Criteria for Determining Malignancy in Pancreatic Intraductal Papillary Mucinous Neoplasm Based on Computed Tomography

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Key Words

Intraductal papillary mucinous neoplasm · Computed tomography · Sensitivity · Specificity · Malignancy

Abstract

Introduction: Determining the dignity of intraductal papillary mucinous neoplasms (IPMNs) by imaging procedures is challenging. Various CT-based criteria were evaluated. **Patients and Methods:** Preoperative CT scans from 47 patients with IPMN were analyzed. Predefined criteria of malignancy were compared between patients with benign (bIPMN; $n = 28$) and malignant (mIPMN; $n = 19$) tumors, and a summation score was determined. **Results:** Preoperative carbohydrate-antigen 19-9 levels were higher in patients with mIPMN ($p = 0.013$). The diameter of the main pancreatic duct was greater in patients with mIPMN ($p < 0.0001$). More patients with mIPMN showed bile duct obstruction ($p = 0.0076$), solid tumor components ($p = 0.0076$), contrast enhancement in cystic walls ($p = 0.0086$), peripancreatic lymph nodes ($p = 0.0076$), and abrupt diameter changes of the main pancreatic duct ($p = 0.0008$). The CT density of the

cysts was higher in mIPMN ($p = 0.0063$). The diagnostic accuracy of the summation score (sensitivity: 0.84, specificity: 0.96) was greater when compared to each individual CT parameter. **Conclusions:** The prevalence and extent of various CT-based abnormalities are greater in patients with mIPMN, but the wide overlap limits the diagnostic value of each individual parameter. A simple summation score largely enhances the diagnostic accuracy.

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Introduction

Intraductal papillary mucinous neoplasms (IPMNs) are cystic formations of the pancreas originating from the ductal tree [1]. In recent years, the prevalence of diagnosed IPMN has increased substantially [2], owing to the growing availability of imaging techniques with high local resolution of pancreatic tissue, such as X-ray CT, MRI, and endoscopic ultrasound (EUS). Indeed, intrapancreatic cystic lesions are incidentally detected in ~1–3% of all CT or MRI examinations [3, 4]. This increasing num-

ber of incidental diagnoses of cystic pancreatic tumors poses the problem of determining the dignity of the lesions. Thus, whereas a majority of serous cystadenomas of the pancreas are benign, malignancy occurs in most mucinous cystadenomas and IPMN over time [1]. Furthermore, an adenoma-to-carcinoma sequence with increasing levels of cell dysplasia has been proposed for the natural history of IPMN, analogous to the carcinogenesis model of colorectal tumors [5].

In light of the high risk of malignant transformation of IPMN, surveillance strategies have been developed to help in making a decision of whether to surgically remove the tumors or whether to monitor them [6, 7]. These involve the evaluation of the pancreatic lesions using EUS, MRI, and CT scans. Although the diagnostic value of MRI and EUS appears to be superior, abdominal CT scans are still the standard procedure [8], given the broad availability of this technique. Therefore, it is important to define criteria that allow for an accurate distinction between benign and malignant IPMN based on abdominal CT scans.

A number of individual criteria have been used to distinguish malignant from benign IPMN. Most importantly, the involvement and dilation of the main pancreatic duct as well as the diameter of the cystic tumor formations have been used as criteria for ascertaining malignancy [6, 9–12].

Indeed, pancreatic surgery is usually recommended in the case of main pancreatic duct involvement or in lesions greater than 30 mm in diameter with high-risk stigmata based on the latest “International Guidelines” [6]. Additional parameters that have been associated with malignant tumor behavior include the obstruction of the bile duct, presence of solid tumor components, contrast enhancement of cystic walls, distal pancreatic atrophy, enlarged peripancreatic lymph nodes, abrupt changes in the diameter of the main pancreatic duct, and the presence of tumor calcifications.

However, even though all of these parameters have been associated with an increased risk of malignancy, they do not allow for a clear-cut distinction between benign and malignant lesions, when determined on an individual basis.

Therefore, the present study was designed to determine the diagnostic sensitivity and specificity of different CT-based parameters for the detection of malignant IPMN. Furthermore, a summation score consisting of different components was developed in order to enhance the diagnostic accuracy of CT-based parameters for the detection of malignant IPMN.

Patients and Methods

Study Protocol

A retrospective analysis of abdominal CT scans was performed in patients who had undergone surgery for the removal of pancreatic IPMN's. Data were obtained from a retrospective chart review of all patients undergoing abdominal CT scans at the Department of Radiology, St. Josef-Hospital, Ruhr-University Bochum, between 2006 and January 2013. All analyses were performed in a blinded fashion after pseudonymization of patient-level data. The study protocol was approved by the Ethics Committee of the medical faculty of the Ruhr-University Bochum.

Patients

A total of 96 patients had undergone pancreatic surgery for the removal of pancreatic IPMN at the Department of Surgery, St. Josef-Hospital Bochum, between 2006 and January 2013. Among those, abdominal CT scans were available for analysis from 47 patients. The diagnosis of pancreatic IPMN was confirmed in all cases by histopathological analysis performed by an experienced pathologist using established criteria [13]. CT scans were performed at the Department of Radiology, St. Josef-Hospital Bochum, in 44 patients, and by external Radiologists in 3 cases. The technical quality and comparability of these external CTs with internal CTs were assured prior to inclusion of these images. To determine potential differences in various anthropometric, clinical chemistry, and CT-based parameters, patients were divided in 2 different groups according to the histopathological evaluation: (A) 28 patients (59.6%) with benign IPMN and (B) 19 patients (40.4%) with malignant IPMN.

Patient Characteristics and Laboratory Determinations

The following parameters were recorded from the patient records: age, gender, carbohydrate-antigen 19-9 (CA 19-9), bilirubin, amylase, lipase, alkaline phosphatase gamma glutamyltransferase (GGT), and fecal elastase. The most recent preoperative laboratory values were used for the analyses. In 1 patient, laboratory values for CA 19-9, bilirubin, amylase, lipase, and GGT were not available. In 10 patients, fecal elastase levels were not available. Furthermore, a history of known diabetes and of exocrine pancreatic insufficiency was recorded from the patient charts.

CT Scan Protocol

All CT-scans were performed on a 16-slice-CT scanner (Somatom 16, Siemens, Erlangen, Germany). The protocol for pancreatic CT included non-enhanced abdominal CT, abdominal arterial phase CT, and portal-venous phase CT. In patients without a known history of pancreatic abnormalities, only standard abdominal CTs without non-enhanced phases were performed ($n = 11$).

All patients were asked to drink an oral iodine-containing contrast agent (30 mL with a concentration of 400 mg iodine/mL diluted in 1 L H₂O), starting approximately 1 h before CT-examination. Iomeprol 300 (300 mg iodine/mL) was injected as an intravenous contrast agent at a rate of 3 mL/s. The total volume of injected contrast agent was 100 mL. One hundred twenty kilovolts voltage was applied during all phases. Collimation was 16 × 1.5 mm in non-enhanced CTs and 16 × 0.75 mm in arterial and portal-venous phases. The pitch was 0.75. Multi-planar reformations were done in a coronal and a sagittal plane. Moreover, curved reformations along the main pancreatic duct were performed.

Table 1. Characteristics and laboratory parameters in patients with benign and malignant IPMN

Parameter	Malignant IPMN	Benign IPMN	<i>p</i> value
Age, years	62.2±2.4	64.8±1.7	0.36
Gender, female/male	10/9	12/16	0.56
CA 19-9, U/mL	50.9±11.4	21.6±5.4	0.013
Bilirubin, mg/dL	0.68±0.11	0.53±0.04	0.13
Amylase, U/L	67.1±22.6	57.2±17.0	0.72
Lipase, U/L	147.4±42.5	110.1±31.9	0.48
AP, U/L	73.1±5.9	78.8±5.8	0.51
γ-GT, U/L	75.7±27.1	40.0±7.7	0.14
Faecal elastase, µg/g	291.3±54.3	287.0±43.5	0.95
Diabetes (yes/no)	8/10	11/16	1.0
Exocrine insufficiency (yes/no)	4/3	27/0	0.051

Means ± SEM; statistics: Student's *t* test or Fisher's exact test.

In CTs obtained before 2009 (*n* = 10), only 5 and 10 mm slices were archived, which did not allow for reformations of the main pancreatic duct.

Criteria for CT Analysis

All CT scans were retrospectively analyzed for potential criteria of malignancy in IPMN. The analyses were performed on a radiological workstation (JiveX Diagnostic Client, Visus, Bochum, Germany) by an experienced radiologist.

The following parameters were derived from the CT images:

1. Maximum diameter of the main pancreatic duct;
2. Maximum diameter of cystic formations;
3. Maximum diameter of the supra-pancreatic bile duct (Ductus choledochus): a diameter of more than 10 mm in the absence of other obvious causes of obstruction was considered as evidence of bile duct obstruction;
4. Presence of solid tumor components or mural nodules;
5. Contrast enhancement of cystic walls;
6. Distal pancreatic atrophy: the axial diameters of the pancreatic parenchyma in the tail and in the corpus were determined: a ratio of less than 0.5 was considered evidence for distal pancreatic atrophy. This parameter could not be determined in 1 patient with benign and 1 patient with malignant IPMN due to previous distal pancreatectomies;
7. Presence of peripancreatic lymph nodes with a maximal diameter of more than 10 mm;
8. Abrupt changes in the diameter of the main pancreatic duct of more than 50%;
9. Presence of tumor calcifications;
10. CT density (Hounsfield Units, HU) in the cystic part of the lesion in non-enhanced phases. This analysis could not be performed in 5 patients with malignant and 6 patients with benign IPMN due to lack of non-enhanced images.

Calculations and Statistical Analyses

Results are reported as mean ± SEM. All parameters were first compared between the patients with benign and malignant IPMN.

Numeric parameters were compared using Student's *t* test. Parametric parameters were compared using Fisher's exact test. A

2-sided *p* value <0.05 was considered to indicate significant differences.

Furthermore, summation scores of all CT-based parameters that were significantly different between the groups were calculated, and the respective values for diagnostic sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of each of these scores for the diagnosis of a malignant IPMN were calculated. All statistical analyses were performed using GraphPad Prism 6.01 (GraphPad Software Inc., 2012, La Jolla, CA, USA).

Finally, a multivariate regression analysis including all CT-based parameters that were significantly different between the groups was performed using Statistica version 5.0 (Statsoft Europe, Hamburg, Germany).

Results

Patient Characteristics and Laboratory Values

The group of malignant IPMN comprised 9 male (47.4%) and 10 female patients (52.6%). In the group of benign IPMN, there were 16 male (57.1%) and 12 female (42.9%) patients (*p* = 0.56). There was no difference in age between patients with malignant and benign IPMN (62.2 ± 10.5 vs. 64.8 ± 8.8 years; *p* = 0.36; Table 1).

Preoperative levels of CA 19-9 were significantly higher in patients with malignant IPMN (50.9 ± 11.4 vs. 21.6 ± 5.4 U/mL; *p* = 0.013; Table 1). However, there was a large degree of overlap between the groups. None of the other laboratory parameters showed significant differences between the groups of patients with benign and malignant IPMN (Table 1).

The presence or absence of known diabetes could be ascertained in 18 patients with malignant and 27 patients

Fig. 1. The mean diameter of the major pancreatic duct (**a**; determined in 47 patients) and the mean CT density of the cystic components of IPMN in non-enhanced CT (**b**; determined in 35 patients)

in patients with malignant and benign pancreatic IPMN. Data are presented as individual numbers; horizontal lines denote the respective mean values. Statistics were carried out using Student's *t* test.

with benign IPMN. There were no differences regarding the prevalence of diabetes between the groups (42.1 vs. 44.4%; $p = 1.0$; Table 1).

Information about exocrine pancreatic insufficiency could be obtained from 17 patients with malignant and 27 patients with benign IPMN. The respective prevalence was 82.4% in patients with malignant and 100% in patients with benign IPMN ($p = 0.051$).

Comparison of CT-Based Parameters

Significant differences between patients with benign and malignant IPMN were found for 7 out of the 10 parameters examined.

The mean diameter of the main pancreatic duct was 9.6 ± 0.9 mm in patients with malignant IPMN and 4.5 ± 0.4 mm in patients with benign IPMN ($p < 0.0001$; Fig. 1). Ten out of 19 patients (52.6%) with malignant IPMN exhibited diameters of the main pancreatic duct >10 mm, and further 8 out of 19 (42.1%) patients had diameters between 5 and 10 mm (Fig. 2). In contrast, in patients with benign IPMN, the main pancreatic duct diameter was >10 mm in 1 patient (3.6%), and between 5 and 10 mm in another 9 patients (32.1%). Thus, the parameter "main pancreatic duct diameter >10 mm" exhibited a diagnostic sensitivity of 0.5, a specificity of 0.96, a PPV of 0.90, and an NPV of 0.75 for the diagnosis of a malignant IPMN.

A maximum diameter of the supra-pancreatic bile duct of more than 10 mm in the absence of other obvious causes of bile duct obstruction was found in 5 out of 19 (26%) patients with malignant and zero out of 28 (0%) patients with benign IPMN ($p = 0.0076$; Fig. 2). Therefore, the diagnostic sensitivity of this parameter for the

diagnosis of a malignant IPMN was 0.16, specificity was 1.0, the PPV was 1.0, and the NPV was 0.64.

Solid tissue components were detectable in 5 out of 19 patients (26%) with malignant and zero out of 29 (0%) patients with benign IPMN ($p = 0.0076$; Fig. 2). Therefore, the sensitivity for the diagnosis of a malignant IPMN was 0.16, specificity was 1.0, the PPV was 1.0, and the NPV was 0.64.

Contrast enhancement in cystic walls was observed in 8 out of 19 patients (42%) with malignant and 2 out of 29 (6.9%) patients with benign IPMN ($p = 0.0086$; Fig. 2). Thus, this parameter exhibited a diagnostic sensitivity of 0.42, a specificity of 0.93, a PPV of 0.8, and an NPV of 0.7 for the diagnosis of a malignant IPMN.

Peripancreatic lymph nodes with a maximum diameter of more than 10 mm were observed in 5 patients with malignant and (17.2%) and no patient with benign (0%) IPMN ($p = 0.0076$; Fig. 2). Therefore, the sensitivity for the diagnosis of a malignant IPMN was 0.26, specificity was 1.0, the PPV was 1.0, and the NPV was 0.67.

Abrupt changes in the diameter of the main pancreatic duct of more than 50% were found in 7 patients with malignant (36.8%) and no patient with benign IPMN ($p = 0.0008$; Fig. 2). On that basis, a sensitivity of 0.37, a specificity of 1.0, a PPV of 1.0, and an NPV of 0.7 for the diagnosis of a malignant IPMN were calculated.

The CT density of the cystic part of the lesions on the non-enhanced images was higher in malignant than in benign IPMN (14.8 ± 3.4 vs. 6.4 ± 0.9 HE; $p = 0.0063$; Fig. 1). When a threshold of 10 HE was defined as diagnostic threshold, a sensitivity of 0.5, a specificity of 0.82, a PPV of 0.64, and an NPV of 0.72 were calculated for the detection of a malignant IPMN.

Fig. 2. a–i Different parameters derived from pancreatic CT scans in patients with malignant and benign pancreatic IPMN. Data are presented as percentage numbers of the respective groups. Statistics were carried out using Student's *t* test.

In contrast to the above-mentioned parameters, the maximum diameter of cystic formations within the lesions was not different between patients with benign and malignant IPMN (29.4 ± 3.9 vs. 36.7 ± 5.2 mm, $p = 0.25$; details not shown). There were also no differences in the presence of tumor calcifications between patients with

malignant (3/19; 15.8%) and benign (0/28; 0%) IPMN ($p = 0.06$; Fig. 2). A ratio of less than 0.5 between the maximum diameter of parenchyma of pancreatic tail and the pancreatic corpus was observed in 3 patients (17%) with malignant and 1 patient (3.6%) with a benign IPMN ($p = 0.29$; Fig. 2).

Table 2. Components of the scoring system for the evaluation of IMPN in abdominal CT scans

Parameter	Value	Score
Maximum diameter of main pancreatic duct, mm	<5	0
	5–10	1
	>10	3
Maximum diameter of cystic formations, mm	<30	0
	≥30	1
Bile duct-obstruction (no/yes)	No	0
	Yes	2
Presence of solid tumor components or mural nodules (no/yes)	No	0
	Yes	3
Contrast enhancement in cystic walls (no/yes)	No	0
	Yes	1
Peripancreatic lymph nodes >10 mm (no/yes)	No	0
	Yes	3
Abrupt diameter changes of the main pancreatic duct >50% (no/yes)	No	0
	Yes	1
CT-density in the cystic part of the lesion on non-enhanced CT, HU	<10	0
	≥10	1

Multivariate Regression Analysis

In a multivariate regression analysis the following were taken as independent variables: the maximum diameter of the main pancreatic duct, the maximum diameter of cystic formations, the presence of bile duct obstruction, the presence of solid tumor components, contrast enhancement in cystic walls, the presence of peripancreatic lymph nodes >10 mm, abrupt changes of the main pancreatic duct of more than 50%, and the CT density in the cystic part of the lesion on the non-enhanced CT. Only the diameter of the pancreatic duct ($p = 0.0015$) and the CT density in the cystic part on the non-enhanced CT ($p = 0.022$) showed a significant association, and the association with enlarged peripancreatic lymph nodes almost reached statistical significance ($p = 0.050$). The overall r^2 value was 0.60, indicating that 60% of the probability for malignancy could be explained by the model.

Diagnostic Accuracy of a Summation Score for the CT-Based Prediction of Malignancy in Pancreatic IPMNs

To create a summation score of predictive factors for the diagnosis of a malignant IMPN, the CT-based parameters exhibiting significant differences between patients with benign and malignant IMPN were selected

(Table 2). In addition, tumor size was included in the score based on the experience from previous studies. Thus, scores from 0 to 3 were assigned to the various components. The relative weight of the individual parameters was based on published recommendations and guidelines and the individual judgment of the investigators.

Details of the scoring system are summarized in Table 2. The final possible scores ranged between 0 and 15. This score yielded the best diagnostic threshold between 2 and 3 points. Thus, the probability of a malignant IMPN in patients with a score of less than 3 points was 10%, whereas the respective probability in patients with a score of 3 points or more was 94%. On that basis, a final score of 3 or more points was considered to predict malignancy. A diagnostic sensitivity of 0.84, a specificity of 0.96, a PPV of 0.94 and an NPV of 0.9 were calculated for this score (Table 3).

A summation score of 6 or more points predicted malignancy at an even higher specificity (1.0), albeit with lower sensitivity (0.42; Table 3).

The respective diagnostic values of the intermediate summation scores (between 3 and 6) for the prediction of malignancy can be derived from Table 3. Overall, the diagnostic accuracy of abdominal CT scans for the detection of malignant IMPN was greatly enhanced by the use

Table 3. Probability of malignancy for different summation scores determined based on abdominal CT scans

Number of points	Number of malignant/ benign tumors	Probability of malignancy, %	Probability of benignancy, %	Sensitivity	Specificity	PPV	NPV
0	0/12	0	100	0	0.57	0	0.46
Less than 2	2/19	10	90	0.11	0.32	0.1	0.35
Less than 3	3/27	10	90	0.16	0.04	0.1	0.06
3 or more	16/1	94	6	0.84	0.96	0.94	0.9
6 or more	8/0	100	0	0.42	1	1	0.72

Diagnostic sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of different summation scores for the detection of a malignant IPMN are presented.

of the summation score compared to the respective accuracies of the individual CT-based parameters.

In addition to this score, in which the relative weight of the individual parameters was determined in a subjective fashion by the investigators, 2 other scores were calculated: a “non-weighted” score, in which the same number of points was assigned to each parameter as well as an “objectively weighted score,” in which higher scores were assigned only to those parameters that were significantly associated with malignancy in the multivariate regression analysis (details not shown). A comparison of these 3 scoring systems yielded the highest sensitivity and specificity for the subjectively weighted score.

Discussion

This study was designed to determine the diagnostic accuracy of various CT-based parameters for the prediction of malignancy of pancreatic IPMN. Based on the analysis of 47 scans, the diameter of the main pancreatic duct, bile duct obstruction, solid tissue components, contrast enhancement in cystic walls, enlarged peripancreatic lymph nodes, abrupt diameter changes of the main pancreatic duct, and a high CT density of the lesions were found to be more prevalent in malignant than in benign IPMN. Among those parameters, the diameter of the main pancreatic duct exhibited the highest individual diagnostic accuracy. This parameter, as well as the CT density in the cystic part, also remained significantly associated with malignancy in a multivariate regression analysis. The diagnostic sensitivity and specificity of a weighted summation score comprising 8 different parameters were much higher than the diagnostic sensitivity and specificity of each individual parameter.

Previous studies have suggested a number of individual criteria to predict malignancy in pancreatic IPMN [6, 14–16]. The summation score suggested here was based on the evaluation of these parameters as well as the determination of the CT density of the lesions. Only parameters that were found to be different between patients with benign and malignant IPMN were selected for the summation score. Notably, using this simple scoring system, IPMN carcinomas were predicted with a sensitivity of 84% and specificity of 96% at a score of 3 or more. This diagnostic specificity was even greater in lesions with higher scores (1.0 at a score of 6 or more), albeit with less sensitivity. In the present analysis, the maximum diameter of the cystic lesions was not different between benign and malignant IPMN. This finding is at variance with some, but not all previous studies. Indeed, more recent guidelines suggest to observe branch duct IPMN even >3 cm if there are no other signs of malignancy [6].

A newly established criterion in this study was the mean CT density of the cystic lesions. This parameter was significantly different between benign and malignant IPMN, although there was still a large degree of overlap between the groups. However, because the determination of CT density involves manual contouring of a region of interest within the lesion, the accurate assessment might depend on the experience of the examiner. Nevertheless, in combination with the other parameters, determining the CT density of the cystic lesions might be a valuable addition to the overall diagnostic evaluation of pancreatic IPMN.

Although it is commonly accepted that the involvement of the main pancreatic duct is strongly associated with malignancy in IPMN, the accurate determination of main duct involvement using CT scan images is quite challenging. Therefore, the dilation of the main pancre-

atic duct has been used as indirect evidence of main pancreatic ductal involvement in this as well as in previous studies [17–20]. Indeed, this indirect parameter exhibited the strongest individual predictive value for malignancy in pancreatic IPMN.

In this study, only CT scan images were analyzed, even though the diagnostic value of pancreatic MRI or EUS is often superior [21–23]. This approach was chosen because of the broad availability of the CT. Furthermore, the evaluation of pancreatic lesions by EUS is more invasive and largely dependent on the experience of the individual examiner as well as the anatomical conditions of the patient [24]. Limitations of pancreatic MRI include the long duration of the examination as well as movement artefacts [25]. Therefore, abdominal CT scans will likely remain important components of the diagnostic workup for pancreatic IPMN.

Although pancreatic CT scans may therefore add some information for the initial evaluation of pancreatic cystic lesions, such examinations cannot be recommended for the long-term follow-up because of the high radiation exposure. Therefore, MRI imaging is considered the gold standard for the long-term surveillance of pancreatic IPMN as recently emphasized in the American Gastroenterological Association Institute Guidelines [26, 27]. Alternatively, branch-duct IPMN without high-risk stigmata or worrisome features may safely be followed up by EUS [28]. If those 2 diagnostic options are not available, patients should be referred to a specialized center.

In addition to the differences in various CT-based parameters between patients with benign and malignant IPMN, this study has also revealed higher CA 19-9 levels in the malignant cases, in agreement with previous studies [17, 29–31]. However, the wide overlap in CA 19-9 levels between the groups does not allow for a clear discrimination based on this parameters. Nevertheless, in combination with radiographic and endoscopic findings as well as the patients' symptoms, determination of CA 19-9 might facilitate the diagnosis of malignant IPMN.

In contrast to these CT-based and laboratory parameters, the prevalence patterns of known diabetes and of exocrine pancreatic insufficiency were not different between the groups. This finding is of interest because both factors are known to be associated with the incidence of pancreatic adenocarcinomas [32–34]. In fact, the occurrence of diabetes in lean individuals of advanced age has even been suggested as a diagnostic signal for the presence of pancreatic carcinomas [35]. Mechanistically, the hyperglycemia in patients with

pancreatic cancer has been associated with the local destruction of islet cell tissue as well as the release of inflammatory cytokines that act to inhibit beta-cell function [36]. The lack of association between diabetes and malignant IPMN underlines the different pathogenetic mechanisms of pancreatic adenocarcinoma and IPMN. However, the prevalence rates of both diabetes (42.1 vs. 44.4%) and exocrine pancreatic insufficiency (82.4 and 100%) were generally quite high in this group of patients, thereby indicating a large extent of both exocrine and endocrine abnormalities in these patients, irrespective of the dignity of the tumors.

As it is for most retrospective studies, certain limitations apply to the present analysis. Most importantly, in terms of design only IPMN that had been subjected to surgery could be included in this study. This was done out of necessity because the histopathological diagnosis was used as the reference standard. Nevertheless, it cannot be excluded that the results of this study would be different in a selection of tumor cases with less obvious pathological findings that are not routinely subjected to surgery. Therefore, it seems advisable to apply the criteria defined here to a prospective series of pancreatic IPMN to further validate this summation score.

From a clinical perspective, a scoring system such as the one proposed here may aid physicians in determining malignancy in pancreatic IPMN. Such formal classification is certainly not meant to substitute for the individual experience of the radiologists evaluating abdominal CT scans. Clearly, in many cases, the accurate diagnosis can already be derived from the image analysis without such classification. However, for less experienced examiners or in cases of less obvious alterations, a scoring system may help physicians to come to an accurate prediction of malignancy. Considering the importance of this clinical judgment in determining whether patients should be subjected to pancreatic surgery or not, such formal criteria may be a helpful clinical tool. Nevertheless, the overall decision-making process in such cases must consider all information available, including patients' symptoms, laboratory abnormalities, and a combination of different imaging techniques, such as CT, MRI, and EUS.

In conclusion, the present study has revealed a number of CT-based criteria that can help to distinguish between benign and malignant pancreatic IPMN. However, the individual sensitivity and specificity of each of these parameters to detect malignancy was rather low. A greater diagnostic accuracy can be obtained from the determination of a simple summation score consisting of 8 different

components. Such summation score may aid physicians in determining malignancy in pancreatic IPMN based on abdominal CT scans.

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Disclosure Statement

The authors report no conflicts of interest in relation to this work.

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Erratum

In the article by Floer M und Meister T, entitled “Endoscopic improvement of the adenoma detection rate during colonoscopy – where do we stand in 2015?” [Digestion 2016;93:202–213, DOI: 10.1159/000442464], the EndoRings seen on Figure 3 was attached from the wrong direction. The corrected figure is shown below:

Fig. 3. EndoRings endoscopic add-on device distally attached to the colonoscope (lateral and forward view).