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The factors that influence the diagnostic accuracy and sample adequacy of EUS-guided tissue acquisition for the diagnosis of solid pancreatic lesions

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ABSTRACT

Background and Objectives: EUS-guided tissue acquisition (EUS-TA) is the preferred method to acquire pancreatic cancer (PC) tissues. The factors associated with false-negative outcomes and inadequate samples should be explored to gain an understanding of EUS-TA.

Methods: The patients who underwent EUS-TA for suspected solid PC but whose results were false-negative were analyzed. The PC patients who underwent EUS-TA with true-positive results on the first day of every month during the study period were selected as the control group. The factors influencing diagnostic accuracy and sample adequacy were explored.

Results: From November 2017 to January 2022, 184 patients were included in the false-negative group, and 175 patients were included in the control group. Multivariate logistic regression demonstrated that the recent acute pancreatitis [odds ratio (OR): 0.478, 95% confidence interval (CI): 0.250–0.914, $P = 0.026$] and high echo component within the tumor (OR: 0.103, 95% CI: 0.027–0.400, $P = 0.001$) were independently associated with false-negative EUS-TA results. Meanwhile, using fine-needle biopsy (FNB) needles (OR: 2.270, 95% CI: 1.277–4.035, $P = 0.005$), more needle passes (OR: 1.651,95% CI: 1.239–2.199, $P = 0.005$), large tumor size (OR: 1.053, 95% CI: 1.029–1.077, $P < 0.001$), and high CA-19-9 level (OR: 1.001, 95% CI: 1.000–1.001, $P = 0.019$) were independently associated with true-positive EUS-TA outcomes. Three needle passes are needed to achieve optimal EUS-TA outcomes. Tumor location in the body/tail (OR: 1.38, 95% CI: 1.01–1.72; $P = 0.04$), needle passes ≥3 (OR: 1.90; 95% CI: 1.22–2.56; $P < 0.001$), and using the FNB needle (OR: 2.10; 95%: 1.48–2.85; $P < 0.001$) were independently related to sample adequacy.

Conclusion: Numerous factors were identified to be associated with the diagnostic accuracy and sample adequacy of EUS-TA.

Key words: pancreatic cancer; EUS-guided tissue acquisition; fine-needle aspiration; fine-needle biopsy; risk factors; sample adequacy

Introduction

Pancreatic cancer (PC) is a highly fatal disease. The 5-year survival rate of PC is approximately 10%.[1] By 2030, it is predicted that PC will rank as the second most common cancer-related cause of death.[2] About 80%–85% of PC patients cannot receive surgical resection directly due to the advanced disease stage, and chemotherapy is needed in these patients.[1] Pathological diagnosis is required for these patients before chemotherapy, and EUS-guided tissue acquisition (EUS-TA) is the preferred method to acquire tissues recommended by guidelines.[3] However, the tissue adequacy and diagnostic accuracy of EUS-TA are far from optimal. The failure to obtain a final diagnosis after EUS-TA may result in repeat procedures and delayed proper treatment.[4] Moreover, with the development of precision treatment for PC, which requires representative samples not only for an accurate diagnosis but also for subsequent molecular analysis, the performance of EUS-TA and sample adequacy could even be of greater significance.

Over the past years, several methods have been proposed to improve the diagnostic performance of EUS-TA. These methods include using different needles,[5] increasing the number of needle passes,[6] fanning techniques,[7] and varied suction techniques.[8,9] Moreover, the findings of macroscopic on-site self-assessment or rapid on-site evaluation (ROSE) in the evaluation of specimens are satisfactory in terms of adequacy, accuracy, and the quantity of needle passes, according to recent researches.[10,11] However, cytopathologists are involved in the procedures, and the condition may not be feasible in some centers.

On the other hand, disease-related variables that affect the performance of EUS-TA have received less attention than technical issues. The diagnostic accuracy of EUS-TA is adversely affected by the small size and cystic appearance of pancreatic lesions.[12] The tumor located in the pancreatic head/uncinate and the presence of fibrosis were also associated with false-negative EUS-TA results.[13,14]

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However, a conclusive analysis of this issue with all the relevant factors included is still lacking.

The main aim of the study was to evaluate the tumor characteristics and technical factors associated with the diagnostic accuracy of EUS-TA. The secondary aim was to evaluate factors associated with sample adequacy of EUS-TA.

Methods

Study design and patients

We retrospectively analyzed the clinical data of patients with PC who underwent EUS-TA at the Changhai Hospital, Shanghai, China, from November 2017 to January 2022. The study was designed to follow the principles of the Declaration of Helsinki (revision of Edinburgh, 2000).

The inclusion criteria were patients who underwent EUS-TA for suspected solid PC, but the results were negative or inconclusive. Follow-up data or repeat EUS-TA confirmed the lesions were PC. The PC patients with positive EUS-TA results who performed the procedure in the first day of every month during the study period were selected as the control group.

Cystic pancreatic lesions, prior attempts at EUS-TA, cholangiocarcinoma, or periampullary carcinoma, and missing information regarding pathology or follow-up were all exclusion criteria.

The following parameters were recorded and analyzed: patients' gender and age, initial symptoms, tumor size and location, history of acute pancreatitis (AP) and chronic pancreatitis (CP), needle type and size, number of needle passes, with biliary stent placement or not, echo of tumor, dilation of biliary duct and pancreatic duct, and carbohydrate antigen (CA) 19-9 level.

The procedures for EUS-TA

Our center is one of the largest endoscopic centers in China. The EUS-TA procedures were all performed by expert endosonographers (>1000 EUS procedures and >200 EUS-TA procedures) under conscious sedation with propofol and sufentanil.

The lesion was identified using a linear echoendoscope (EG-580UT; Fujifilm, Tokyo, Japan). The color Doppler energy helped to prevent blood flow around the puncture spot. EUS-FNA was performed using 19G, 22G, and 25G FNA needles (Cook Ltd., Limerick, Ireland; or Boston Scientific Corp., Spencer, IN). EUS fine-needle biopsy (FNB) was performed using first-generation 22G or 25G needles (Cook Ltd., Limerick, Ireland; Boston Scientific, Marlborough, MA). The Fanning technique was used in all the procedures of EUS-TA. Different TA techniques may be used in different needle passes during a single EUS-TA procedure. The suction technique and slow pull were the most frequently used to puncture the lesions. The stylet was taken out for the suction technique, which involved using a 10-cc prevacuum syringe for continuous vacuum suction. To acquire an aspirate, the needle was inserted into the lesion and moved back and forth 20 times. When using the slow pull technique, the stylet was progressively and constantly withdrawn throughout the to-and-fro motions.

After being punctured, the sample was put onto a slide and examined to see if a sample was present. If there was a macroscopic sample, it was removed and preserved in formalin for histological examination. The suitability of the aspirated sample was assessed by the endosonographers themselves because there was no ROSE available. The remaining material was utilized for a cytological smear.

Diagnostic criteria

The final diagnosis was established if one of the following criteria was followed: (1) pathological diagnosis after surgical resection and/or EUS-TA; (2) radiological follow-up identified tumor progression and/or patient died due to the disease; (3) no progression after 1 year of EUS-TA was considered a benign sign.

The samples were regarded as "inadequate" when the specimen could not provide diagnostic information. If the specimen was adequate, the cytological results were reported as follows: (1) presence of malignant cells, (2) suspicion of malignant cells, (3) atypical cells, and (4) benign cells. Lesions were identified as malignant if cytological findings indicated the presence or suspicion of malignant cells, and benign if atypical or benign cells were found.

To assess the sample's adequacy, the following criteria were adopted: 0 = inadequate (entirely or mainly represented by blood or contaminating, gastric, or duodenal mucosal flaps); 1 = poor cellularity (just above the threshold of 100 pancreatic cells); 2 = moderate cellularity (cellular clusters visible in some low-power magnification fields and many high-power magnification fields); and 3 = rich cellularity (cellular clusters visible in many low-power magnification fields and all high-power magnification fields).[15] The adequacy judgment was performed in all the patients.

Statistics analysis

The analyses were performed using SPSS version 26.0 for Windows (SPSS Inc., an IBM company, Chicago, IL). The differences in categorical variables were assessed using the χ^2 test or Fisher exact test. In terms of quantitative factors, mean ± standard deviation (SD) was used to describe factors that are in accordance with normal distribution. If not, median and interquartile range (IQR) were to describe quantitative factors. By using multiple logistic regression analyses, the factors influencing diagnostic accuracy and core tissue adequacy were explored (entry strategy). Statistical significance was defined as a 2-sided $P < 0.05$.

Results

Patients baseline characteristics

From November 2017 to January 2022, 184 PC patients who underwent EUS-TA with negative results were included. Among them, 93 (50.5%) were confirmed as PC by repeat EUS-TA or endoscopic retrograde cholangiopancreatography (ERCP) cytology, 36 (19.6%) were confirmed as PC by surgical resection, and 55 (29.9%) were confirmed as PC by follow-up. The baseline characteristics of the included patients are shown in Table 1.

Among the 184 patients, 117 (63.6%) were males and 67 (36.4%) were females. The median age was 62 (IQR: 54–68.75) years. In total, 81 tumors (44.0%) were located in the head, 20 (10.9%) tumors were located in the uncinate, 55 (29.9%) tumors were located in the body, and 28 (15.2%) tumors were located in the tail. The median tumor size was 34 mm (IQR: 26.25–40.00).

Table 1

The baseline characteristics of the study cohort.

	Negative (*n* = 184)	Positive (*n* = 175)	*P* value
Age, median (IQR), y	62.0 (54.0–68.75)	65.0 (56.0–72.0)	**0.018**
Sex (M/F)	117/67	109/66	0.678
Tumor location (H/U/B/T), *n* (%)	81/20/55/28	54/19/54/48	**0.015**
Tumor size, median (IQR), mm	34 (26.25–40.00)	39 (30–46)	**<0.001**
Symptoms, *n* (%)			0.941
no	109 (59.2)	108 (61.7)	
pain	56 (30.4)	48 (27.4)	
obstructive jaundice	26 (14.1)	25 (14.3)	
With ERCP, *n* (%)			0.854
Plastic stent	3 (1.6)	5 (2.9)	
Metal stent	10 (5.4)	4 (2.3)	
Recent acute pancreatitis history, *n* (%)	46 (25.0)	21 (12.0)	**0.002**
Chronic pancreatitis history, *n* (%)	16 (8.7)	5 (2.9)	**0.018**
Pancreatic duct dilation, *n* (%)	100 (54.3)	97 (55.4)	0.837
Distal bile duct dilation, *n* (%)	33 (17.9)	40 (22.9)	0.236
Serum CA-19-9 level, mean ± SD, ng/mL	609.8 ± 523.4	818.5 ± 508.0	**<0.001**

The data in boldface format means statical significance ($P < 0.05$).

SD: Standard deviation; IQR: Interquartile range; ERCP: Endoscopic retrograde cholangiopancreatography; H/U/B/T: Head/uncinate/body/tail.

The tumors in 109 (59.2%) were found incidentally without any symptoms; 56 (30.4%) were complicated with back or abdominal pain; and 26 patients (14.1%) were complicated with obstructive jaundice. Among the 26 patients with obstructive jaundice, 13 (50%) underwent ERCP drainage before EUS-TA, and 10 (76.9%) of them received drainage using a metal stent. Moreover, 46 patients (25.0%) of them had an AP history within 3 months, and 16 (8.7%) of them had a CP history. One hundred (54.3%) of them had dilated pancreatic ducts, and 33 (17.9%) had dilated distal bile ducts. The mean serum CA-19-9 level was 609.8 ± 523.4 ng/mL.

The imaging features and EUS-TA techniques are presented in Table 2. EUS-TA was performed in 149 (81.0%) cases using EUS-FNA needles (3 by 19G, 80 by 22G, and 66 by 25G); 35 (19.0%) were performed using needles (23 by 22G and 12 by 25G). The median needle pass was 3.0 (IQR: 2.0–4.0). Based on EUS imaging features, 134 tumors had uneven low echo, 34 had uniform low echo, and 19 had a high echo component (<50%) within the tumors.

The pathology reports showed that among the 184 patients, 81 (44.0%) were identified as atypical cells, 50 (27.2%) were benign cells, and 43 (23.4%) were inclusive.

Multivariate analysis for the prediction of false-negative EUS-TA

In total, 175 patients underwent EUS-TA on the first day of every month during the study period, and they were selected as the control group. The differences in factors between the false-negative group and the control group were compared and are presented in Tables 1 and 2.

For baseline characteristics, age was significantly older in the control group (median 62.0 *vs.* 65.0, $P = 0.018$); more tumors were located in the body/tail process in the control group ($P = 0.015$); tumor size was significantly larger in the control group (median 34 *vs.* 39 mm, $P < 0.001$); AP (25% *vs.* 12%, $P = 0.002$), and CP history (8.7% *vs.* 2.9%, $P = 0.018$) were more common in the false-negative group; and CA-19-9 level was significantly higher in the control group. The gender, symptoms, ERCP history, stent type, pancreatic duct,

Table 2

The EUS imaging features and techniques of the study cohort.

	Negative (*n* = 184)	Positive (*n* = 175)	*P* value
Number of needle passes, median (IQR), *n*	3.0 (2.0–4.0)	3.0 (3.0–4.0)	**<0.001**
Tumor echo, *n* (%)			**0.007**
Uneven low echo	34 (18.5)	40 (22.9)	
Uniform low echo	131 (71.2)	131 (74.9)	
High echo component	19 (10.3)	4 (2.3)	
Needle size, *n* (%)			**0.014**
19G	3 (1.6)	7 (4.0)	
22G	103 (56.0)	118 (67.4)	
25G	78 (42.4)	50 (28.6)	
Needle design, *n* (%)			**0.003**
FNA	149 (81.0)	118 (67.4)	
FNB	35 (19.0)	57 (32.6)	

The data in boldface format means statical significance ($P < 0.05$).

IQR: Interquartile range; FNA: Fine-needle aspiration; FNB: Fine-needle biopsy.

Table 3

Multivariable analysis of factors associated with positive EUS-TA outcomes.

	OR	95% CI	*P* value
Age	1.019	0.996–1.043	0.106
Recent acute pancreatitis history	0.478	0.250–0.914	**0.026**
Chronic pancreatitis history	0.561	0.176–1.790	0.329
Tumor location (body/tail)	1.211	0.728–2.015	0.46
Tumor echo			
Uniform low echo	0.863	0.470–1.584	0.635
High echo component	0.001	0.027–0.400	**0.001**
FNB needle	2.27	1.277–4.035	**0.005**
Needle size			**0.003**
22G	0.512	0.111–2.353	0.389
25G	0.330	0.068–1.608	0.170
Number of needle passes	1.651	1.239–2.199	**0.001**
Serum CA-19-9 level	1.001	1.000–1.001	**0.019**
Tumor size	1.053	1.029–1.077	**<0.001**
Sex	1.063	0.648–1.742	0.810

The data in boldface format means statical significance ($P < 0.05$).

FNA: Fine-needle aspiration; FNB: Fine-needle biopsy.

and distal bile duct had no differences between the 2 groups. Regarding EUS imaging features and techniques, the number of needle passes was higher in the control group (median 3.0 *vs.* 3.0, $P < 0.001$); the high echo component was more commonly observed in the negative group (10.3% *vs.* 2.3%, $P = 0.002$); and 22G needles (67.4% *vs.* 43.5%, $P = 0.026$) and FNB needles ($P = 0.003$) were more commonly used in the control group. The above factors were included in the logistic regression analysis. The gender, symptoms, ERCP history, stent type, pancreatic duct, and distal bile duct had no differences between the 2 groups.

Multivariate logistic regression demonstrated that the recent AP odds ratio [(OR): 0.478, 95% confidence interval (CI): 0.250–0.914, $P = 0.026$] and high echo component within the tumor (OR: 0.103, 95% CI: 0.027–0.400, $P = 0.001$) were independently associated with false-negative EUS-TA results. Meanwhile, using FNB needles (OR: 2.270, 95% CI: 1.277–4.035, $P = 0.005$), more needle passes (OR: 1.651, 95% CI: 1.239–2.199, $P = 0.005$), large tumor size (OR: 1.053, 95% CI: 1.029–1.077, $P < 0.001$), and high CA-19-9 level (OR: 1.001, 95% CI: 1.000–1.001, $P = 0.019$) were independently associated with positive EUS-TA outcomes [Table 3]. All the factors were adjusted by sex.

Based on the receiver operating characteristic curve analysis, the optimal number of needle passes was 2.5 [Figure 1], and we deemed 3 needle passes or more to be needed to achieve optimal EUS-TA outcomes.

Multivariate analysis for the prediction of core tissue adequacy

In the false-negative group, 131 (71.2%) patients had an adequacy score of 2–3, and 129 (73.7%) patients had an adequacy score of 2–3 in the control group. The tissue adequacy rate had no significant difference between the 2 groups ($P = 0.594$).

Univariate and multivariate analyses of factors related to sample adequacy (score 2 or 3) are shown in Table 4. Univariate analysis showed that tumor location (body/tail) (OR: 1.35, 95% CI: 1.05–1.68; $P = 0.02$), tumor size (OR: 1.04; 95% CI: 1.00–1.08; $P = 0.04$), CP history (OR: 0.68; 95% CI: 0.38–0.98; $P = 0.04$), needle passes ≥3 (OR: 1.87; 95% CI: 1.21–2.54; $P < 0.001$), and using FNB needle (OR: 2.05; 95% 1.43–2.79; $P < 0.001$) were associated with sample adequacy. On multivariate analyses, tumor location in the body or tail (OR: 1.38, 95% CI: 1.01–1.72; $P = 0.04$), needle passes ≥3 (OR: 1.90, 95% CI: 1.22–2.56; $P < 0.001$), and using FNB needles (OR: 2.10, 95% CI: 1.48–2.85; $P < 0.001$) were independently related to sample adequacy, and CP history (OR: 0.69; 95% CI: 0.40–0.99; $P = 0.05$) was an independent predictor of sample inadequacy.

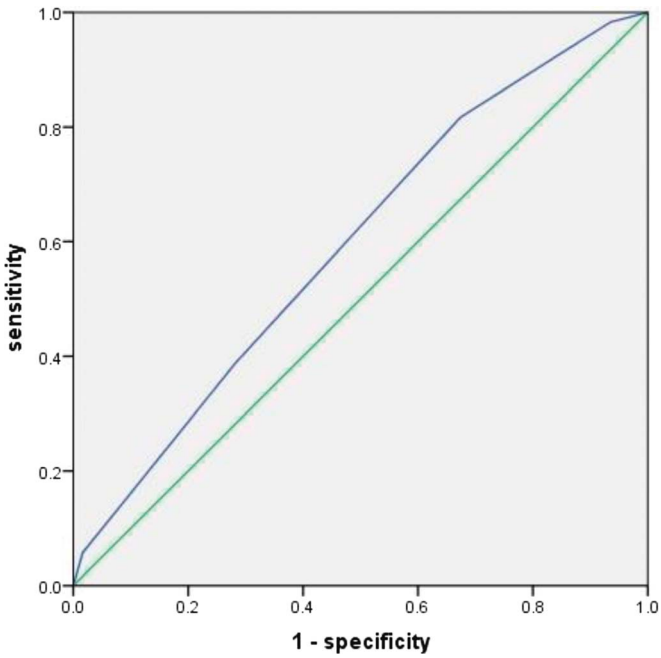

Figure 1. The receiver operating characteristic curve to predict the optimal needle passes for diagnosing solid pancreatic lesions.

Discussion

In this large single-center study, the parameters of patients who underwent EUS-TA of PC with false-negative results were compared with those of PC patients with true-positive EUS-TA who were systematically sampled from our electronic database. We found that recent AP and a high echo component within the tumor were independently associated with false-negative EUS-TA results. Using FNB needles, more needle passes, a large tumor size, and a high CA-19-9 level were independently associated with positive EUS-TA outcomes. Moreover, tumor location in the body or tail, needle passes ≥3, and using an FNB needle were independently related to sample adequacy. Our study may provide a comprehensive understanding of the factors that may influence the outcomes of EUS-TA and guide endoscopists on how to perform an optimal EUS-TA procedure.

EUS-TA was recommended as the first-line method to obtain cytological and histological specimens for pancreatic lesions.[16] The reported sensitivity and specificity of EUS-TA for pancreatic lesions range from% 64 to 95% and 94% to 100%, respectively, whereas the negative predictive value was only 50%–83%.[17–19] This implies that the likelihood of cancer in puncture-negative patients cannot be completely ruled out. The primary issue with low tumor cell sampling is sample contamination by blood, inflammatory cells, and even gut wall epithelial cells.[20] Several tumor factors have been identified to be associated with EUS-TA outcomes, including tumor size,[21] tumor location in the head/uncinate,[13] presence of fibrosis,[13] and CP.[22,23] These results were consistent with our study. High echo component within the tumor implies calcification and fibrosis within the tumor. Therefore, it is not surprising that high echo component was associated with false-negative EUS-TA results. However, the associations between recent AP and false-negative EUS-TA were not identified by previous studies. The AP history was a defined predictor of PC.[24,25] The most common EUS feature of AP is hypoechogenicity of the pancreas, indicating edema.[26] Sometimes, the border of the tumor cannot be clearly visualized. In severe cases, the tumor cannot be recognized. Therefore, these EUS imaging features of AP may significantly influence the outcomes of EUS-TA.

CA-19-9 is widely used for screening, diagnosis, staging, and therapy response prediction of PC.[27] Several studies found that lowering CA-19-9 (20%–89%) significantly improved overall survival, which indicated the activity and number of tumor cells may be in line with the level of CA-19-9. It may be the reason why a high CA-19-9 level was associated with true-positive EUS-TA results, but further studies are needed to verify the finding.

Many technical factors can also influence the outcomes of EUS-TA, which can be options for endoscopists. The FNB needle is a new kind of needle that was created in order to gather samples with higher cell counts and intact tissue architecture. In our study, the second generation of FNB needles with a reverse-bevel design, Procore needles, was used. The advantages of FNB needles over FNA have been confirmed by many studies. A meta-analysis by Renelus et al. with eleven randomized controlled trials (RCTs) included. When compared with FNB, they discovered that FNA had considerably lower diagnostic accuracy (81% and 87%, respectively, P = 0.005). Additionally, compared with FNB, FNA needed more mean passes (2.3 *vs.* 1.6, P 0.0001) than the latter. The rate of adverse events between FNA and FNB needles was also not significantly different (1.8% and 2.3%, respectively, P = 0.64).[28] In an RCT that focused on cost-effectiveness, it was discovered that EUS-FNB for PC, which involves 2 passes without on-site cytopathology evaluation, is more

Table 4

Factors associated with tissue core adequacy of EUS-TA.

	Univariate Analysis, OR (95% CI)	*P* value	Multivariate Analysis, OR (95% CI)	*P* value
Age	1.02 (0.99–1.04)	0.11		
Sex	1.24 (0.68–1.89)	0.59		
Tumor location (B/T)	1.35 (1.05–1.68)	**0.02**	1.38 (1.01–1.72)	**0.04**
Tumor size	1.04 (1.00–1.08)	**0.04**	1.03 (0.98–1.06)	0.08
Symptoms				
Pain	1.60 (0.75–2.55)	0.36		
Obstructive jaundice	1.41 (0.86–1.99)	0.16		
With ERCP				
Metal stent	1.68 (0.85–2.21)	0.34		
Recent acute pancreatitis history	0.75 (0.51–1.02)	0.08		
Chronic pancreatitis history	0.68 (0.38–0.98)	**0.04**	0.69 (0.40–0.99)	**0.05**
Pancreatic duct dilation	1.25 (0.71–1.80)	0.38		
Distal bile duct dilation	1.06 (0.55–1.67)	0.72		
Serum CA-19-9 level	1.01 (0.99–1.01)	0.13		
Needle passes ≥3	1.87 (1.21–2.54)	**<0.001**	1.90 (1.22–2.56)	**<0.001**
Tumor echo				
Uniform low echo	1.22 (0.88–1.59)	0.25		
High echo component	1.05 (0.61–1.56)	0.49		
Needle size				
22G	1.36 (0.95–1.79)	0.11		
25G	1.12 (0.82–0.45)	0.51		
Needle design				
FNB	2.05 (1.43–2.79)	**<0.001**	2.10 (1.48–2.85)	**<0.001**

SD: Standard deviation; IQR: Interquartile range; ERCP: Endoscopic retrograde cholangiopancreatography; H/U/B/T: Head/uncinate/body/tail.

cost-effective than EUS-FNA. The cost of the EUS process and sedation, the sufficiency of the specimen, and the EUS-FNB diagnostic yield were the factors that had the most effects.[29] Moreover, compared with FNA, FNB produced a larger percentage of samples that were adequate for targeted next-generation sequencing (NGS).[30] Similarly, in this study, we also found that using an FNB needle was associated with tissue adequacy. Therefore, based on the results of our study and previous studies, the FNB needle should be considered the first choice to perform EUS-TA.

The needle type was another important factor that can influence the outcomes of EUS-TA. Oh et al. reported that there was no diagnostic accuracy difference between 22G and 25G needles; however, the 22G Franseen needle was superior to the 25G needle in collecting histologic core tissue.[31] It was stated that the 19G FNB needle may make it simpler to collect the proper specimens for NGS than the 22G FNB needle. However, concerns were raised concerning hazards such as hemorrhage and pancreatic juice leaking.[32,33] The differences among different needle types were not verified in our study. The reason may be that the latest type of 22G needle was not used in our study, and the 19G needle was rarely used in our center.

According to the guidelines, 2–3 needle passes are needed to guarantee a sensitivity of at least 90% for the diagnosis of malignancy.[34] However, the number of needle passes required for sample adequacy is rarely reported. Three FNB needle passes (IQR 3–4) yielded sufficient tissue for targeted NGS in 91% of patients in a retrospective study.[30] Our study confirmed that 3 needle passes were required to yield sample adequacy. We provided more evidence on the optimal number of needle passes for sample adequacy.

The suction techniques (stylet retraction, no suction, and negative suction),[35] puncture techniques (torque, fanning and standard techniques),[36] and ROSE[37] may also have an impact on EUS-TA outcomes. However, the negative suction and fanning techniques were the standard techniques, and ROSE was unavailable in our center. Therefore, these factors were not analyzed in this study. The value of these factors should be verified in future studies.

Our study had several limitations. First, the results of our study were obtained from a single center. The outcomes might not apply at other centers. Second, the retrospective nature of the study may cause significant selection bias. Third, the experience of endoscopists was not analyzed, which may greatly influence the outcomes of EUS-TA.[38] In general, further prospective studies with a large sample size are needed to verify the results of our study.

Conclusion

We conducted this retrospective study to explore the factors that may affect the diagnostic accuracy and sample adequacy of EUS-TA, with all the related factors included. We found that recent AP and a high echo component within the tumor were independently associated with false-negative EUS-TA results. Using FNB needles, more needle passes, a large tumor size, and a high CA-19-9 level were independently associated with positive EUS-TA outcomes. Moreover, tumor location in the body or tail, needle passes ≥3, and using an FNB needle were independently related to sample adequacy. However, further prospective studies with a large sample size are needed to verify the results of our study.

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Conflicts of Interest

Zhendong Jin is an Associate Editor of the journal. The article was subjected to the standard procedures of the journal, with a review process independent of the editor and his research group.

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Author Contributions

Dr. Haojie Huang and Zhendong Jin designed the study. Yuqiong LI performed the data collection; Qiuyue Song performed the data analysis; Lisi Peng and Ying Xing performed the validation; Liqi Sun wrote and revised the manuscript.

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