

Comparison of Endoscopic Ultrasound, Computed Tomography and Magnetic Resonance Imaging for Preoperative Tumor-Size Assessment in Resected Pancreatic Neoplasms

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Abstract

Background and Aims

Current imaging-based T staging of pancreatic cancer relies primarily on computed tomography (CT), magnetic resonance imaging (MRI), and endoscopic ultrasound (EUS). However, discrepancies are frequently observed between tumor size reported on CT or MRI and the actual size measured after surgery. This study aimed to compare the absolute deviation of EUS with that of CT and MRI in evaluating pancreatic tumor size.

Methods

This retrospective single-center study included 60 patients with confirmed pancreatic malignancy who underwent surgical intervention, endoscopic ultrasound (EUS), computed tomography or magnetic resonance imaging. Tumor size measured by en bloc resection was regarded as the reference standard. Measurements obtained from EUS were compared with those from CT and MRI to evaluate relative precision. The primary outcome was absolute deviation of evaluating tumor size by different imaging techniques.

Results

In tumor smaller than 40 mm, EUS demonstrated the lowest mean absolute error (MAE) in tumor size measurement compared with surgical specimen (0.41), followed by MRI (0.47) and CT (0.68). Paired analysis showed EUS was more accurate than CT ($n = 48$, $p = 0.03$; 95% CI: -0.52 to -0.03).

Conclusions

In this retrospective surgical cohort, EUS showed lower absolute tumor-size deviation than CT for tumors < 40 mm, whereas its accuracy was comparable to MRI. These findings support further evaluation of EUS as a complementary modality for preoperative tumor-size assessment.

Introduction

Pancreatic cancer remains one of the most lethal malignancies, with prognosis largely dependent on accurate T staging at diagnosis. Among the various factors influencing staging, tumor size plays a pivotal role in determining the T category within the TNM classification system. Among the various factors influencing staging, tumor size plays a pivotal role in determining the T category within the TNM classification system. Accurate tumor-size assessment is therefore clinically important, as it contributes to disease staging, assessment of resectability, and multidisciplinary treatment planning¹⁻². Larger tumors are therefore associated with more advanced disease, reduced resectability, and increased likelihood of complex perioperative management, all of which directly influence therapeutic strategies and survival outcomes.

Beyond its role in staging, tumor size is also a well-recognized prognostic indicator. Numerous studies have demonstrated that patients with smaller tumors generally exhibit better overall survival and higher rates of curative resection compared with those harboring larger lesions^{3–5}. Tumor size correlates with biological aggressiveness and the probability of metastatic spread, making precise measurement critical not only for accurate T staging but also for predicting prognosis and guiding individualized treatment planning.

However, discrepancies in size estimation across imaging modalities and between preoperative assessment and pathological findings present ongoing challenges⁶. These inaccuracies may lead to misclassification of disease T stage and suboptimal therapeutic decisions. Therefore, improving the measurement error of preoperative tumor size measurement is essential for optimizing both T staging and prognostic assessment in pancreatic cancer.

Endoscopic ultrasound (EUS) has become an essential diagnostic tool for evaluating solid pancreatic masses¹. Tumor size is a critical factor in pancreatic cancer assessment because it directly influences TNM staging and subsequent clinical decision making⁷. With advances in modern medical imaging, several modalities, including EUS, computed tomography (CT), and magnetic resonance imaging (MRI), are now widely used to measure pancreatic tumor size. However, no single method has yet been universally recognized as the most accurate for tumor size determination.

This study aimed to compare EUS, CT, and MRI for measuring pancreatic tumor size using surgical pathology as the reference standard.

Materials and Methods

Study Design and Patient Selection

This retrospective, single-center study was conducted at Tri-Service General Hospital in Taiwan, a tertiary referral hospital, between January 2022 and June 2026. The study was approved by the Institutional Review Board (IRB approval number: A202505188), and informed consent was waived owing to the retrospective nature of the analysis. Eligible patients were adults (≥ 18 years) with a definite diagnosis of pancreatic malignancy. Patients were excluded if (1) surgical resection was not performed, (2) EUS was not performed, (3) at least one evaluable cross-sectional imaging modality (CT or MRI), (4) pathology indicated malignancy originating from metastatic sites, or (5) image interval with surgery exceeded 120 days.

The retrospective single-center design and inclusion criteria inherently selected patients who underwent both surgical resection and EUS. This cohort therefore represents a subset of patients with resectable disease, favorable performance status, lower metastatic burden, and specific referral patterns, which may limit the generalizability of the findings.

EUS Procedure and tumor size measurement

All EUS examinations were performed using a linear-array echoendoscope (GF-UCT260; Olympus Medical Systems, Tokyo, Japan) and EU-ME2 Premier Plus machine. The endoscopist conducted dynamic scanning to identify the most representative and largest tumor cross-section. Both long and short axes were measured, and the larger value was recorded as the EUS tumor size.

CT Procedure and tumor size measurement

Pancreatic CT was performed using a multiphase contrast-enhanced protocol, typically including arterial/pancreatic and portal venous phases. Patients were scanned supine with arms elevated, using ≤ 120 kVp tube voltage and automatic current modulation. Scan coverage extended from the diaphragm to the iliac crest. Tumor size was determined as the maximal diameter measured across multiplanar and contrast-enhanced sequences. All CT tumor size measurements were confirmed during a multidisciplinary consensus meeting to reduce inter-observer variability.

MRI Procedure and tumor size measurement

MRI examinations followed a pancreas-tailored protocol. Patients fasted ≥ 4 hours before imaging. Multiplanar T1- and T2 weighted sequences, including in-/out-of-phase T1 GRE, high-resolution T2, and MRCP sequences, were obtained. Gadolinium-based contrast (2 cc/sec) was administered. Tumor size was determined as the maximal diameter measured across multiplanar and contrast-enhanced sequences. All MRI tumor size measurements were confirmed during a multidisciplinary consensus meeting to reduce interobserver variability.

Final Diagnosis and Histologic Confirmation

Pathological tumor size was measured using fresh surgical specimens, assessed by macroscopic examination of the tumor. The measurement was defined as the maximum diameter of the tumor portion, ensuring consistency across cases. Final diagnosis was based on histopathologic evaluation of resected tumor specimens. Pancreatic ductal adenocarcinoma, neuroendocrine tumors, GISTs, and pancreatic carcinomas were classified as malignant. The complete-cohort analysis is the primary analysis, with a tumor smaller than 40 mm subgroup (a subgroup analysis was performed for tumors < 40 mm, a clinically relevant size threshold corresponding to the T2/T3 boundary for pancreatic ductal adenocarcinoma); all classifications were based on pathological tumor size.

Outcome Measures

The primary outcome was the absolute deviation of tumor size measurement among the three imaging modalities: EUS, CT, and MRI and we used the surgical specimen measurement as the reference

standard. Accuracy was evaluated by comparing absolute deviation (|imaging size – surgical size|) for each modality.

Statistical Analysis

Continuous variables were summarized as means $\pm$ standard deviation (SD). Categorical variables were presented as frequencies and percentages, and group differences were assessed using the Chi-square test or Fisher's exact test when appropriate. For all analyses, a two-tailed p-value < 0.05 was considered statistically significant. Statistical analyses were conducted using GraphPad Prism or SPSS software version 24 (IBM Corp., Armonk, NY, USA).

Results

Patient Characteristics

A total of 401 patients were diagnosed with pancreatic malignancy during the study period. After applying exclusion criteria: surgery was not done ($n = 279$), EUS was not done ($n = 8$), at least one evaluable cross-sectional imaging modality (CT or MRI) ($n = 3$), diagnosis based on metastatic lesion ($n = 25$), or image interval with surgery exceeded 120 days ($n = 26$). Total 60 patients were included in the final analysis (Fig. 1).

In total, 46 patients underwent all three imaging modalities (EUS, CT, and MRI), while 12 patients did not undergo MRI, and 2 patients did not undergo CT. Analyses of CT versus EUS and MRI versus EUS were performed in the respective paired subsets to ensure methodological consistency. CT and MRI measurements were unavailable in some patients despite the stated exclusion criteria because certain imaging studies were either incomplete, technically inadequate, or performed at outside institutions where image quality or access did not meet the standards required for inclusion. These practical limitations, inherent to retrospective data collection, occasionally prevented the use of all modalities despite initial eligibility, and were carefully documented to maintain transparency and internal consistency.

The mean age of enrolled patients was 65.7 ± 12.2 years, and 50.0% were male. Most patients (71.7%) were diagnosed with pancreatic ductal adenocarcinoma (PDAC), followed by neuroendocrine tumors (18.3%), intraductal papillary mucinous neoplasm (IPMN, 6.7%), and other neoplasms (3.3%). The PDAC group had a mean age of 68.0 ± 9.2 years, with 48.8% being male. Detailed demographics and clinical features, including smoking, alcohol use, diabetes, family history, viral hepatitis status, tumor location, disease stage and tumor size, are summarized in Table 1.

Tumors were mostly located in the head and uncinate process ($n = 40$), followed by body and neck ($n = 10$), and tail ($n = 10$). Disease stage distribution was Stage 0 ($n = 1$), Stage I ($n = 26$), Stage II ($n = 24$), Stage III ($n = 6$), and Stage IV ($n = 3$). Lesions < 40 mm accounted for 83.3% ($n = 50$) of cases. Lesions

larger than 40 mm accounted for 16.7% (n = 10). Table 2 showed similar time interval between imaging modalities and surgery: EUS has 34.0 ± 39.6 days, CT has 37.3 ± 37.4 days, and MRI has 41.8 ± 45.6 days.

Tumor Size Comparison

In tumor size smaller than 40 mm, EUS demonstrated the lowest mean absolute error (MAE) in tumor size measurement compared with pathology (0.41), followed by MRI (0.47) and CT (0.68). In paired analyses, EUS was more accurate than CT (n = 48, p = 0.03; 95% CI: -0.52 to -0.03), while no significant difference was observed between EUS and MRI (n = 41, p = 0.8; 95% CI: -0.21 to 0.17). CT measurements deviated more than MRI (n = 39, p = 0.01; 95% CI: 0.06 to 0.55) (Fig. 2). For tumor larger than 40 mm, there is no difference between the 3 imaging modalities.

Agreement Analysis of Imaging Modalities

Bland–Altman plots demonstrated that, for EUS (n = 60), the mean bias was -0.23 cm (95% CI, -0.44 to -0.02 cm), with limits of agreement of -1.81 cm (95% CI, -2.16 to -1.45 cm) and 1.34 cm (95% CI, 0.98 to 1.70 cm). For CT (n = 58), the mean bias was -0.47 cm (95% CI, -0.87 to -0.06 cm), with limits of agreement of -3.49 cm (95% CI, -4.18 to -2.79 cm) and 2.55 cm (95% CI, 1.85 to 3.24 cm). For MRI (n = 48), the mean bias was -0.16 cm (95% CI, -0.52 to 0.19 cm), with limits of agreement of -2.57 cm (95% CI, -3.18 to -1.96 cm) and 2.24 cm (95% CI, 1.63 to 2.85 cm).

Proportional bias was assessed by regressing the imaging–pathology difference against the mean of the imaging and pathological measurements. A statistically significant proportional bias was observed for EUS (slope = -0.186, 95% CI -0.337 to -0.035; p = 0.017), indicating increasing underestimation as tumor size increased. No statistically significant proportional bias was identified for CT (slope = 0.099, 95% CI -0.196 to 0.395; p = 0.504) or MRI (slope = -0.265, 95% CI -0.622 to 0.092; p = 0.142) (Fig. 3).

Discussion

In this study, for smaller pancreatic tumor (< 40 mm), EUS provides lower measurement error than CT in smaller resected tumors, with performance comparable to MRI, but exhibits size-dependent proportional bias. These findings highlight the inherent advantages of EUS—its high resolution and close-proximity imaging—which make it especially effective for characterizing pancreatic tumors. It is also noteworthy that CT and MRI measurements in this study were reviewed during a multidisciplinary combined meeting for pancreatic cancer, a process that helps maintain measurement quality and consistency across imaging modalities. Collectively, these results suggest that the clinical value of precise preoperative measurement by EUS is crucial for accurate T staging and treatment planning.

An additional methodological consideration involves operator variability. Because CT, MRI, and EUS were performed by different operators following routine clinical practice, and because the study was retrospective, the examiners were unaware that their measurements would later be analyzed for research purposes. This real-world setting may help reduce measurement distortion associated with operator expectations, which can occur in prospective or randomized trials; however, retrospective

studies are also inherently vulnerable to missing data, inconsistent protocols, unmeasured confounding, and selection bias. Therefore, while the retrospective design provides valuable insight into routine performance, these limitations must be acknowledged, and the comparative absolute deviation observed among the three modalities should be interpreted with appropriate caution.

The generalizability of the findings may be influenced by several factors beyond ethnic or regional differences. While tumor size measurement relies primarily on imaging physics, acquisition parameters, and operator technique, broader elements such as center expertise, EUS operator experience, imaging protocols, multidisciplinary review, surgical indications, and pathology processing can also affect reproducibility. Unlike treatment response or genetic predisposition, size assessment is fundamentally morphology-based; however, institutional practices and operator variability may introduce differences across centers. Therefore, although the study was conducted at a single institution, the applicability of the methodology and conclusions regarding modality-specific accuracy should be interpreted with caution, acknowledging that generalizability may be limited by practice-related factors.

EUS plays a particularly important role in the detection and characterization of smaller or early-stage pancreatic cancers^{8,9}. Its superior spatial resolution and ability to visualize the pancreas at close proximity allow EUS to identify subtle parenchymal changes and delineate small lesions that may be overlooked or underestimated on CT or MRI¹¹. The high precision observed in our study for tumors < 40 mm likely reflects this inherent technical advantage. Early-stage lesions often lack distinct radiologic features on cross-sectional imaging, making accurate size estimation challenging¹¹; however, EUS can provide clearer margin definition and more reliable measurement¹². This enhanced precision is clinically meaningful, as early detection and accurate size assessment directly influence T staging and downstream treatment decisions, including the timely identification of patients who may proceed to surgery versus those who may require neoadjuvant therapy. Furthermore, the superiority of EUS over CT remained significant after adjustment for multiple potential confounders and was consistently demonstrated in mixed-effects model, supporting the robustness of the findings.

Several limitations should be acknowledged. The sample size was relatively small, which may affect statistical power and limit broader applicability. Moreover, the sample size of non-PDAC cases was insufficient to allow for meaningful subgroup statistical analysis. Given the inclusion of neuroendocrine tumors, IPMN, and other neoplasms—which differ in growth pattern, margin definition, imaging appearance, and pathological assessment—we recognize that our findings cannot be generalized to all pancreatic malignancies. Time intervals between CT, MRI, and EUS may have introduced variability due to tumor progression or interval morphological changes; however, we excluded cases in which the image interval with surgery exceeded 120 days to minimize bias. Furthermore, our analysis of EUS performance by anatomical region did not include direct comparisons with CT or MRI within each region due to limited subgroup sample sizes; therefore, these findings should be interpreted cautiously and considered exploratory. Moreover, the retrospective, single-center design and inclusion of only patients who underwent surgical resection and EUS inherently selected for individuals with resectable disease, favorable performance status, and lower metastatic burden. As a result, the findings may not be

generalizable to patients with unresectable pancreatic cancer, borderline resectable disease, locally advanced disease, or metastatic disease. Finally, the cohort consisted exclusively of patients who underwent EUS, limiting applicability to settings where EUS is not routinely performed. Differences in imaging availability and institutional practices may also affect reproducibility across centers. These factors should be considered when interpreting the findings. Future multicenter studies with larger cohorts and standardized imaging timelines are warranted to further validate and refine these results.

Conclusion

In this selected retrospective cohort of resected pancreatic neoplasms, EUS showed a lower absolute deviation from pathological tumor size than CT, particularly among lesions with a pathological diameter below 40 mm. These findings require confirmation in larger prospective studies using standardized, blinded measurements and clinically relevant T stage classification outcomes.

Abbreviations

CT	computed tomography
EUS	endoscopic ultrasound
MRI	magnetic resonance imaging
MAE	mean absolute error
NET	neuroendocrine tumor
IPMN	intraductal papillary mucinous neoplasm
HBV	hepatitis B virus
HCV	hepatitis C virus
SD	standard deviation
CI	confidence interval
MRCP	magnetic resonance cholangiopancreatography

Declarations

Disclosures:

The authors disclose no conflicts.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Tri-Service General Hospital, Taiwan (IRB approval number: A202505188). Given the retrospective design, the requirement for informed consent was waived in accordance with institutional regulations.

IRB statement:

TSGHIRB No. A202505188

Research institution Tri-Service General Hospital

Principle investigator Dr. Chen Hsuan-Wei

Co-investigator Dr. Chia-Che Wu

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Extended Period of Patients enrollment 2022/1/1 2026/6/30

Human Ethics and Consent to Participate declarations: This study was conducted in accordance with the Declaration of Helsinki. The institutional review board approved the retrospective study protocol and granted a waiver of informed consent given the use of existing clinical and imaging data. No prospective interventions were performed, and all patient information was handled in compliance with institutional and national ethical standards.

Consent for publication

Not applicable, as no individual patient data (images, videos, or identifiable information) are included in this manuscript.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy and institutional restrictions but are available from the corresponding author upon reasonable request and with permission from Tri-Service General Hospital, National Defense Medical University.

Competing Interests

The authors declare that they have no competing interests.

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Author's contributions

Dr. Chia-Che Wu drafted the main manuscript text.

Dr. Te-Jung Chuang and Dr. Jung-Chun Lin prepared Figures 1–3.

Dr. Hsuan-Wei Chen contributed to the conception and design of the study, acquisition, analysis, and interpretation of data, development of new software used in the work, and substantive revision of the manuscript.

All authors reviewed and approved the final version of the manuscript.

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Tables

Table 1: Patient Characteristics.

Characteristics	Adenocarcinoma	NET	IPMN	others
Patient number (%)	43 (71.7%)	11 (18.3%)	4 (6.7%)	2 (3.3%)
Patient age (yrs)	68.0 ± 9.2	61.0 ± 12.2	73.5 ± 10.7	30.5 ± 16.3
Gender (male)	21 (48.8%)	4 (36.4%)	4 (100.0%)	1 (50.0%)
Smoking, no. (%)	10 (23.3%)	1 (9.1%)	2 (50.0%)	0 (0.0%)
Alcohol, no. (%)	6 (14.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Diabetes mellitus, no. (%)	19 (44.2%)	3 (27.3%)	2 (50.0%)	0 (0.0%)
Family history, no. (%)	3 (7.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
HBV, no. (%)	5 (11.6%)	1 (9.1%)	0 (0.0%)	0 (0.0%)
HCV, no. (%)	1 (2.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Tumor location				
Head/Uncinate process	32	5	2	1
Body/Neck	7	2	1	0
Tail	4	4	1	1
Disease stage				
Stage 0	0	0	1	0
Stage I	19	5	1	1
Stage II	18	4	1	1
Stage III	4	1	1	0
Stage IV	2	1	0	0
Tumor size				
≥40mm	6	0	3	1
<40mm	37	11	1	1

Table 2: Resected tumor size evaluated by different techniques.

	Number	Mean ± SD(mm)	Mean absolute error (MAE) and 95% CI (mm)	Time Interval with Surgery (TIS) ± SD (day)	Median, IQR and full range of TIS (day)
Surgery	n=60	31.3 ± 15.0	—	—	—
CT	n=58	26.5 ± 16.5	7.2 (4.7-9.7)	37.3 ± 37.4	22.0, 24.3, 117
MRI	n=48	29.2 ± 10.5	4.2 (3.2-5.1)	41.8 ± 45.6	21.0, 45.3, 119
EUS	n=60	29.0 ± 12.6	4.4 (3.3-5.6)	34.0 ± 39.6	15.5, 29.5, 110

Figures

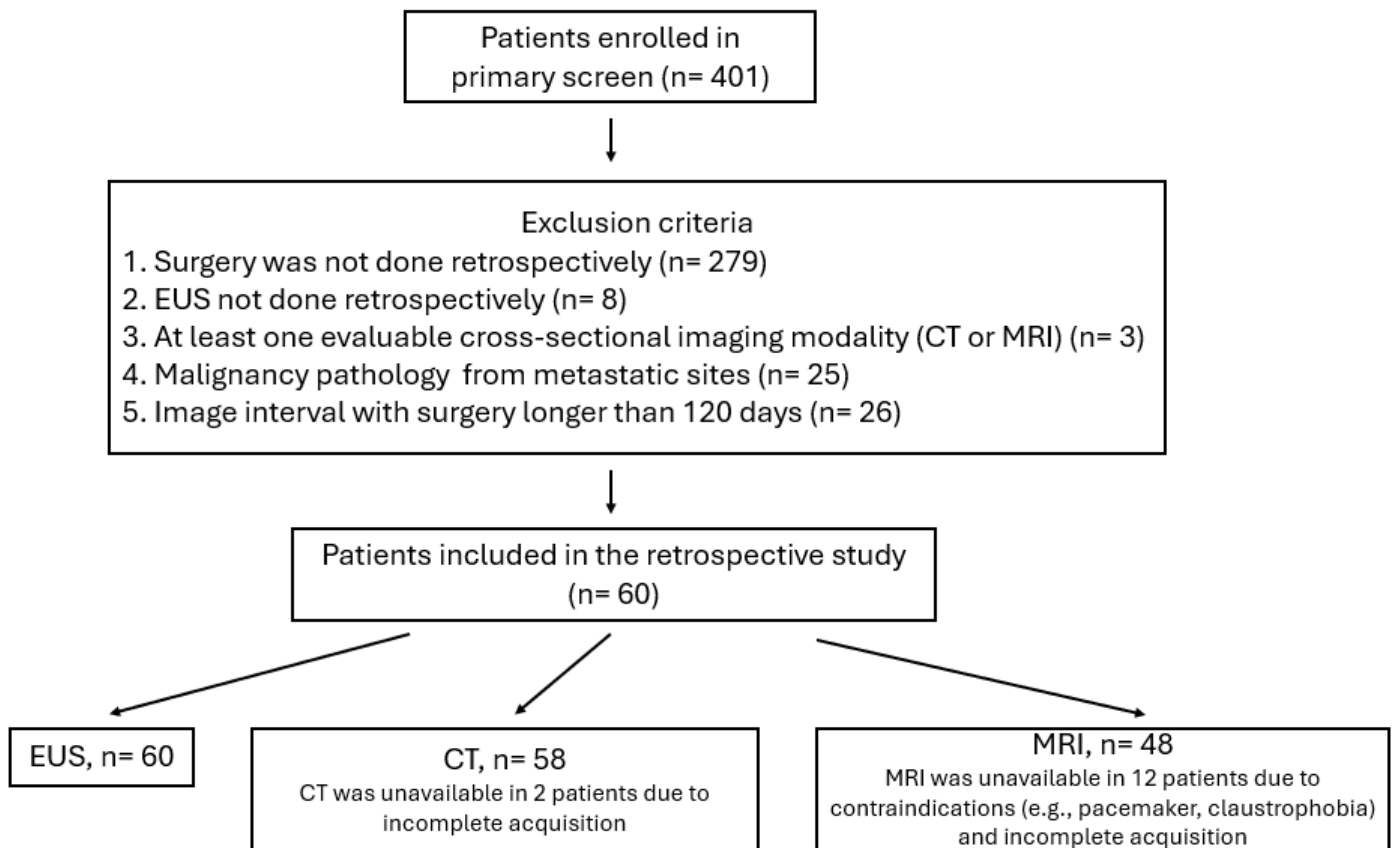


Figure 1

Flow chart of our study.

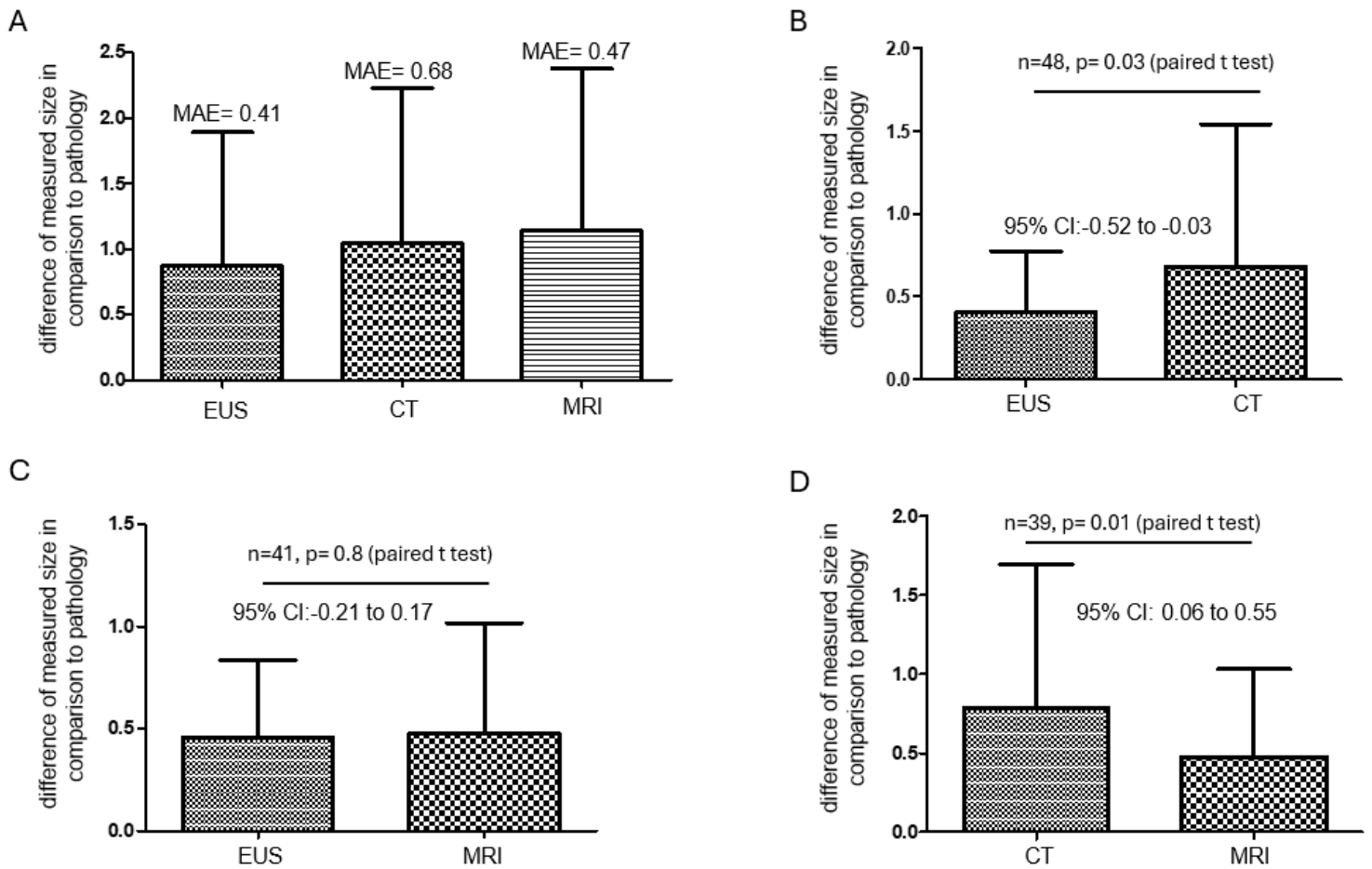


Figure 2

Absolute tumor-size measurement errors for pancreatic tumors less than 40 mm. (A) Mean absolute errors (MAEs) for EUS, CT, and MRI relative to pathological tumor size. (B–D) Pairwise comparisons of absolute measurement errors among imaging modalities in patients with paired measurements. Error bars indicate SD. The reported 95% confidence intervals represent the paired mean differences in absolute error.

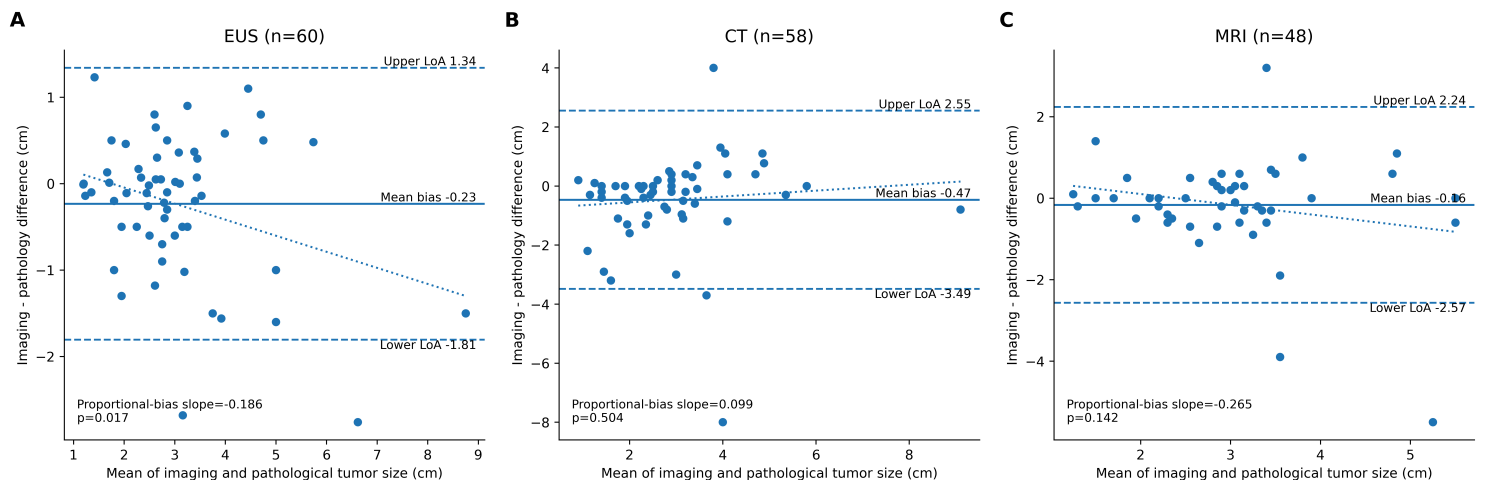


Figure 3

Bland-Altman plots.