DOI:10.1111/j.1477-2574.2009.00145.x

HPB

ORIGINAL ARTICLE

Escalating computed tomography angiogram (CTA) grade predicts unresectability and margin status for pancreaticobiliary neoplasms

Tara S. Kent[1], Vassilios Raptopoulos[2], Mark P. Callery[1], Shiva Gautam[3] & Charles M. Vollmer Jr[1]

Departments of [1]Surgery, [2]Radiology, and [3]Medicine Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, MA, USA

Abstract

Background and aims: The Raptopoulos computed tomography (CT) grading system of pancreaticobiliary cancers was conceived to predict resectability based on tumour involvement of critical vasculature. The aim of the present study was to investigate the relationship between CT grade, resectability, margin status and survival after pancreatic resection.

Methods: Patients with presumed pancreaticobiliary malignancy and a pancreas protocol computed tomography angiogram (CTA) who underwent attempted curative resection from October 2001 and August 2008 were identified. The relationship between radiographical involvement of critical vasculature, according to a five-point scale, and ultimate resectability, margin status and survival was assessed.

Results: Overall, 276 (70.2%) out of 393 patients were resectable. The proportion of patients who were unresectable at laparotomy increased as CT grade escalated; 41/250 (16.4%) CT Grade 0, 16/55 (29.1%) CT Grade 1, 33/55 (60%) CT Grade 2, 27/33 CT Grade 3, $P < 0.001$. Local invasion or vascular involvement was the reason for unresectability in 14/41, 12/16, 23/33, 16/27 patients with CT Grade 0–3, respectively. A R0 resection was achieved in 84/131 patients with pancreatic adenocarcinoma and varied significantly by CT grade, $P = 0.021$. Significant predictors of survival were age ($P < 0.0001$), resectability ($P < 0.0001$) and diagnosis ($P < 0.009$).

Conclusions: Escalating Raptopoulos CT grade is correlated with increasing probability of unresectability and R1 resection.

Keywords

pancreaticobiliary neoplasms, unresectability, CT grade

Received 24 March 2009; accepted 29 October 2009

Correspondence

Tara S. Kent, Beth Israel Deaconess Medical Center Department of Surgery, 330 Brookline Avenue, Stoneman 9th floor, Boston, MA 02215, USA. Tel: 781 453 3650; Fax: 617 667 7756; E-mail: tkent@bidmc.harvard.edu

Introduction

Multiphase computed tomography angiography (CTA) is the mainstay of pre-operative planning for patients with presumptive pancreaticobiliary neoplasms. It predicts *un*resectability quite well,[1] allowing such patients to avoid an unnecessary laparotomy. However, CTA has not been as successful in predicting actual resectability, with reported predictive values of 45–79%.[2–4] The Raptopoulos CT grading system was developed to help predict pre-operatively which of these tumours might be resectable. Understanding that pancreaticobiliary tumours are often unresectable by virtue of intimate involvement with critical vasculature, this five-point scale (Fig. 1) describes the radiographical relationship of the mass to adjacent vessels (portal vein, superior mesenteric vein, superior mesenteric artery and celiac trunk).[4] On radiographical grounds, Grades 0 and 1 lesions are typically considered resectable, Grades 2 and 3 potentially resectable and Grade 4 unresectable.[1,4] However, clinical experience has shown the correlation between radiographical findings and intra-operative findings/resectability to be imperfect.[2–4]

The terms 'borderline resectable' or 'marginally resectable' for pancreaticobiliary malignancies have crept into the vernacular, yet, as discussed during the 2008 AHPBA sponsored Consensus Conference on Resectable and Borderline Resectable Pancreatic

Presented at the 9th Annual Meeting of the American Hepato-Pancreato-Biliary Association, 12–15 March 2009, Miami, FL, USA.

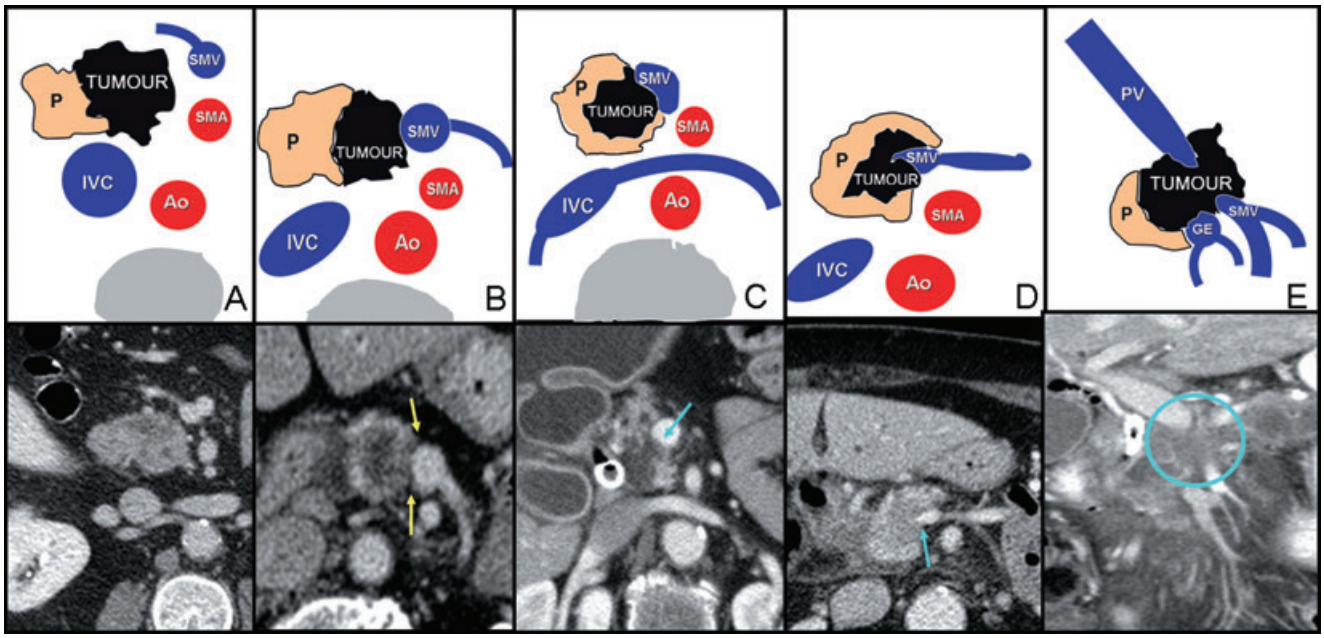

Figure 1 Raptopoulos computed tomography (CT) grading system for Pancreaticobiliary Neoplasms. (A) Grade 0: no vascular involvement with interposition of either pancreatic parenchyma or fat between the vessel and the tumour. (B) Grade 1: loss of the fat plane between the tumour and vessel *without* vessel distortion. (C) Grade 2: slight flattening or indentation of vessel, or surrounding up to 2/3 the vessel perimeter. (D) Grade 3: tumour extends around at least 2/3 of the vessel perimeter, changing its contour and narrowing the lumen; sometimes referred to as the 'teardrop sign'. (E) Grade 4: occlusion or obliteration of vessel without option for reconstruction

Cancer, a standardized definition does not exist.[5] Terminology of vascular involvement of these lesions is inconsistent and various groups have put forth alternative definitions.[3,5,6] The National Comprehensive Cancer Network (NCCN) guidelines use anatomic criteria to define anticipated resectability with particular emphasis on vascular considerations.[6] Although anatomic criteria for resection have been fairly consistent in terms of delineating such vascular involvement, the *degree* and *severity* of involvement have varied in the literature. To further confuse the issue, the term 'borderline resectable' has also been applied to scenarios beyond vascular relationships with the tumour, such as possible distant disease identified by imaging and/or marginal medical status of the patient.[7,8] As a result, clinical experiences with this problem are difficult to compare.

The importance of radiographical tumour characterization as it affects operative inclusion or exclusion has not been well studied. While resectability[2–4] and margin status[3,7,9] have been assessed with respect to CT findings, other clinical outcomes including survival have yet to be evaluated. In fact, the aforementioned AHPBA Consensus Conference emphasized the need to study these important clinical outcomes as they relate to pre-operative radiographical criteria.[5] An understanding of these relationships would be valuable in defining which tumours deserve an attempt at resection. The present study investigates the association between radiographical tumour involvement with local vascular structures and these important outcomes using an established and objective CT grading scale. Through this analysis, outcomes and indications for resection based on pre-operative imaging criteria might be better refined.

Methods

Under the approval of an institutional Institutional Review Board, a prospectively maintained pancreatic surgical database of presumptive pancreaticobiliary malignancy cases that were ultimately operated upon between October 2001 and August 2008 was reviewed. Patients were only included if their pre-operative CTA had been performed locally and if curative resection was attempted. All lesions that had a pre-operative working diagnosis of presumed malignant potential irrespective of site were included.

Patients were excluded if they had pre-operative diagnoses of high- or mid-duct cholangiocarcinoma, or small, radiographically obvious neuroendocrine tumours where vascular invasion was unlikely. Patients with cystic lesions were excluded with the exception of those with concerns for malignancy based on clinical presentation (jaundice and weight loss), presence of solid components on imaging, elevated serum tumour markers, or a suspicious aspirate. Using CTA imaging, patients with obvious regional or distant metastatic disease were also excluded.

Helical CTA was performed in each patient, using a multidetector (4–64 row) CT employing a bolus tracking technique as previously described.[4] Biphasic (arterial and portal venous) phase

high resolution scans were done using 0.5–1 mm collimation followed by multiplanar reconstructions and expert 3-D imaging at the imaging lab. These studies were interpreted by dedicated pancreatic radiologists for clinical care, and the CT grades were then tabulated for the purpose of this study. The Raptopoulos grading system is illustrated in Fig. 1 and details of each individual grade are explained in the legend. This was originally devised for tumours in the head of the pancreas, looking at vascular involvement of the portal and superior mesenteric veins (SMV), and the superior mesenteric artery (SMA). Its use has since been extended and applied to the celiac axis, and to body/left-sided tumours in proximity to the confluence and/or the celiac axis or SMA. For the purpose of this study, venous involvement pertains to the SMV and portal vein. Arterial involvement refers to the SMA, hepatic artery or celiac trunk.

Further evaluation with staging laparoscopy +/– intra-operative ultrasound was selectively applied for solid pancreatic and biliary malignancies as previously described,[10] with the exception of ampullary or duodenal lesions and in those patients in which laparotomy would be required for palliation in the event that resection was not possible. Pre-operative biopsy confirmation of malignancy was not routinely obtained and neoadjuvant chemoradiation therapy was never employed.

A standard pylorus-preserving pancreaticoduodenectomy was performed as previously described, including skeletonization of the SMA[11]. Vascular resection/reconstruction was performed during trial dissection when tumour involvement of the vasculature precluded safe and complete dissection of the portal-SMV confluence or for limited segmental hepatic artery involvement. Vascular resection was not technically feasible in the following scenarios: an inability to obtain both proximal and distal control, greater than short segment vascular encasement, peritumoral fibrosis precluding appropriate identification/negotiation of the portal canal, or the presence of extensive lymphatic involvement. For left-sided tumours, local resection was performed as indicated. For those patients who were deemed unresectable at laparotomy a selective approach to palliative procedures as necessary was applied.

Intra-operative frozen section analysis of the bile duct or pancreatic neck transection margin was employed selectively. Peri-operative variables assessed included estimated blood loss, intra-operative transfusion, operative time and whether or not portal-superior mesenteric vein resection was performed. Extreme blood loss was defined a priori as those patients whose estimated blood loss was greater than one standard deviation above the mean. Once resected, the specimen was marked intra-operatively identifying the following margins: bile duct, pancreatic transection margin and SMA. A standardized pathological assessment was performed by dedicated pancreatic pathologists. Margin status was ascribed as follows: all margins devoid of tumour (R0), microscopic tumour present at the margin(s) (R1) and gross residual tumour as determined by the surgeon at the time of surgery (R2).

A reproducible post-operative Carepath for Pancreatic Resection was followed.[12] Post-operative data recorded included major complications (as defined by the Clavien scale[13]) and hospital stay. Peri-operative death was defined as death within 30 days of the operation *or* at any point during the index hospitalization. Survival information was obtained from our institutional cancer registry and confirmed by the Social Security Death Index 6 months after accrual of the final patient.[14]

Table 1 Univariate analysis of pre-operative factors predicting resection

	Resected (276)	Unresected (117)	*P*-value
CT Grade			<0.0001
0	209 (75.7)	41 (35.0)	
1	39 (14.1)	16 (13.7)	
2	22 (8.0)	33 (28.2)	
3	6 (2.2)	27 (23.1)	
Age	65 (27–85)	66 (33–84)	0.246
Sex	124M/152F	56M/ 61F	0.593
Presence of symptoms	234 (84.8)	110 (94.1)	0.011
Pre-operative diagnosis			<0.0001
Pancreatic mass	192 (69.6)	106 (90.6)	
Concerning cystic lesion	75 (27.2)	8 (6.8)	
Other	9 (3.2)	3 (2.6)	
Staging laparoscopy alone	61 (22.1)	65(55.6)	<0.0001
Staging laparoscopy with IOUS	25 (9.1)	32 (27.4)	<0.0001

Table 2 Number of patients who were deemed unresectable (with reason) at laparotomy by CT grade

CT grade	Total	0	1	2	3	*P*-value
n (%)	(*n* = 393)	(*n* = 250)	(*n* = 55)	(*n* = 55)	(*n* = 33)	
Unresectable	117 (29.8)	41 (16.4)	16 (29.1)	33 (60.0)	27	
0.003						
Metastatic disease	49 (12.5)	26 (10.4)	4 (7.3)	10 (18.2)	9	
Vascular involvement	45 (11.5)	14 (5.6)	12 (21.8)	23 (41.8)	16	
Other[a]	3 (0.8)	1 (0.4%)	0	0	2	

[a]Physiological instability, severe pancreatitis, hostile abdomen.

Table 3 Univariate analysis of peri-operative variables by CT grade for those patients who underwent resection

Peri-operative variable	Total	Grade 0	Grade 1	Grade 2	Grade 3	*P*-value
n (%), median (range)	(*n* = 276)	(209)	(39)	(22)	(6)	
Operation						0.078
Pancreaticoduodenectomy	196 (71)	139 (66.5)	32	19	6	
Left-sided pancreatectomy	61 (22.1)	55 (26.3))	5	1	0	
Other[a]	19 (6.9)	15 (7.2)	2	2	0	
Operative time (min)	383 43–681	368 133–681	422 43–635	383 243–662	453 363–669	0.006
Vascular resection/reconstruction	8 (2.9)	3 (1.4)	1	3	1	
Blood loss (ml)	350 25–2500	325 25–2500	350 25–1000	400 150–1800	350 200–1900	0.669
Number of patients with extreme blood loss	32 (11.6)	21 (10.0)	5	5	1	0.604
Number of patients transfused	37 (13.4)	29 (13.9)	3	4	1	0.563
Number of patients with major complications	125 (45.2)	94 (45.0)	19	10	2	0.910
Length of stay (days)	8 (1–67)	8 (1–67)	8 (5–28)	8 (6–25)	8 (7–9)	1.000
Peri-operative mortality	4	3	1	0	0	
Histology						0.006
Pancreatic ductal adenocarcinoma	131 (47.5)	86 (41.1)	27	12	6	
Other malignancy[b]	53 (19.2)	6 (2.9)	4	3	0	
Benign neoplastic	60 (21.7)	50 (23.9)	3	7	0	
Benign non-neoplastic	32 (11.6)	27 (12.9)	5	0	0	

[a]7central pancreatectomy, 8 total pancreatectomy, 4 enucleations.
[b]24 ampullary, 11 endocrine, 7 cholangiocarcinoma, 3 duodenal, 2 solid pseudopapillary, 1 each of neuroendocrine, clear cell, GIST, mixed ductal/endocrine, poorly differentiated unclear origin, IOPN.

Statistical analysis was performed using SAS version 9.1 to obtain Kaplan–Meier survival curves. Fisher's exact test, Kruskal–Wallis, the log-rank test and Mann–Whitney *U* or Student's *t*-test were also used when appropriate. Data were checked for normality, and parametric or non-parametric tests were used as required. Results with a *P*-value of 0.05 or less were considered significant.

Results

During the 7-year time period, 393 patients met inclusion criteria. Of these, 250 (63.6%), 55 (14.0%), 55 (14.0%), 33 (8.4%) were categorized as CT grade 0–3, respectively. In 143 (36.4%) patients, the CT showed evidence of vascular involvement by the tumour. In 97 (67.8%), 34 (23.8%), 12 (8.4%) patients this was venous alone, venous and arterial or arterial alone, respectively.

Out of 126 patients undergoing staging laparoscopy, 32 (25.3%) avoided further intervention, 15 (11.9%) required open staging and/or biopsy (classified as non-therapeutic laparotomy) and 18 (14.3%) underwent palliative bypass. With respect to laparoscopic intra-operative ultrasound ($n = 57$), 15 (26.3%) patients avoided laparotomy, 7 (12.3%) had non-therapeutic laparotomy and 10 (17.5%) underwent palliative bypass. Therefore, staging laparoscopy and intra-operative ultrasound allowed 47 (37.3%) patients to avoid a non-therapeutic laparotomy.

During surgery, 276 (70.2%) patients underwent resection, 71 (18.1%) laparotomy only and 46 (11.7%) a palliative bypass. Univariate analysis of factors predicting resection is shown in Table 1. In multivariate regression analysis, higher CT grade ($P < 0.001$) and staging laparoscopy ($P = 0.004$) remained as independent predictors of unresectablity. Vascular involvement as the reason for unresectability was correlated with increasing CT grade as shown in Table 2.

Peri-operative variables by CT grade for those patients who underwent resection are shown in Table 3. Out of the eight

Table 4 Univariate comparison of margin negative vs. margin positive patients

	Margins negative (125)	Margins positive (58)	*P*-value
CT Grade			0.020
0	96 (76.8)	35 (60.3)	
1	17 (13.6)	14 (24.1)	
2	11 (8.8)	4 (6.9)	
3	1 (0.8)	5 (8.7)	
Age	67.5	67	0.651
	39–85	39–83	
Gender	55 (44.0)	24 (41.4)	0.739
Presence of symptoms	120 (96.0)	57 (98.3)	0.421
Pre-operative diagnosis			0.866
Pancreatic mass	111 (88.8)	50 (86.2)	
Concerning cystic lesion	10 (8.0)	6 (10.3)	
Other	4 (3.2)	2 (3.5)	
Estimated blood loss (ml):	350 (100–2000)	350 (25–1900)	0.176
Operative time (min)	397 (43–520)	401 (152–722)	0.656
Staging laparoscopy alone	24 (19.2)	11(19.0)	0.970
Staging laparoscopy with IOUS	11 (8.8)	8 (13.8)	0.303
Type of operation			0.291
Pancreaticoduodenectomy	100 (80.0)	47 (81.0)	
Left pancreatectomy	17 (13.6)	10 (17.2)	
Other	8 (6.4)	1 (1.7)	
Vascular resection/reconstruction	4 (3.2)	4 (6.7)	0.255
Pathology			0.014
PDAC	82 (65.6)	48 (82.8)	
Other malignancy	43[a]	10[b]	
Number of patients with major complications	59 (47.2)	32 (55.2)	0.316
Perioperative mortality	2 (1.6)	1 (1.7)	0.951

[a]Ampullary (22), cholangio (4), other (16).
[b]Ampullary (1), cholangio (3), other (6).

patients who underwent vascular reconstruction, four involved the SMV, three the portal vein and one the hepatic artery. Univariate analysis of factors predicting margin status is shown in Table 4. Multivariate regression analysis identified only higher CT grade to be a predictor of positive margins ($P = 0.044$). For those patients with pancreatic ductal adenocarcinoma (Table 5), univariate analysis confirmed increasing CT grade was significantly related to resection margin status but not T or *n* stage. Locations of positive margins are shown in Table 5.

Data regarding the use of adjuvant therapy were available for 233 out of 301 patients with malignant diagnoses (by intra-operative or other pathologic specimen). In those who underwent resection, adjuvant therapy was administered to 80/99 (80.8%), 24/27, 10/13 and 5/5 patients with CT grade 0–3, respectively, $P = 0.593$. Similarly for those who did not undergo resection the corresponding figures for CT grade 0–3 were 22/25, 13/13, 25/25 and 15/18, respectively ($P = 0.087$).

The median follow-up was 11 months (0–85), and 168 (42.7%) patients had died at the completion of the study. Kaplan–Meier survival analyses was performed for patients with pancreatic adenocarcinoma, demonstrating that there was no significant difference in survival as CT grade increased ($P = 0.232$). Using univariate analysis, age ($P < 0.0001$) and pathology ($P < 0.009$) were significant variables. In multivariate regression analysis considering all resected patients with pancreas cancer, significant variables that remained were age ($P = 0.003$) and pathological diagnosis ($P < 0.0001$).

Discussion

In the current era of high-quality imaging and safer post-operative outcomes, resectability is better predicted than in the past, but approximately a quarter of patients deemed eligible for resection are still found to be unresectable at the time of surgery.[1]

Table 5 Analysis of pathological variables by CT grade for patients with pancreatic adenocarcinoma

	Total	Grade 0	Grade 1	Grade 2	Grade 3	*P*
	131	86	27	12	6	
T						0.863
1	11 (8.4)	10 (11.6)	1	0	0	
2	27 (20.6)	16 (18.6)	6	3	2	
3	85 (64.9)	54 (62.8)	18	9	4	
4	1 (0.7)	1 (1.2)	0	0	0	
n						0.878
0	44 (33.6)	31 (36.0)	8	4	1	
1a	33 (25.2)	21 (24.4)	7	4	1	
1b	47 (35.9)	29 (33.7)	10	4	4	
R0	84 (64.1)	58 (67.4)	13	9	1	0.021
Margins positive	47	27	14	3	5	
Locations of positive margins[a]						
SMA	23	11	7	3	2	
Pancreatic neck	17	6	6	1	4	
Radial	15	10	4	0	1	
CBD/duodenum	6	4	1	1	0	

[a]Includes multiple positive margins where applicable.

Previous work by Raptopoulos and others[1,4,15] has demonstrated the important role of high-quality CTA imaging in guiding operative decision-making for pancreatic resection. In the five-point Raptopoulos scale, Grades 0 and 1, denoting no vascular involvement and tumour/vessel abutment, respectively, have previously been considered resectable on radiographical grounds. Grades 2 and 3 are determined to be potentially resectable. Finally, Grade 4 lesions are deemed unresectable.[1] The current study has confirmed these findings, showing that an increasing CT grade is associated with increasing probability of unresectability irrespective of underlying pathology. In addition, patients with a higher CT grading are more likely to be unresectable as a result of vascular invasion (Table 2). The fact that 10.4% of patients with CT grade 0 had unresectable disease owing to low volume metastases, while a further 5.6% were unresectable because of locally advanced disease indicates the limitations of current cross-sectional imaging and raises the issue of the role of laparoscopic staging in such patients.

Several groups have advocated for the sole use of CT to guide operative decision-making, stating that additional imaging modalities and laparoscopy are superfluous in patients without CT evidence of local vascular encroachment.[2] Details of technical factors and image post-processing that create such quality CT imaging as were used for this study and at other high-volume pancreas centres have been previously established.[16] Additionally, House *et al.*[3] report that pre-operative 3D-CT accurately predicted resectability for periampullary cancers in 98% of patients, and for pancreatic cancer in 79% of patients. The margin-negative resection rate was reported to be 86% and 73%, respectively. Other groups have investigated the accuracy of PET and PET/CT at predicting resectability (70 and 82%, respectively),[17] utility of EUS[9], or the additive value of CA19-9 to laparoscopy[18] and intra-operative ultrasound.[19] White *et al.* recently reported that laparoscopy alone was useful, particularly when pre-operative imaging was obtained outside of their institution.[20] The present study has demonstrated that a higher percentage of unresectable patients underwent both laparoscopy (55.6%) and intra-operative ultrasound (37.2%), compared with its usage in resectable patients. For both, the difference was statistically significant in univariate analysis but only laparoscopy proved to be a significant contributor in multivariate analysis. This likely reflects some degree of bias resulting from a selective use of these modalities, but also emphasizes those scenarios in which staging with laparoscopy and/or ultrasound demonstrated metastatic disease or confirmed vascular involvement that prevented a laparotomy. As described above, a non-therapeutic laparotomy was avoided in 32 (25.3%) patients with staging laparoscopy and in 15 (11.9%) patients with ultrasound (although it was used less frequently than laparoscopy alone). Further study is required to better delineate the usage and the utility of ultrasound as a modality in this setting.

Several groups have also described the relationship between vascular involvement and positive margins.[3,7] This has been confirmed by the present study. The positive margin rate for those patients which were ultimately resected also increased as CT grade increased. Even CT Grade 0 tumours ultimately had positive margins 21% of the time. Previously, margin positivity has been considered a predictor of poor prognosis.[21–24] Yet, as discussed at

the AHPBA sponsored 2008 Consensus Conference on Resectable and Borderline Resectable Pancreatic Cancer, the actual relevance of margins in pancreatic surgery is nebulous.[25]

Survival specifically for pancreatic adenocarcinoma patients did not vary by CT grade but rather solely on age and pathology, in multivariate analysis. Although higher grade lesions were less likely to be resectable, when resection was accomplished, it was generally done safely. Operative time was significantly related to CT grade (longer in CT Grade 3), but there was no significant increase in estimated blood loss, extreme blood loss, transfusions, complications or death rates as grade increased (Table 3). Therefore, these advanced-appearing lesions should not be categorically excluded from an attempted resection although a higher incidence of a positive margin is likely.

Although CT quality was considered state-of-the-art throughout this contemporary series, advances in imaging certainly have occurred over this period, possibly influencing the ability to accurately grade tumours from the earlier portion of the study. In addition, there is a probable selection bias when it comes to advanced grade lesions (particularly CT Grade 3) which may be precluded from surgical referral based on the practitioner's interpretation of radiographic reports of dubious resectability. Furthermore, the authors have not commonly found the occasion for vein resection in our practice. Of the 393 patients considered for potential resection, in only eight was it deemed that vein resection/venorrhaphy was either indicated or technically achievable. In the authors' experience, a tumour can frequently be negotiated off the confluence more often than predicted, thus avoiding the need for vein resection. The overall 70% resectability rate is generally in line with other published data[26,27] and a published series of vein resections show actual tumour involvement of the vein in as few as 38% or as many as 78% of specimens.[28–32] Similarly, no patients who received neoadjuvant therapy were included in this series. Although others[7,8] have reported neoadjuvant therapy as routine in their management of these patients, there is not yet a good understanding of how to reassess such patients after their treatment in terms of downstaging, or how delaying the operation affects ultimate outcome. An interesting question to evaluate would be if such a 'downstaging' approach might regress tumours from higher to lower Raptopoulos CT Grades and therefore afford fewer positive margins, higher resectability rates and potentially better survival.

By using objective criteria, rather than ambiguous nomenclature (i.e. terms such as encroachment, encasement, infringement, abutment and invasion), CTA grading is useful in predicting tumour resectability of pancreaticobiliary neoplasms. With higher degrees of vascular involvement, margins are more likely to be positive and the resection is likely to take longer. Survival for pancreas cancer does not depend on CT grade.

Conflict of interest

None declared.

References

1. Raptopoulos V, Steer ML, Sheiman RG, Vrachliotis TG, Gougoutas CA, Movson JS. (1997) The use of helical CT and CT angiography to predict vascular involvement from pancreatic cancer: correlation with findings at surgery. *AJR Am J Roentgenol* 168:971–977.
2. Saldinger PF, Reilly M, Reynolds K, Raptopoulos V, Chuttani R, Steer ML *et al.* (2000) Is CT angiography sufficient for prediction of resectability of periampullary neoplasms? *J Gastrointest Surg* 4:233–237.
3. House MG, Yeo CJ, Cameron JL, Campbell KA, Schulick RD, Leach SD *et al.* (2004) Predicting resectability of periampullary cancer with three-dimensional computed tomography. *J Gastrointest Surg* 8:280–288.
4. Zamboni GA, Kruskal JB, Vollmer CM, Baptista J, Callery MP, Raptopoulos VD. (2007) Pancreatic adenocarcinoma: value of multidetector CT angiography in preoperative evaluation. *Radiology* 245:770–778.
5. Callery MP, Chang KJ, Fishman EK, Talamonti MS, Traverso LW, Linehan DC. (2009) Pretreatment assessment of resectable and borderline resectable pancreas cancer: expert consensus statement. *Ann Surg Oncol* 16:1727–1733.
6. National Comprehensive Cancer Network (NCCN) practice guidelines in oncology v.1.2008: pancreatic adenocarcinoma. Available at: http://www.nccn.org (accessed February 24, 2009).
7. Varadhachary GR, Tamm EP, Abbruzzese JL, Xiong HQ, Crane CH, Wang H *et al.* (2006) Borderline resectable pancreatic cancer: definitions, management, and role of preoperative therapy. *Ann Surg Oncol* 13:1035–1046.
8. Katz MHG, Pisters PWT, Evans DB, Sun CC, Lee JE, Fleming JB *et al.* (2008) Borderline resectable pancreatic cancer: the importance of this emerging stage of disease. *J Am Coll Surg* 206:833–848.
9. Bao PQ, Johnson JC, Lindsey EH, Schwartz DA, Arildsen RC, Grzeszczak E *et al.* (2008) Endoscopic ultrasound and computed tomography predictors of pancreatic cancer resectability. *J Gastrointest Surg* 12:10–16.
10. Vollmer CM Jr, Drebin JA, Middleton WD, Teefey SA, Linehan DC, Soper NJ *et al.* (2002) Utility of staging laparoscopy in subsets of peripancreatic and biliary malignancies. *Ann Surg* 235:1–7.
11. Vollmer CM Jr, Pratt W, Vanounou T, Maithel SK, Callery MP. (2007) Quality assessment in high-acuity surgery: volume and mortality are not enough. *Arch Surg* 142:371–380.
12. Vanounou T, Pratt W, Fischer JE, Vollmer CM Jr, Callery MP. (2007) Deviation-based cost modeling: a novel model to evaluate the clinical and economic impact of clinical pathways. *J Am Coll Surg* 204:570–579.
13. Dindo D, Demartines N, Clavien PA. (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 240:205–213.
14. Social Security Death Index. Available at: http://ssdi.rootsweb.ancestry.com (accessed February 24, 2009).
15. Bronstein YL, Loyer EM, Kaur H, Choi H, David C, DuBrow RA *et al.* (2004) Detection of small pancreatic tumors with multiphasic helical CT. *AJR Am J Roentgenol* 182:619–623.
16. Brennan DD, Zamboni GA, Raptopoulos VD, Kruskal JB. (2007) Comprehensive preoperative assessment of pancreatic adenocarcinoma with 64-section volumetric CT. *Radiographics* 27:1653–1666.
17. Strobel K, Heinrich S, Bhure U, Soyka J, Veit-Haibach P, Pestalozzi BC *et al.* (2008) Contrast-enhanced 18F-FDG PET/CT: 1-stop-shop imaging for assessing the resectability of pancreatic cancer. *J Nucl Med* 49:1408–1413.

18. Maithel SK, Maloney S, Winston C, Gönen M, D'Angelica MI, Dematteo RP *et al.* (2008) Preoperative CA 19-9 and the yield of staging laparoscopy in patients with radiographically resectable pancreatic adenocarcinoma. *Ann Surg Oncol* 15:3512–3520.

19. Halloran CM, Ghaneh P, Connor S, Neoptolemos JP, Raraty MGT. (2008) Carbohydrate antigen 19-9 accurately selects patients for laparoscopic assessment to determine resectability of pancreatic malignancy. *Br J Surg* 95:453–459.

20. White R, Winston C, Gonen M, D'Angelica M, Jarnagin W, Fong Y *et al.* (2008) Current utility of staging laparoscopy for pancreatic and peripancreatic neoplasms. *J Am Coll Surg* 206:445–450.

21. Van den Broeck A, Sergeant G, Ectors N, Van Steenbergen W, Aerts R, Topal B. (2009) Patterns of recurrence after curative resection of pancreatic ductal adenocarcinoma. *Eur J Surg Oncol* 35:600–604.

22. Bilimoria KY, Talamonti MS, Sener SF, Bilimoria MM, Stewart AK, Winchester DP *et al.* (2008) Effect of hospital volume on margin status after pancreaticoduodenectomy for cancer. *J Am Coll Surg* 207:510–519.

23. Winter JM, Cameron JL, Campbell KA, Arnold MA, Chang DC, Coleman J *et al.* (2006) 1423 Pancreaticoduodenectomies for cancer: a single-institution experience. *J Gastrointest Surg* 10:1199–1210.

24. Raut CP, Tseng JF, Sun CC, Wang H, Wolff RA, Crane CH *et al.* (2007) Impact of resection status on pattern of failure and survival after pancreaticoduodenectomy for pancreatic adenocarcinoma. *Ann Surg* 246:52–60.

25. Evans DB, Farnell MB, Lillemoe KD, Vollmer CM, Jr, Strasberg SM, Schulick RD. (2009) Surgical treatment of resectable and borderline resectable pancreas cancer: expert consensus statement. *Ann Surg Oncol* 16:1736–1744.

26. Barreiro CT, Lillemoe KD, Koniaris LG, Sohn TA, Yeo CJ, Coleman J *et al.* (2002) Diagnostic laparoscopy for periampullary and pancreatic cancer: what is the true benefit? *J Gastrointest Surg* 6:75–81.

27. Maire F, Sauvanet A, Trivin F, Hammel P, O'Toole D, Palazzo L *et al.* (2004) *Pancreatology* 4:436–440.

28. Yekebas EF, Bogoevski D, Cataldegirmen G, Kunze C, Marx A, Vashist YK *et al.* (2008) En bloc vascular resection for locally advanced pancreatic malignancies infiltrating major blood vessels: perioperative outcome and long-term survival in 136 patients. *Ann Surg* 247:300–309.

29. Carrère N, Sauvanet A, Goere D, Kianmanesh R, Vullierme MP, Couvelard A *et al.* (2006) Pancreaticoduodenectomy with mesentericoportal vein resection for adenocarcinoma of the pancreatic head. *World J Surg* 30:1526–1535.

30. Müller SA, Hartel M, Mehrabi A, Welsch T, Martin DJ, Hinz U *et al.* (2009) Vascular resection in pancreatic cancer surgery: survival determinants. *J Gastrointest Surg* 13:784–792.

31. Tseng JF, Raut CP, Lee JE, Pisters PW, Vauthey JN, Abdalla EK *et al.* (2004) *J Gastrointest Surg* 8:935–949.

32. Baulieux J, Adham M, Oussoultzoglou E, De la Roche E, Berthoux N, Bourdeix O *et al.* (1998) Is pancreatectomy with resection of the retropancreatic vessels for cancer justified? *Chirurgie* 123:438–444.