Published in final edited form as:

J Magn Reson Imaging. 2019 November ; 50(5): 1633–1640. doi:10.1002/jmri.26714.

Pancreas Deformation in the Presence of Tumors Using Feature Tracking From Free-Breathing XD-GRASP MRI

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Abstract

Background: Quantifying the biomechanical properties of pancreatic tumors could potentially help with assessment of tumor aggressiveness, prognosis, and prediction of therapy response.

Purpose: To quantify respiratory-induced deformation in the pancreas and pancreatic lesions using XD-GRASP (eXtra-Dimensional Golden-angle RADial Sparse Parallel), MRI.

Study Type: Retrospective study where patients undergoing clinically indicated abdominal MRI which included free-breathing radial T₁-weighted (T₁W) imaging were studied.

Subjects: Thirty-two patients (12 male and 20 female) including nine with pancreatic lesions constituted our study cohort.

Field Strength/Sequence: 3.0 T with T₁WI contrast-enhanced gradient echo radial free-breathing acquisition.

Assessment: Using the XD-GRASP imaging technique, the acquired free-breathing radial data were sorted and binned into 10 consecutive respiratory motion states that were jointly reconstructed. 3D deformation fields along the respiratory dimension were computed using an optical flow method and were analyzed in the pancreas.

Statistical Tests: The Wilcoxon signed-rank test was used to assess the difference in average displacement across pancreatic regions, while the Wilcoxon rank-sum test was used for displacement differences between patients with and without tumors. The interclass correlation coefficient (ICC) was computed to assess consistency between observers for each image quality measure.

Results: There was a significantly larger displacement in the pancreatic tail compared with the head (8.2 ± 3.7 mm > 5.8 ± 2.4 mm; $P < 0.001$) and body regions (8.2 ± 3.7 mm > 6.6 ± 2.9 mm; P

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< 0.001). Furthermore, there was reduced normalized average displacement in patients with pancreatic lesions compared with subjects without lesions ($0.33 \pm 0.1 < 0.69 \pm 0.26$, $P < 0.001$ for the head; $0.30 \pm 0.1 < 0.84 \pm 0.31$, $P < 0.001$ for the body; and $0.44 \pm 0.31 < 1.08 \pm 0.53$, $P < 0.001$ for the tail, respectively).

Data Conclusion: Free-breathing respiratory motion-sorted XD-GRASP MRI has the potential to noninvasively characterize the biomechanical properties of the pancreas by quantifying breathing-induced mechanical displacement.

PANCREATIC CANCER is the third leading cause of cancer mortality in the United States.¹ According to the American Cancer Society, ~54,000 patients will be diagnosed with pancreatic cancer in 2018 in the United States and 43,000 will die from it.² Currently, the only curative treatment for pancreatic cancer is surgical resection with disease-free margins. Surgical candidacy requires that the tumor be confined to the pancreas and have limited involvement of the adjacent vasculature at the time of diagnosis. Only 20% of patients meet these requirements for candidacy.³ For the remaining 80% of the cases, the tumor has spread beyond the pancreas and thus precludes surgical resection. Although these patients are routinely treated with chemotherapy,³ the median survival remains less than 18 months.⁴

This notoriously low level of response and resistance to chemotherapy in pancreatic cancer is partially attributed to the unique tumor microenvironment, characterized by extensive stromal fibrosis and desmoplastic reaction from deposition of extracellular matrix including compressive and shear-resistant hyaluronan and collagen.^{5–8} The fibrotic microenvironment along with increased mechanical stiffness is associated with tumor aggressiveness and resistance to chemotherapy.^{5–8} Therefore, there is tremendous interest in quantifying the mechanical properties of the pancreas and pancreatic tumors.^{9,10} At the same time, there is a lack of noninvasive, quantitative in vivo methods that can interrogate the biomechanical properties of the pancreas and changes associated with lesions.

Magnetic resonance imaging (MRI) plays an increasingly important role in imaging of the pancreas and pancreatic cancer. One of the imaging methods to measure the mechanical properties of soft tissue in vivo is magnetic resonance elastography (MRE).¹¹ A phase contrast MRI technique, MRE measures tissue displacement in response to an internal or external deformation force, based on which it computes tissue elasticity using an inverse model. While MRE has been an established clinical method for evaluating chronic liver disease and liver fibrosis,^{12–14} its use in the assessment of the pancreas is still limited.^{15,16} In order to induce deformation, an external source of vibration is used during acquisition. However, the quantitative results are nonlinearly dependent on the frequency of stimulation,¹⁵ which limits the robustness of the method.

The recently introduced XD-GRASP (eXtra-Dimensional Golden-angle RADial Sparse Parallel) method¹⁷ enables extraction of motion information directly from the continuously acquired, free-breathing imaging data. The data are sorted into consecutive undersampled motion states and simultaneously reconstructed. XD-GRASP has been demonstrated to reconstruct motion-sorted data along cardiac and respiratory physiological dimensions in motion-resolved cine MRI¹⁸ and in respiratory-resolved dynamic contrast MRI of the liver.¹⁹

Feature tracking image analysis methods are increasingly used in clinical practice for tissue tracking in temporal MR image series of the cardiac motion²⁰ and respiration-induced liver motion.^{21,22} In this study, we propose to use an algorithm based on optical flow to track the pancreatic tissue in 4D motion-resolved MRI and to measure pancreas and tumors displacement induced by respiratory motion. We show that we can measure a significantly reduced displacement in the presence of tumors. The purpose of this work was to test if XD-GRASP MRI can provide not only diagnostic image quality for the morphological assessment of the pancreas, which we show through a small image quality observer study, but also has the potential to noninvasively characterize the biomechanical properties of the pancreas through the quantification of respiration-induced mechanical displacement.

Materials and Methods

This retrospective study was approved by our Institutional Review Board (IRB), with no requirements for individual informed consent. We included patients who underwent free-breathing T₁-weighted imaging (T₁WI) contrast-enhanced gradient echo (GRE) radial acquisition MRI of the abdomen, with or without pancreatic lesions. At our institution, patients who are referred for abdominal MRI are scanned with a conventional breath-held T₁W GRE acquisition protocol. Patients who are unable to hold their breath are in addition examined using free-breathing T₁-weighted dynamic contrast enhanced imaging method with radial acquisition scheme. We searched our database for patients who underwent T₁WI contrast-enhanced GRE radial imaging of the upper abdomen from 2016–2017 and we identified a total of 29 patients (11 male, 18 female) with a mean age of 78.6 years (range 39–96 years). For 18 subjects conventional breath-held T₁W GRE acquisition had first been attempted, before the free-breathing radial acquisition, and was therefore available for image quality comparison.

In addition, we obtained three anonymized datasets (one male, two females), mean age 60 (range 50–67 years), from an external collaborator. These datasets were acquired under the IRB-approved study at that institution. These three subjects were imaged with the same free-breathing imaging protocol.

Acquisition and Reconstruction

All patients were scanned on a clinical 3.0 T MRI scanner (Magnetom Skyra, Siemens Healthineers, Germany). Free-breathing (without respiratory triggering) T₁WI contrast-enhanced gradient echo acquisition of the liver was performed in all patients in the axial plane using a fatsaturated stack-of-stars golden-angle radial imaging sequence, in which Cartesian sampling is employed along the slice dimension (k_z) and radial sampling is applied in the k_x – k_y plane with each spoke rotated by a golden angle ($\sim 111.25^\circ$). Other imaging parameters included: repetition time / echo time (TR/TE) = 4.12/1.81 msec, matrix size = $256 \times 256 \times (46\text{--}56)$, field of view (FOV) = $385 \times 385 \times (230\text{--}280)$ mm² which cover the abdominal region, acquired voxel size = $1.5 \times 1.5 \times 5.0$ mm³, flip angle = 12° . In all, 1904 spokes were acquired for each partition, with a total scan time of 345.2 ± 29 seconds. For each scan, a weight-based (0.1 mmol per kg of body weight) of Gadavist (Bayer Healthcare, Berlin, Germany) was injected ~ 30 seconds after the start of data acquisition, at

a rate of 2 mL/sec. Contrast enhancement is essential to detect the presence or absence of pancreatic lesions and is routine for our abdominal MRI protocol.

The acquired k -space data were retrospectively reconstructed offline using the XD-GRASP method.¹⁹ The quasi-periodic respiratory motion signal was extracted from the centers of stack-of-stars k -space data, which reflects the change of average image intensity over time. The respiratory motion detection was performed using the principal component analysis (PCA)-based method previously proposed.^{17,23,24}

Given the extracted respiratory motion signal, the radial spokes were sorted into 10 consecutive respiratory phases spanning from end-expiration to end-inspiration, which form a new temporal dimension, as shown in Fig. 1. The XD-GRASP reconstruction was performed by solving the following cost function¹⁹:

$$m = \arg \min_m \|Em - y\|_2^2 + \lambda \|Tm\|_1$$

where m is the 3D temporal image series to be reconstructed, y is the acquired and sorted k -space data, E is the multicoil encoding matrix given by the concatenation of single coil

encoding models $E = \begin{bmatrix} FS_1 \\ \dots \\ FS_N \end{bmatrix}$ (where F is the nonuniform fast Fourier transform FS defined on

the radial trajectory, S_i is the coil sensitivity matrix for the i -th coil, and N is the number of coils), and λ is a regularizing parameter that controls the contribution trade-off between the sparsity term and the data consistency term. A first-order finite difference operation along the temporal dimension was chosen as the sparsifying transform, T .²⁵ The reconstruction of whole 4D dataset (x-y-z-respiration) was implemented in MatLab (MathWorks, Natick, MA) using a nonlinear conjugate gradient algorithm.²⁶ The reconstruction time was ~20 minutes per 4D volume. Figure 2 shows a reconstructed time series of a single slice of an abdominal MRI in all respiratory motion states.

In 18 patients, conventional Cartesian k -space sampling volumetric interpolate breath-hold examination (BH VIBE) was also available in the venous phase with the following parameters: TR/TE: 3.56–3.62/1.51–1.55 msec, (interpolated) voxel size: 1.4–1.6 × 1.4–1.6 × 3 mm, partial Fourier in the slice- and phase-encoding direction, and a parallel-imaging GRAPPA factor of 2. A total of 72–88 axial slices were acquired in 10–16 seconds.

Conventional breath-held T₁W GRE datasets were directly reconstructed on the scanner.

Estimation of Breathing-Induced Deformation Field

To estimate the 3D nonrigid deformation field along the respiratory dimension, a 3D optical flow method based on the locations of the edges in the image was used to compute the displacement of each voxel according to the following optical flow equation²⁷:

$$\iiint (I_x u + I_y v + I_z w + I_t)^2 + \alpha^2 (\|\nabla u\|_2^2 + \|\nabla v\|_2^2 + \|\nabla w\|_2^2) dx dy dz$$

where I_x , I_y , I_z , and I_t are the derivatives of the image intensity values in the x, y, z , and t directions, respectively, and ∇u , ∇v , and ∇w are optical flow displacements along the x, y , and z dimensions, respectively.

Standard optical flow methods can be subjected to gray-level fluctuations between MR images. Thus, we used a method specifically designed for MR images with improved robustness to image intensity fluctuations as described previously.²⁸ The method has previously been validated in MRI for high-frequency ultrasound.²⁹ Unlike classical optical flow methods, it uses an L1 optical flow data fit term and an L2 regularizer (ie, an L1–L2 model)²⁸:

$$\iiint \left| I_x u + I_y v + I_z w + I_t \right| + \beta^2 \left(\|\nabla u\|_2^2 + \|\nabla v\|_2^2 + \|\nabla w\|_2^2 \right) dx dy dz$$

We used the suggested value of $\beta = 0.4$ from the freely available optical flow package.²⁸ This algorithm is robust to outliers that deviate from the optical flow equations, which can arise from gray-level fluctuations. The runtime for the deformation field computation was ~30 seconds per 4D volume.

The local deformations were computed for each voxel between each of two consecutive respiratory phases using the above optical flow method. The total deformation between end-inspiration and end-expiration for the entire time series was computed using Runge-Kutta integration (RK4) over the motion field along the temporal dimension, to reduce noise propagation. The average total deformation was computed for each segmented pancreatic region and tumor, if present. Figure 3 shows the magnitude of the local deformation vectors between end-inspiration and end-expiration overlaid for the manually segmented pancreatic regions. The average displacement D over time was computed for each pancreas region: D_h , D_b , D_t for the head, body, and tail, respectively.

In order to account for the variable body size, as well as for the different breathing amplitude across the patient population, we normalized the local pancreas displacement to the magnitude of the bulk abdominal motion during respiration. Specifically, we normalized the average motion of the pancreatic region by the maximum magnitude of diaphragm displacement, n (the distance between the minimal and maximal diaphragm positions during the respiratory cycles), which is directly proportional to the maximum breathing amplitude among the binned respiratory cycles. The minimal and maximal positions of the diaphragm in a given temporal image series can be computed based on manually placed markers in the sagittal plane. We obtained the average normalized displacement for each pancreatic region: d_h , d_b , d_t for the head, body, and tail, respectively, which is dimensionless. Image analysis was performed in Python.

Qualitative Data Analysis

In 18 subjects, radial XD-GRASP reconstruction in end-expiratory phase and conventional breath-held T₁W GRE datasets were evaluated in a blinded and random fashion by three independent radiologists for quality assessment (H.C., 11 years of postresidency experience, B.D., 1 year of postresidency experience, C.H., 2 years of postresidency experience). Overall

image quality, pancreatic edge sharpness, and splenic vein clarity (as a subjective perceptual measure of image sharpness), and level of artifacts were evaluated on a 4-point score as shown in Table 1.

One reader (B.D.) evaluated the motion-sorted XD-GRASP reconstruction and performed the pancreas and pancreatic lesion segmentation. Three pancreatic regions (head, body, and tail) and any tumors, if present, were manually segmented from the T₁W XD-GRASP images by placing regions of interest in the end-expiratory image frame (Fig. 3). The annotation was performed using a custom-built software developed using the MeVisLab platform³⁰ that enables manual image segmentation and deformation field visualization. The identified pancreatic lesions were classified as resectable, borderline resectable, and unresectable based on the 2017 NCCN Clinical Practice Guidelines according to arterial and venous involvement by tumor.³¹

Statistical Analysis

Image quality parameters were compared between conventional breath-held T₁W GRE and free-breathing XD-GRASP acquisition for both readers using a Wilcoxon signed-rank test (R). The intraclass correlation coefficient (ICC) was used to assess the interobserver agreement for all image quality measures. Displacement was compared between each of the head, body, and tail pancreatic regions also using a Wilcoxon signed-rank test (R). Furthermore, the displacement of pancreas was compared in the subjects who had pancreatic tumor to those without tumor using the Wilcoxon rank-sum test (R). The correlation between the pancreas displacement and the breathing amplitude was computed as the Pearson correlation coefficient (Microsoft Excel 2010, Redmond, WA). $P < 0.05$ was considered statistically significant.

Results

We analyzed 32 patients who underwent abdominal MRI acquired with free-breathing radial T₁W acquisition and reconstructed with XD-GRASP. The average quality of the end-expiratory phase XD-GRASP image data (based on the average assessment of all observers) was significantly superior compared with the conventional breath-held T₁W GRE data in all quality measures: overall image quality ($3.52 > 2.52$, $P < 0.001$) and pancreatic edge sharpness and splenic vein clarity ($3.48 > 2.52$, $P = 0.007$). No significant difference in the level of the artifacts ($3.5 > 3.28$, $P = 0.075$) was found. The compared results are shown in Fig. 4. The image quality scores were very similar for all three criteria, with a high ICC = 0.96 ± 0.04 for overall image quality, ICC = 0.97 ± 0.03 for the sharpness measure, and moderate ICC = 0.47 ± 0.37 for the artifacts level. Pancreatic lesions were identified and segmented in nine subjects. One cystic lesion measuring 0.4 cm was not identified on T₁W images, but was only seen on the high-resolution MRCP dataset. There were nine subjects with pancreatic lesions segmented on the XD-GRASP image data, two of which were unresectable, based on NCCN Clinical Practice Guideline.³¹ The measured size of each of the lesions and their location with respect to the pancreas regions are shown in Table 2, with the size of the unresectable tumors being larger on average than the size of the other lesions.

Pancreas and Tumor Displacement

Figure 5 shows the average displacement of each pancreas region over time for the entire patient population. We found a significantly larger displacement in the pancreas tail compared with the head (8.2 ± 3.7 mm $>$ 5.8 ± 2.4 mm; $P < 0.001$) and compared with the body (8.2 ± 3.7 mm $>$ 6.6 ± 2.9 mm; $P < 0.001$).

Figure 6 (top) shows the average displacement and normalized displacement from end-inspiration to end-expiration for the three pancreatic regions for patients with and without pancreatic tumors, and for the pancreatic tumors independently. We found a reduced average displacement of each of the three pancreatic regions in the presence of lesions: 4.2 ± 1.4 mm $<$ 6.4 ± 2.4 mm for the head $P = 0.028$; 3.9 ± 1.7 mm $<$ 7.7 ± 2.6 mm, $P < 0.001$ for the body; and 5.2 ± 2.6 mm $<$ 9.4 ± 3.3 mm, $P < 0.001$ for the tail. We also found a lower tumor to pancreas displacement ratio in a nonresectable tumor compared with the resectable tumors ($79.5 \pm 5.5\%$ vs. $109.4 \pm 44\%$).

Normalized Displacement

However, the average displacement of each of the pancreatic regions was correlated with the breathing amplitude measured as the change in diaphragm position: $r = 0.59$, $P < 0.001$ for the pancreas head, $r = 0.45$, $P = 0.01$ for the pancreas body, and $r = 0.33$, $P = 0.06$ (not significant) for the pancreas tail, as shown in Fig. 7. To account for differences in the breathing effort between the subjects, we normalized the displacement by the diaphragmatic displacement (Fig. 6, bottom). There was significantly reduced normalized average displacement in each of the three pancreatic regions in the presence of the tumor: 0.33 ± 0.1 $<$ 0.69 ± 0.26 , $P < 0.001$ for the head; 0.30 ± 0.1 $<$ 0.84 ± 0.31 , $P < 0.001$ for the body; and 0.44 ± 0.31 $<$ 1.08 ± 0.53 , $P < 0.001$ for the tail.

Discussion

The quality evaluation demonstrates that the end-expiratory phase XD-GRASP postcontrast image data has superior quality for morphological assessment of the pancreas in the case of patients who cannot hold their breath. The conventional breath-held T₁W GRE sequence underperforms in patients who are unable to hold their breath because it is not able to compensate for respiratory motion. With XD-GRASP, we can mediate this problem by binning the acquired free-breathing data into different respiratory states from inspiratory to expiratory phase and reconstruct motion-sorted images to avoid the effect of motion artifacts and improve overall image quality, as previously shown.¹⁹ The independent observers were in very good agreement on quality assessment. Additionally, it is possible to extract motion information from the same dataset and reconstruct motion-sorted images using a combination of compressed sensing and parallel imaging. This extra dimensionality of the data permits computation of the displacement that the pancreas and pancreatic tumor in response to the intraabdominal pressure changes during respiratory motion.

The pancreatic head is expected to have a relatively lower deformation compared with the body and tail, due to the more fixed position, surrounded by the duodenum,³² which was confirmed by our results. However, the MRE literature finds no significant difference

between the three pancreatic regions, perhaps because of the use of an external source of deformation as opposed to an internal one such as the breathing motion. By simply using free-breathing MRI, we have the potential to quantify the local pancreas displacement in response to respiration, without the need for an external source of vibration.

Interestingly, the pancreas has a reduced displacement associated with normal breathing motion in patients with pancreatic lesions compared with subjects without tumors. Furthermore, the patients with unresectable tumors showed an even more reduced pancreas displacement compared with the rest of the patients with pancreatic tumor. This may be related to the larger size of the unresectable tumors, but also secondary to local extension, which is associated with tumor aggressiveness.^{5–8} The normalized displacement of the pancreas regions to the total bulk abdominal motion approximated by the diaphragm motion during respiration was helpful in distinguishing between the subgroup of patients with and without pancreatic tumors. This normalization allows correction for variations in body size and breathing pattern between subjects. However, our current study was limited to a small number of subjects with pancreatic tumors. Larger studies with different types of pancreatic tumors would be helpful to assess if the measurements of pancreatic and tumor displacement are associated with fibrosis and tumor aggressiveness.

This initial feasibility study was performed on a limited number of patients, partially due to the novelty of the imaging and reconstruction method and due to the low number of patients with pancreatic lesions available. Also, no histological information was available to diagnose these lesions as pancreatic ductal adenocarcinoma or to further assess the aggressiveness of the tumors. Although strong statistical evidence still needs to be gathered to support our initial findings, we want to emphasize the potential of free-breathing respiratory sorted XD-GRASP imaging to estimate the pancreas and pancreatic tumor deformation during normal respiration.

In future studies, we plan to further investigate the relation between the tumor size, stage, and aggressiveness to the derived stiffness measure and to compare these results to findings from MRE.

In this study, we included a small number of subjects, in addition to our own patient cohort, acquired in a different center, but with the same free-breathing radial acquisition protocol. While this could potentially introduce an additional source of error due to scanner variability, we wanted to maximize the amount of data available in this preliminary study. The robustness of our analysis method still needs further investigation when a larger multicenter dataset becomes available.

Computing a precise deformation field from highly undersampled and relatively low-resolution MRI series is another challenge. In our experiments, the L1–L2 method led to discontinuous motion within certain imaging regions, and the L2 regularizer can promote oversmoothing across image boundaries. Other recent optical flow methods use a Total Variation regularization rather than L2 regularization³³ (ie, an L1 regularizer). Total Variation promotes smooth transitions from the optical flow fields calculated at either boundary of the organs. However, these methods may not be robust to the gray-level

fluctuations present in MR images. If the end goal is to compute the local pancreatic strain tensors that use the spatial gradients of the deformation field, then a more robust displacement map is required. To this end, we will continue to investigate the use of other registration algorithms to compute the breathing-induced deformation field.

In conclusion, the free-breathing XD-GRASP MRI acquisition method not only produced diagnostic-quality images for the assessment of the pancreas, but also offers additional information about the pancreas displacement as a result of respiratory motion. We have shown that it is possible to compute local pancreas displacement in response to respiration from respiratory motion-sorted XD-GRASP reconstructed data based on 3D feature tracking using an optical flow method. We noted a larger displacement of the pancreas tail compared with the more fixed pancreas head. In the case of patients with pancreatic tumors, the average displacement was significantly reduced compared with the pancreas without tumors, but further validation is needed in a larger patient cohort. Nevertheless, XD-GRASP MRI could in the future potentially contribute to the biomechanical assessment of the pancreas and pancreatic tumors.

Acknowledgment

The reconstruction tasks were performed under the rubric of the Center for Advanced Imaging Innovation and Research (CAI²R), an NIBIB Biomedical Technology Resource Center. We thank Jeong Hee Yoon, MD, Associate professor of Radiology, Seoul National University Hospital for sharing the additional data.

Contract grant sponsor: National Institutes of Health (NIH); Contract grant number: P41 EB017183.

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FIGURE 1:

(a) k-space data-sorting procedure based on a respiratory motion signal in XD-GRASP. (b) Undersampled motion-sorted data in each respiratory state is reconstructed using compressed sensing and parallel imaging.

FIGURE 2:

Time series showing a single slice of an XD-GRASP reconstructed abdominal MRI in all respiratory motion states (from top-left: end-expiration to bottom-right: end-inspiration).

FIGURE 3:
Magnitude of the local displacement vectors for each pancreatic region: head (red), body (green), tail (blue), and tumor (yellow) for patients with a resectable tumor.

FIGURE 4:

Image quality scores for end-expiratory phase XD-GRASP (blue) vs. conventional breath-held T₁W GRE (red) based on two observers for three measures: overall image quality, pancreatic edge sharpness, and splenic vein clarity, and level of the artifacts. Boxplots show mean, median, 25–75 percentiles, and outliers. XD-GRASP image quality is significantly higher based on all image quality measures.

FIGURE 5:

Average normalized local displacement ($\pm$ SD) is significantly higher for tail when compared with the body and head. Significant differences ($P < 0.05$) between each pair or regions along the respiratory dimension are marked on the top.

FIGURE 6: Average displacement (top) and normalized displacement (bottom) of three pancreatic regions (head, body, tail) for subgroups of patients with and without pancreatic tumors, as well as average displacement of all resectable pancreatic lesions compared with the unresectable tumors. Note that the normalized displacement provides a better separation between the subgroups with and without tumors.

FIGURE 7:

Correlation between the average displacement regions and the displacement of the diaphragm for each patient.

TABLE 1.

Image Quality Parameters and Score

Quality measure	1	2	3	4
Overall image quality	Unacceptable	Poor	Acceptable/ good	Excellent
Pancreatic edge sharpness and splenic vein clarity	Unreadable	Moderate blur	Mild blur	No blur
Level of the artifacts	Unreadable	Moderate artifact	Mild artifact	No artifact

TABLE 2.

Bidimensional Measurements of Pancreatic Tumors in the Axial Plane and Their Locations

#	Size (cm)	Resectable/unresectable	Position (head/body/tail)
1	3.3×1.6	Resectable	Body
2	1.3×1.2	Resectable	Tail
3	1.1×1.0	Resectable	Head/body
4	1.4×1.3	Resectable	Head
5	0.8×0.7	Resectable	Body
6	9.0×8.4	Unresectable	Head/body/tail
7	1.1×0.7	Borderline	Head
8	1.2×0.6	Resectable	Head
9	6.9×2.0	Unresectable	Head