows: sensitivity of 36.8 %, specificity of 57.5 %, positive predictive value of 69.6 %, and negative predictive value of 25.5 % in the PDA group. These findings were similar in the non-pancreatic periampullary adenocarcinoma group. In both groups, radiographic lymph node size had no correlation with true lymph node metastases (0.8 cm radiographically in patients with true lymph node involvement, vs 0.9 cm in patients without, $p=0.939$). Unlike regional lymph node metastases, endoscopic placement of a biliary stent, which was performed in 50 % of patients with a periampullary adenocarcinoma, was associated with lymphadenopathy on CT (63 vs 37 %, $p=0.013$). In a covariate analysis adjusting for a stent placement, CT lymphadenopathy and radiographic lymph node size continued to be poor predictors of true lymph node metastases ($p=0.279$ and $p=0.766$, respectively).

Major Visceral Vessel Involvement

Since visceral vascular involvement limiting margin negative resection (portal vein, superior mesenteric artery, and superior mesenteric vein) is most common with PDAs, the present analysis was restricted to this periampullary adenocarcinoma subtype ($n=117$). Of this cohort, only eight (6 %) patients underwent neoadjuvant therapy prior to resection. CT detected major visceral vessel involvement in 33 (28 %) patients. However, the rate of vessel resection was low ($n=3$), regardless of whether involvement was suggested by CT (3 %) or not (2 %, $p=0.842$). The percentage of PDAs with microscopic disease at the uncinate resection margin was similar between patients with and without vascular involvement suggested on CT: 24 % of patients with radiographic vascular involvement had a positive uncinate margin as compared to 20 % without radiographic vascular involvement having a positive uncinate margin ($p=0.634$). The results are summarized in Table 5, and Fig. 1 provides representative images where the radiograph interpretation and intraoperative findings were discrepant.

Table 2 Under- and overestimations of periampullary cancer sizes by CT, $n=73$

	Underestimations by CT				Overestimations by CT			
	Total (>1 cm)	1–2 cm, *n* (%)	2–3 cm, *n* (%)	>3 cm, *n* (%)	Total (>1 cm)	1–2 cm, *n* (%)	2–3 cm, *n* (%)	>3 cm, *n* (%)
PDA, $n=60$	44	32 (73)	8 (18)	4 (9)	16	9 (56)	6 (38)	1 (6)
NP-PA, $n=13$	11	8 (73)	1 (9)	2 (18)	2	2 (100)	0 (0)	0 (0)

PDA pancreatic ductal adenocarcinoma, *NP-PA* non-pancreatic periampullary adenocarcinoma

Table 3 Incidence of PD dilatation and BD dilatation in periampullary cancers detected by CT, n=202

	PD dilatation, n (%)	p value[a]	BD dilatation, n (%)	p value
PDA	102 (65.8)	–	67 (66.3)	–
AA	12 (57.1)	0.470	18 (90.0)	>0.001*
Distal BDA	3 (25.0)	0.001[b]	8 (66.7)	0.588
DA	5 (45.5)	0.201	5 (50.0)	1.000

p values reflect comparisons between non-pancreatic PAs and PDAs

PDA pancreatic ductal adenocarcinoma, *AA* ampullary adenocarcinoma, *BDA* bile duct adenocarcinoma, *DA* duodenal adenocarcinoma, *PD* pancreatic duct, *BD* bile duct

p>0.001, statistical significance

Discussion

Modern-day, high-resolution, CT imaging using a pancreas-specific protocol provides unprecedented detail of pancreatic and periampullary structures and pathology, and has become a routine test used by pancreatic surgeons in the preoperative setting.[7,8,12] The test is particularly informative in the assessment of surgical candidates in three particular areas: (1) cancer staging (i.e., evidence of distant spread), (2) extent of local progression (i.e., resectability), and (3) anatomic variation (i.e., typically in aberrant arterial anatomy). Oral water and intravenous contrast administration with multi-phase acquisition and other technical advancements have greatly improved CT's capabilities towards these ends. Arterial structures are best imaged in the arterial phase, delineating the relationship between arterial branches and the tumor with exquisite detail; in addition, major anatomic vascular variations are readily apparent.[14] Such CT "arteriography" now obviates conventional invasive arteriography, which was commonly performed preoperatively for periampullary adenocarcinomas just two decades ago.[29] For periampullary tumors, the primary tumor mass and their relationship to portal and superior mesenteric veins are best visualized in the late arterial or portal venous phase.[15] Oral water is ingested pre-scan to distend the bowel (not oral contrast) and minimize contrast artifact around the vessels. Scans can also be reconstructed in sagittal and coronal plains, and the vascular anatomy reconstructed in three dimensions as surface renderings.[1] Multiple studies have shown that dedicated pancreas protocol scans are superior to routine abdominal CT scans,[18,30] and often impact patient management.[8,31] As the quality of imaging continues to improve, we expect pancreas protocol CT studies to provide even greater amounts of information. In light of these advantages, we set out to analyze a wide breadth of routinely reported findings with modern-day CT imaging at our institution, all performed using a pancreas-specific protocol, to assess the significance of reported findings with respect to underlying cancer biology and clinically relevant outcomes.

Table 4 Correlation of CT detection of lymphadenopathy and true lymph node metastatic disease in the pancreatic ductal adenocarcinoma and non-pancreatic periampullary adenocarcinoma groups, n=187

	Lymphadenopathy by CT, n (%)	No lymphadenopathy by CT, n (%)	p value
Pancreatic Ductal Adenocarcinoma group			
True LN metastases	39 (69.6)	67 (74.4 %)	0.527
No LN metastases	17 (30.4)	23 (25.5 %)	
Non-pancreatic Periampullary Adenocarcinoma group			
True LN metastases	5 (50.0 %)	19 (61.3 %)	0.529
No LN metastases	5 (50.0 %)	12 (38.7 %)	

LN lymph node

Table 5 Correlation of vessel involvement reported by CT versus the need for vessel resection and uncinate margin status in PDAs, n=121

	Vessel involvement by CT, n=25 n (%)	No vessel involvement by CT, n=96 n (%)	p value
Vessel resection performed	1 (3.0)	2 (2.0)	0.842
Positive uncinate margin	8 (24.2)	17 (20.2)	0.634

PDA pancreatic adenocarcinoma

CT failed to depict a mass in roughly 10 % of periampullary adenocarcinomas in our population of resected patients. The inability to appreciate a mass on CT was not related to the size of the tumor, but rather was associated with the primary tumor's site of origin. PDAs were only occasionally inconspicuous on CT (6 %), while BDAs were not appreciated in 47 % of cases. Lack of visualization may have been related to technical aspects of the scan (i.e., suboptimal acquisition timing), CT reader variability, or perhaps an undefined physical property of the tumor. Regardless of the reason, this observation highlights one limitation for present-day CT as an early detection strategy for periampullary adenocarcinomas. For instance, a 94 % sensitivity for 3-cm PDAs in this study underscores the challenge at detecting smaller lesions, when the cancer may still be curable. Mass size was frequently underestimated by CT as well, providing additional evidence that high-quality imaging often underappreciates the extent of the primary tumor. It is possible that MRI might have fared better for detecting some of the tumors, but generally provides less detail regarding major visceral vessels with thicker cross-sectional cuts and therefore is not routinely obtained as part of surgical planning for pancreatic resection at our institution.

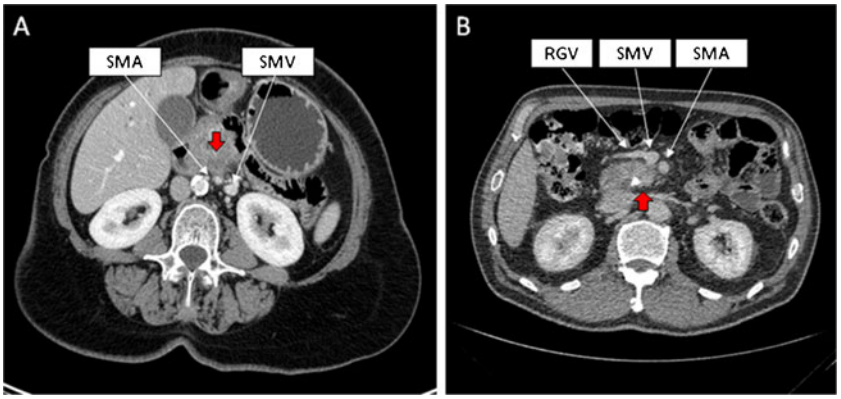

Fig. 1 Examples of pancreatic ductal adenocarcinomas where the radiology report and intraoperative findings were discrepant, with regard to vessel involvement. **a** The CT scan suggests the presence of cancer around the SMA and would technically be a "borderline" PDA.[23] The report described a "pancreatic mass medially encasing the SMA by 150° with fatty infiltration." The tumor was resected with negative margins. **b** No involvement was noted on CT, but clear invasion was encountered intraoperatively requiring vascular resection. The report described an "ill-defined hypovascular pancreatic head mass, abutting the posterior aspect of the SMV without evidence of direct invasion and a patent SMA." *CT* computed tomography, *PDA* pancreatic adenocarcinoma, *SMA* superior mesenteric artery, *SMV* superior mesenteric vein, *RGV* right gastroepiploic vein; *Red arrow* indicates the PDA in each case

While pancreas protocol CT underappreciates the primary mass in many instances, we found that standard CT criteria overestimated the extent of disease with regard to lymph node and vascular involvement. The results from the present study validate previous studies which failed to observe an association between radiographic lymph node size and true lymph node involvement with metastatic tumor.[19,32–37] Lymphatic metastases are common within normal sized nodes, and enlarged lymph nodes are often inflammatory in nature, related to a preoperatively placed stent.[19,21] These and previous results suggest that enlarged lymph nodes on CT are not a contraindication for exploration for a presumed periampullary cancer. It should be noted that this study or previous ones have not anatomically correlated abnormal lymph nodes on CT with corresponding lymph nodes in a pathology specimen.

With regard to assessing vascular involvement, previous studies report conflicting results.[38,39] One recent meta-analysis reported the sensitivity and specificity of CT as a measure of vascular invasion at 85 and 82 %, respectively.[13] Our data are not directly comparable since all of the patients in the present study were determined to have potentially resectable disease by a pancreatic surgeon and explored with intent to cure. Patients determined to have locally advanced disease were excluded from the study cohort. These data should therefore be interpreted in this context. As other studies have suggested, in the majority of instances, modern imaging is highly accurate at identifying many patients with locally advanced and unresectable disease who should not be explored.

Nevertheless, in the present cohort of resected patients, vascular involvement was reported in almost 30 % of the scans, yet only 5 % of PDAs (and 1 % of non-pancreatic periampullary adenocarcinomas) required a vascular resection. It should be noted that the need for vascular resection varies among pancreatic surgeons and across institutions. The differences may be a function of surgeon philosophy, comfort with the technique, and radiographic interpretation.

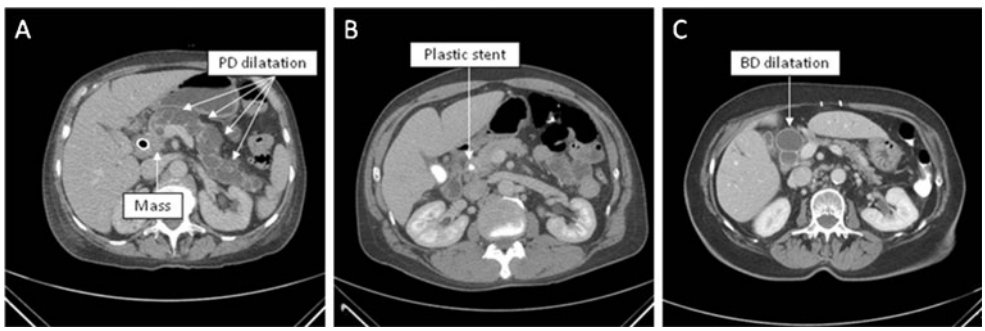

Fig. 2 Typical presentations of periampullary adenocarcinoma subtypes on CT based on radiographic features of the mass and associated ducts. **a** A PDA presents as a heterogenous pancreatic head mass with diffuse PD dilatation and pancreatic tail atrophy. **b** A BDA is not easily visualized. A biliary stent is present, without any associated PD or BD dilatation. **c** An AA is associated with massive BD dilatation that tapers at the distal CBD without associated PD dilatation. There is circumferential soft tissue thickening suspicious for a mass at the ampulla (not shown here). *CT* computed tomography, *PDA* pancreatic adenocarcinoma, *PD* pancreatic duct, *BD* bile duct, *CBD* common bile duct

The surgeons at our institution routinely skeletonize the SMV and SMA for periampullary cancers and resect the SMV or PV when there appears to be gross invasion and reconstruction is feasible. Surgeons with a lower threshold for vascular resection might very well have performed a greater number of vascular resection on a similar patient cohort. Of note, the ~20 % positive uncinate margin rate observed in this study is similar to other reports.[40]

This discrepancy between the radiographic interpretation and operative findings in the present study may be related to several factors. First, it is difficult in many instances to determine whether or not abnormal findings around the visceral vessels represent true vascular invasion by invasive cancer or peri-tumoral inflammation (i.e., pancreatitis or desmoplasia). Second, there is inconsistency with how radiologists routinely convey information on radiographic reports. Terms such as abutment and encasement have been previously defined and strict definitions typically apply for clinical trials.[23] Standardized reporting of the relationship between tumors and visceral vessels however has not been widely adopted in routine diagnostic studies. The present study provides a rationale for standardized radiographic reporting of periampullary cancer, as has been previously proposed for pathologic assessment.[41] Third, assessment of resectability is not always straight forward. As a general guideline, we employ the Varadhachary CT staging system[23] in assessing resectability of periampullary cancers, and typically refer patients with borderline or locally advanced cancers for neoadjuvant treatment. However, other important factors may influence the decision of whether or not to explore a patient. It is difficult to retrospectively determine the specific considerations for each patient included in the present cohort. However, the surgeon must consider such factors as usage of neoadjuvant chemotherapy (e.g., a trial of neoadjuvant treatment may be warranted in certain instances; in addition, the viability of cancer cells around vessels is unknown in treated tumors), the degree of pancreatitis present, trends in serum tumor markers, evidence of extra-pancreatic disease, signs of mesenteric venous obstruction on imaging (e.g., venous collaterals or splenomegaly), and patient comorbidities.[42]

A recent population-based study from the National Cancer Database observed that less than 35 % of patients with apparent stage I pancreatic cancer undergo resection in the USA and that nearly 40 % of patients with localized pancreatic cancer are not offered surgery,[22,43] even in the absence of apparent contraindications. Based on the findings from the present study, it is possible that overinterpretation of certain radiographic findings (e.g., enlarge lymph nodes or vascular invasion) by radiologists, surgeons, internists, or other involved health care providers could contribute to this trend. This study suggests that certain routinely reported radiographic findings, such as lymphadenopathy and vascular involvement, do not necessarily preclude an attempt at resection. Radiographic findings should be interpreted in the context of other radiographic and clinical data on a case-by-case basis. Patients may benefit from referral to a high-volume center or case discussion in a multidisciplinary setting to determine if resection is indicated.

An interesting by-product of the analysis was that certain radiographic features or patterns (e.g., absence of a mass on imaging, pancreatic duct size, and bile duct size) can provide clues preoperatively as to the periampullary adenocarcinoma subtype (Fig. 2). For instance, we noted that PDA frequently was associated with a dilated PD, in contrast to BDAs. A dilated BD was observed in a large majority of AAs, and the classic "double duct" sign was most common in PDAs and AAs.

This analysis represents an exploratory retrospective study that correlates routinely reported radiographic findings with clinicopathologic data in resected periampullary cancers. As stated, comparable data for patients determined to have unresectable disease were not readily available, and therefore, the study findings should not be generalized to these patients. Importantly, CT scans were originally reviewed and interpreted for clinical purposes, and not specifically to answer the subtle and nuanced research questions posed in the present study. Thus, the present study is not a critique on the quality of radiographic reporting, but rather an analysis of the clinical significance of routine radiographic observations. These preliminary data support the need for template radiologic reporting of objective findings, and multidisciplinary review by surgeons, radiologists, and oncologists to assess resectability and need for neoadjuvant therapy in patients with periampullary cancers.

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