Comparison of Diagnostic Efficacy of US, CT, and MRI for Pancreatic Intraductal Papillary Mucinous Neoplasms

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Objective: Imaging modalities for pancreatic intraductal papillary mucinous neoplasm (IPMN) often provide a large amount of information, and an adequate comparison of their diagnostic efficacies cannot be made by simply referring to the diagnostic accuracy rates. The aim of the study was to apply a novel scoring system to evaluate the pancreatic IPMN diagnostic efficacy of transabdominal ultrasound (TAUS), computed tomography (CT), and magnetic resonance imaging (MRI).

Methods: The clinical and diagnostic imaging data of 42 patients with pancreatic IPMN diagnosed at Fujian Medical University Union Hospital between January 2014 and November 2020 were retrospectively analyzed. We applied our scoring system for the quantitative, location, and qualitative diagnosis of each imaging modality, and the diagnostic efficacy was determined.

Results: The mean rank scores of quantitative diagnosis for MRI, CT, and TAUS were 53, 48.96, and 48.54, respectively ($P = 0.267$). The mean rank scores of location diagnosis for these three methods were 51.72, 49.58, and 48.97, respectively ($P = 0.752$). The mean rank scores of qualitative diagnosis for MRI, CT, and TAUS were 59.69, 41.08, and 51.18, respectively; the difference was statistically significant ($P = 0.015$).

Conclusions: The novel scoring system could comprehensively and accurately evaluate the diagnostic efficacy of TAUS, CT, and MRI for pancreatic IPMN. MRI had the highest quantitative, localization, qualitative, and comprehensive diagnostic efficacy.

Key words: Diagnosis; Ultrasonography; Computed tomography; Magnetic resonance imaging; Pancreatic neoplasm

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Pancreatic intraductal papillary mucinous neoplasm (IPMN) is an exocrine tumor characterized by abnormal papillary hyperplasia in the pancreatic duct and the production of a large amount of mucus [1,2]. It has an incidence of approximately 0.31 – 4.35/100,000 and is more common in elderly men [3,4]. According to the 2019 WHO classification of digestive tumors, IPMN is histologically classified into low/moderate-grade dysplasia, high-grade dysplasia, and IPMN with an associated invasive carcinoma [5]. The clinical manifestations of pancreatic IPMN are predominantly occult and lacking in specificity; initial imaging examination is often made by transabdominal ultrasound (TAUS) and computed tomography (CT), while endoscopic ultrasonography (EUS), magnetic resonance imaging (MRI)/magnetic resonance cholangiopancreatography (MRCP), or endoscopic retrograde cholangiopancreatography (ERCP) are often
used for further examination [6-9].

EUS is valuable for the diagnosis of pancreatic IPMN. It uses a high-frequency probe with high image resolution which has a high sensitivity to pancreatic ducts, cystic lesions, and mural nodules; and allows for the use of fine needle aspiration [10-12]. However, EUS is invasive and patient compliance is poor. Patients with serious cardiovascular and cerebrovascular diseases and mental disorders are not candidates for EUS. TAUS primarily uses low-frequency convex array probes, and the image resolution is not as good as that of EUS. However, it is a non-invasive imaging modality with good compliance and broad indications. With adequate preparation before examination and the application of a gastroduodenal acoustic window, pancreatic image quality is often satisfactory. Meanwhile, for underweight patients, a high-frequency linear array probe is available, which has an image quality similar to that of EUS.

When comparing the diagnostic efficacy of different imaging modalities, traditional statistical methods predominantly refer to the diagnostic accuracy rate, which is the evaluation index of the total coincidence rate. However, imaging reports contain a large amount of information, including quantitative diagnosis (tumor number), location diagnosis (tumor location), and qualitative diagnosis (tumor differential diagnosis), all of which cannot simply be classified into “right” or “wrong.” At present, scoring methods have been widely used in the diagnosis, staging, and evaluation of disease severity [13-17]. In this study, a novel scoring method was developed and applied to compare the diagnostic efficacy of TAUS, CT, and MRI for pancreatic IPMN.

**Materials and Methods**

This retrospective study was approved by the ethics committee (approval no. 2020KY058) of the Fujian Medical University Union Hospital, China. The requirement for informed consent was waived by the ethics committee. All study protocols were performed in accordance with the relevant guidelines and regulations.

**Patients**

We retrospectively collected the multiple imaging data of 42 patients with pathologically confirmed pancreatic IPMN who underwent pancreatoduodenectomy at Fujian Medical University Union Hospital between January 2014 and November 2020. There were 35 males and 7 females, aged 31 – 74 years, with an average age of 60.5 ± 10.0 years. Among the 42 included patients, 34, 36, and 29 underwent TAUS, CT, and MRI examination (3 with MRI and MRCP simultaneously), respectively, within two weeks before surgery.

**Imaging examination**

Patients fasted at least 8 hours prior to undergoing imaging examinations. For TAUS, ultrasound diagnostic instruments (Aplio 500, Toshiba, Tokyo, Japan; LOGIQ E9, GE Healthcare, Chicago, Japan; LOGIQ E9, GE Healthcare, Chicago, Japan) with 3.5-MHz probes (PVT-375BT and C1-6-D, respectively) were used. The gastroduodenal acoustic window was created by drinking 500 ml warm water or echoic gastrointestinal contrast agent. The pancreas was scanned in multiple sections, including cross-, longitudinal, and oblique sections. The lesion number, location, size, shape, echogenicity, pancreatic duct, and color Doppler flow signals of the pancreatic lesions were recorded in detail. One patient received contrast-enhanced ultrasonography (CEUS) by intravenous administration of SonoVue (Bracco SpA, Milan, Italy).

For the CT examination, a Sensation 40-row scanner (Siemens Healthcare, Erlangen, Germany) was used, with a slice thickness of 5 mm, a thin layer of 2 mm, a voltage of 120 kV, and a current of 250 mA. The CT contrast agent (Ioversol injection, Hengrui Pharmaceutical Co., Ltd., Lianyungang, Jiangsu) was injected intravenously; at 35 s and 70 s after injection, a contrast-enhanced scan in the pancreatic parenchymal phase and a contrast-enhanced scan in the portal venous phase were done, respectively.

For MRI examination, a Discovery MR750 3.0 T (GE Healthcare, Chicago, IL) superconducting magnetic resonance scanner with an eight-channel abdominal coil was used. The main scanning sequences used were the conventional MRI axial scan, diffusion-weighted imaging scan, and T1-weighted enhanced scan. Contrast agent (Gd-DTPA, Bayer Company, Leverkusen, Germany) was used for enhanced scanning and injected by a high-pressure syringe through the vein of the upper extremity. The arterial and parenchymal scans were performed at 18-25s and 40-45s after injection.

**Scoring protocol**

The medical records of the 42 enrolled patients, including patient information; clinical presentation; TAUS, CT, and MRI imaging reports; and postoperative pathology results were collected and analyzed. The scoring system including the number of lesions, their location, and qualitative diagnosis scores were designed as follows. Regarding the quantitative diagnosis, if the imaging detected all the lesions, 2 points were awarded; if a partial number of lesions were detected, 1 point was awarded; if no lesions were detected (missed diagnosis), 0 points were awarded. For the lesion location, if the imaging located all lesions correctly, 2 points were awarded; if it located some lesions correctly, 1 point was awarded; and if did not locate any lesions correctly,
0 points were awarded. As for the qualitative diagnosis (radiologic impression), the radiologist often suggests one or more pathological diagnoses, such as IPMN, cystadenoma, or cancer, for differential diagnosis of pancreatic masses. Thus, for the qualitative diagnosis score, if the first suggested diagnosis was IPMN, 2 points were awarded; if the first suggested diagnosis was not IPMN, but the second diagnosis was IPMN, 1 point was awarded; if IPMN was not suggested (or no qualitative diagnosis was provided), 0 points were awarded. The comprehensive diagnostic efficacy score was calculated as the sum of the three scores for each patient. The surgical pathologic results were served as reference standard.

Statistical analysis

The R statistical software package (R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analyses. The Kruskal-Wallis nonparametric test was used to assess the differences in the TAUS, CT, and MRI scores. The Dwass-Steel-Critchlow-Fligner method was used for pairwise comparison between groups. A two-sided $P$ value of $<0.05$ was considered to indicate statistical significance.

Results

Among the 42 patients with pancreatic IPMN, 21 had low/moderate-grade dysplasia, eight had high-grade dysplasia, and 13 had IPMN with an associated invasive carcinoma; twenty-nine lesions were in the head of the pancreas, nine were in the body and tail, and four were multifocal lesions distributed throughout the pancreas.

Ultrasound features

Table 1 listed the features of pancreatic IPMN on TAUS. According to the echogenicity, the lesions can be divided into cystic, mainly solid, and main pancreatic duct dilation. The cystic and mainly solid lesions were often accompanied by main pancreatic duct dilation (Fig. 1,2,3).

Quantitative diagnosis scores

Since the original scores of the three imaging modalities were non-normally distributed, they could not be presented as means ± standard deviation. The mean scores below were the rank scores of the Kruskal-Wallis nonparametric test.

As indicated in Table 2, the quantitative diagnosis accuracy of the three imaging modalities was the highest for MRI, followed by CT and TAUS. The mean rank scores of quantitative diagnoses for these three modalities were 53, 48.96, and 48.54, respectively, with no significant difference among the groups ($P = 0.267$).

| Feature | Finding |
|---------|---------|
| Size (mm) | $36.3 \pm 22.2$ |
| Echogenicity | |
| Cystic | 6/31 |
| Mainly solid | 16/31 |
| Main pancreatic duct dilation | 9/31 |
| Adler grade | |
| 0 | 27/31 |
| I | 4/31 |
| II | 0 |
| III | 0 |
| Pancreatic duct dilation | 25/31 |
| Inner diameter of dilated pancreatic duct, cm | $1.1 \pm 1.3$ |
| Common bile duct dilation | 3/31 |
| Inner diameter of dilated common bile duct, cm | $1.2 \pm 0.6$ |

Swollen lymph nodes | 3/31 |

Data are shown as mean ± standard deviation or number of cases.

"Among the 34 patients on whom transabdominal ultrasound was performed, 3 were missed.

Location scores

As indicated in Table 3, the location accuracy of the three imaging modalities was the highest for MRI,
followed by CT and TAUS. The mean rank scores of location diagnosis for these three modalities were 51.72, 49.58, and 48.97, respectively, with no significant differences among the groups ($P = 0.752$).

Table 2  Comparison of the quantitative diagnostic efficacy of transabdominal ultrasound, computed tomography, and magnetic resonance imaging

| Group     | Cases (n) | Correct quantity n (%) | Correct partially n (%) | Missed n (%) |
|-----------|-----------|-------------------------|-------------------------|--------------|
| TAUS      | 34        | 31 (91.18)              | 0                       | 3 (8.82)     |
| CT        | 36        | 33 (91.67)              | 2 (5.56)                | 1 (2.78)     |
| MRI       | 29        | 29 (100)                | 0                       | 0            |

TAUS, transabdominal ultrasound; CT, computed tomography; MRI, magnetic resonance imaging

Table 3  Comparison of the localization diagnostic efficacy of transabdominal ultrasound, computed tomography, and magnetic resonance imaging

| Group        | Cases (n) | Correct localization n (%) | Error localization n (%) | Missed n (%) |
|--------------|-----------|-----------------------------|--------------------------|--------------|
| Ultrasound(TAUS) | 34        | 30 (88.24)                  | 1 (2.94)                 | 3 (8.82)     |
| CT           | 36        | 32 (88.89)                  | 3 (8.33)                 | 1 (2.78)     |
| MRI          | 29        | 27 (93.10)                  | 2 (6.90)                 | 0            |

TAUS, transabdominal ultrasound; CT, computed tomography; MRI, magnetic resonance imaging

**Qualitative Diagnosis Scores**

Among the 34 patients who underwent TAUS examination, 26 were first diagnosed with IPMN, and 19 of them were correct, including 17 pancreatic IPMNs and two pancreatic IPMNs with invasive carcinoma diagnosed as malignant tumors (MTs) (Table 4).

Of the 36 patients who underwent CT examination, 12 (33.33%) received a correct first suggested diagnosis, 10 of which were IPMN and two of which were IPMNs with invasive carcinoma diagnosed as MTs. Three (8.33%) received a correct second diagnoses, one of which was an IPMN, and the remaining two were IPMNs with invasive carcinoma diagnosed as MTs.

Of the 29 patients who underwent MRI examination, 18 (62.07%) received a correct first diagnosis, 17 of which were IPMN and one of which was an IPMN with invasive carcinoma diagnosed as an MT. Six (20.69%) received a correct second diagnosis, five of which were...
IPMN and one of which was an IPMN with invasive carcinoma diagnosed as an MT.

The qualitative diagnostic efficacy significantly differed among the three imaging modalities ($P = 0.015$). The mean rank scores of qualitative diagnosis for TAUS, CT, and MRI were 51.18, 41.08, and 59.69, respectively. The qualitative diagnostic efficacy of TAUS was higher than that of CT, and the diagnostic efficacy of MRI was higher than that of TAUS, but there was no significant difference between each pair ($P = 0.272$ and 0.459, respectively). However, the qualitative diagnostic efficacy of MRI was significantly higher than that of CT ($P = 0.008$).

**Table 4** Comparison of the qualitative diagnostic efficacy of transabdominal ultrasound, computed tomography, and magnetic resonance imaging

| Group | Cases ($n$) | Correct 1st diagnosis $n$ (%) | Correct 2nd diagnosis $n$ (%) | Non-qualitative diagnosis $n$ (%) | Missed $n$ (%) |
|-------|-------------|------------------------------|------------------------------|----------------------------------|---------------|
| TAUS  | 34          | 19 (55.88)                   | 0                            | 2 (5.88)                        | 3 (8.82)       |
| CT    | 36          | 12 (33.33)                   | 3 (8.33)                     | 9 (25.00)                       | 1 (2.78)       |
| MRI   | 29          | 18 (62.07)                   | 6 (20.69)                    | 0                                | 0              |

Comprehensive diagnosis scores

The comprehensive diagnostic efficacy significantly differed among the three imaging modalities ($P = 0.025$). The average rank scores were 50.76, 41.71, and 59.40 for TAUS, CT, and MRI, respectively. The diagnostic efficacy of TAUS was higher than that of CT, and the diagnostic efficacy of MRI was higher than that of TAUS, but the differences were not significant ($P = 0.403$ and 0.480, respectively). However, the diagnostic efficacy of MRI was significantly higher than that of CT ($P = 0.013$).

**Discussion**

As per the general pathological classification, pancreatic IPMN is divided into main duct, branch duct, and mixed types [18,19]. The main duct type manifests as a dilated main pancreatic duct with mural nodules, while the branch duct type is characterized by a tumor located solely in the branch pancreatic duct. When both the main and branch pancreatic ducts are involved, IPMNs are classified as the mixed type.

According to the echogenicity, we roughly divided pancreatic IPMN into cystic, mainly solid, and main duct types. Dilation of the main pancreatic duct is the most common ultrasound manifestation of IPMN. If mural nodules are located in the pancreatic duct and/or focal pancreatic lesions communicating with the main pancreatic duct are found, IPMN can be diagnosed confidently by ultrasound. The most common type of pancreatic IPMN is cystic; the solid type is relatively rare. When the IPMN is located in the head of the pancreas, it may compress the common bile duct, resulting in bile duct dilation. On the other hand, the secreted mucus may block the ampulla, also leading to bile duct dilation.

Different imaging modalities have distinct advantages and disadvantages. TAUS is advantageous as it can be performed in real-time, involves no radiation, and is highly cost-effective. Ultrasound can sensitively detect pancreatic duct dilation and cystic lesions. However, TAUS is highly dependent, for example, on image quality and the radiologist’s diagnostic experience. With the development and application of new ultrasound technology, CEUS and shear wave elastography have demonstrated good diagnostic value in the diagnosis of pancreatic diseases [20-25].

Compared to TAUS, CT can better recognize the relationship between pancreatic lesions and the surrounding tissues in that it is relatively less affected by the patient's body mass index and gastrointestinal gas [26,27]. However, CT involves radiation exposure, which is of particular concern for children and pregnant women, and some patients who are allergic to contrast agents cannot undergo enhanced CT examination. MRI examination is non-invasive and has a high resolution for soft tissues, which can better display the range of pancreatic duct lesions. MRCP is more sensitive than ERCP in imaging pancreatic cystic lesions and has good diagnostic value [28,29]. Nevertheless, MRI is expensive and time-consuming. In addition, in some patients, such as those with pacemakers and other metallic implants, MRI cannot be performed.

The information obtained from the diagnostic imaging of tumors is varied and complex. This makes it difficult to simply use the diagnostic accuracy rate to evaluate the diagnostic efficacy. In this study, we established a novel scoring method by assigning scores according to the diagnostic results.

Quantitative diagnosis is of great significance to determine whether there is pancreatic disease and to
determine the number of lesions. Most pancreatic IPMNs are asymptomatic and are detected through imaging. When the imaging examination misses the lesion, delays occur in diagnosis and treatment, resulting in undesirable consequences. In this study, preoperative TAUS examination missed lesions located in the tail of the pancreas in three cases. MRI had higher sensitivity in detecting pancreatic lesions and had the best quantitative diagnostic value.

Pancreatic IPMNs may be associated with multiple lesions, and some smaller mural nodules may be missed by preoperative imaging, which affects surgical planning and patient prognosis. Therefore, accurately locating lesions is of great importance during surgery to fully remove the lesion; thus, in our scale, 2 points were awarded for identifying the correct location. According to the scoring criteria above, the location diagnostic efficacy of MRI was slightly higher than that of CT, while the location diagnostic efficacy of CT was slightly higher than that of TAUS, but the differences were not significant.

The preoperative tumor qualitative diagnosis is often rather difficult. When radiologists issue diagnostic reports, they often consider more than one radiologic impression in their differential diagnosis. Different qualitative diagnoses are arranged in order; the higher the ranking, the higher the clinical diagnostic value. This scoring system fully considers the qualitative diagnoses and assigns the scores more objectively. According to the scoring system, MRI exhibited significantly better qualitative diagnostic efficacy than CT and ultrasound.

There were several limitations in this study. First, in our hospital, due to patient compliance and the heavy endoscopist workload, among the included 42 cases of pancreatic IPMN, no one underwent EUS examination before surgery. Second, CEUS is helpful for differentiating between mucinous and real mural nodules. In this study, only one patient underwent CEUS, which may have affected the ultrasound diagnostic efficacy. Third, this was a single-center study with a small sample size. Future studies should include larger samples in order to yield more reliable data.

Conclusions
The novel scoring system could comprehensively and accurately evaluate the diagnostic efficacy of TAUS, CT, and MRI for pancreatic IPMN. MRI had the highest quantitative, localization, qualitative, and comprehensive diagnostic efficacy. This scoring method is clinically relevant and could be applied for the comparison of the efficacy of different imaging modalities in other diseases.

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Conflict of Interests
The authors declare that they have no competing interests relevant to this study to disclose.

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