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Comprehensive review on endoscopic ultrasound-guided tissue acquisition techniques for solid pancreatic tumor

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Abstract

Pancreatic ductal adenocarcinoma is speculated to become the second leading cause of cancer-related mortality by 2030, a high mortality rate considering the number of cases. Surgery and chemotherapy are the main treatment options, but they are burdensome for patients. A clear histological diagnosis is needed to determine a treatment plan, and endoscopic ultrasound (EUS)-guided tissue acquisition (TA) is a suitable technique that does not worsen the cancer-specific prognosis even for lesions at risk of needle tract seeding. With the development of personalized medicine and precision treatment, there has been an increasing demand to increase cell counts and collect specimens while preserving tissue structure, leading to the development of the fine-needle biopsy (FNB) needle. EUS-FNB is rapidly replacing EUS-guided fine-needle aspiration (FNA) as the procedure of choice for EUS-TA of pancreatic cancer. However, EUS-FNA is sometimes necessary where the FNB needle cannot penetrate small hard lesions, so it is important clinicians are familiar with both. Given these recent developments, we present an up-to-date review of the role of EUS-TA in pancreatic cancer. Particularly, technical aspects, such as needle caliber, negative pressure, and puncture methods, for obtaining an adequate specimen in EUS-TA are discussed.

Key Words: Endoscopic ultrasound-guided fine needle biopsy; Endoscopic ultrasound-guided tissue acquisition; Personalized medicine; Genomic profiling test; Pancreatic cancer; Puncture procedure

Masuda S, Koizumi K, Shionoya K, Jinushi R, Makazu M, Nishino T, Kimura K, Sumida C, Kubota J, Ichita C, Sasaki A, Kobayashi M, Kako M, Haruki U. Comprehensive review on endoscopic ultrasound-guided tissue acquisition techniques for solid pancreatic tumor . *World J Gastroenterol* 2023; In press

Core Tip: Endoscopic ultrasound (EUS)-guided tissue acquisition (TA) began in 1992 as EUS-guided fine-needle aspiration (FNA). Recently, with the development of personalized medicine and precision treatment, the fine-needle biopsy (FNB) needle

was developed. EUS-FNB is rapidly replacing EUS-FNA for pancreatic cancer. The EUS-TA strategy with three or more punctures, the stylet retraction method, the torque or fanning technique, and a 22-G or thicker FNB needle may be effective in patients with solid pancreatic tumors scheduled for treatment, including personalized medicine. It is also important clinicians are familiar with both procedures, as EUS-FNA is occasionally necessary when FNB is unsuccessful.

INTRODUCTION

Approximately 80%-85% of patients with pancreatic cancer are borderline-resectable (BR) requiring neoadjuvant treatment and unresectable with metastases. International guidelines for pancreatic neoplasms recommend pathological diagnosis of pancreatic adenocarcinoma prior to chemotherapy. Therefore, endoscopic ultrasound (EUS)-guided tissue acquisition (TA) is usually performed in patients with BR requiring neoadjuvant therapy, or in metastatic disease requiring palliative therapy[1]. The remaining 15%-20% of patients may benefit from EUS-TA prior to surgery; this can confirm pancreatic neoplasms, and reduce the number of unnecessary operations for other similar conditions (*e.g.*, autoimmune pancreatitis, local chronic pancreatitis, and lymphomas). Before the development of EUS-TA, 5%-10% of patients were misdiagnosed with pancreatic cancer and underwent surgery for pancreatic lesions[2-4].

EUS-TA can be divided into EUS-fine-needle aspiration (FNA) using Menghini needles, and EUS-fine-needle biopsy (FNB) using Franseen or fork-tip needles. FNB has equal or better diagnostic accuracy than FNA, with increased tissue volume and decreased number of punctures for diagnosis[5-8]. Moreover, EUS-FNB may provide higher diagnostic yield for peri-hepatic lymph nodes[9]. FNB increases the number of cases for which ancillary tests such as immunohistochemistry and tumor molecular profiling can be performed[9,10]. Therefore, with the advent of personalized medicine and precision therapy, EUS-FNB is rapidly becoming the procedure of choice for EUS-TA of pancreatic cancer. However, EUS-FNA may be used where the FNB needle cannot penetrate small hard lesions; therefore, there is a need for familiarity

with both procedures. Conti *et al*[11] also recommend EUS-FNA and FNB in difficult cases of puncture and sampling. Needle size, the negative pressure applied to the needle, and puncture techniques are important for obtaining an adequate specimen in EUS-TA.

Considering recent developments, we present an up-to-date review of the role of EUS-TA in pancreatic cancer. In particular, technical aspects and novel applications for obtaining appropriate specimens during EUS-TA are discussed.

EUS-FNA

EUS-FNA has 87%-92% sensitivity and 96%-98% specificity for the pathological diagnosis of solid pancreatic malignancy[12-15]. FNA needles with calibers ranging from 19-gauge (G)–25G are available, with many studies comparing the different calibers and technical aspects of the EUS-FNA technique. We present a table summarizing the respective characteristics of FNA and FNB, focusing on key points (Table 1).

FNA needle caliber

The small 25G FNA needle may have a technical advantage over larger bore needles when sampling very fibrous, solid lesions. Moreover, its superior flexibility improves operability, especially when sampling pancreatic head and apex masses from the duodenum[1]. Three meta-analyses compared 25G FNA needles with 22G FNA needles. One of them showed increased diagnostic sensitivity (with similar specificity), while the other two showed no significant differences. Therefore, both calibers (25G and 22G needles) can be used when sampling solid pancreatic lesions[16]. Compared with thinner needles, 19G FNA needles are stiffer and harder to manipulate, increasing technical failure when sampling pancreatic head lesions[17].

Negative pressure during EUS-FNA

The conventional aspiration method, where 10 mL of negative pressure is applied using a syringe attached to a needle, is recommended because of its higher sensitivity and diagnostic rate[18,19]. In addition, EUS-FNA with 50 mL negative

pressure is superior to 10 mL during tissue collection[20]. The wet aspiration method involves precleaning the needle with saline solution, replacing the air column with liquid, and applying negative pressure. Theoretically, this method improves the cell count and sample quality compared with the conventional aspiration and suction methods, as the negative pressure applied from the syringe is better transmitted to the needle tip[21]. In the stylet-throw-pull method, the stylet is slowly and gradually removed (without using a syringe) while the needle is moved within the lesion to create minimal negative pressure. The diagnostic results for solid pancreatic lesions sampled using stylet-throw-pull method are comparable to the conventional aspiration method[22,23].

EUS-FNA puncture technique

The fanning technique is used to collect specimens from multiple sites with a single puncture by fanning the needle back and forth using the elevator of the endoscope and the up/down dial control. The fanning technique improves diagnostic yield, especially in cancerous tumors with necrotic centers. In a study of pancreatic masses, fanning reduced the number of passes required for diagnosis and resulted in a high first-pass diagnostic rate[24]. The door knocking method (DKM), in which the needle is moved forward within the mass so quickly and powerfully that a sound is emitted when a part of the handle hits the needle stopper, did not improve the accuracy of histological diagnosis. However, it enabled the acquisition of a larger amount of tissue specimen compared with the conventional puncture[25]. Thus, DKM may be advantageous for genomic profiling tests; however, to our knowledge, no study has verified this.

Uehara *et al*[26] reported the optimal number of needle passes for accuracy of histological diagnosis: 3 where the head was < 15 mm; 2 where the head was ≥ 15 mm; 2 where the body and tail were ≤ 15 mm; and 1 where the body and tail were ≥ 15 mm. In total, 93% of pancreatic lesions were correctly diagnosed using these numbers of passes. In addition, size of ≤ 15 mm, head location, and neuroendocrine tumors independently required 2 or more needle passes[26].

EUS-FNB FOR HISTOLOGICAL DIAGNOSIS

The desire to collect samples with increased cell counts and preserved tissue structures led to the development of a new type of needle, the FNB needle. This needle is specifically designed to collect core tissue samples. To date, three generations of FNB needles exist. The first generation, the Tru-Cut 19G needle (QuickCore, Cook Endoscopy, Limerick, Ireland), became rapidly outdated due to inflexibility and technical problems[27]. In a randomized controlled trial (RCT) comparing a 19G Tru-Cut needle with a conventional 22G FNA needle in transduodenal EUS-TA of pancreatic head lesions, Sakamoto *et al*[28] reported that the 22G FNA needle group had significantly higher diagnostic accuracy for malignancy and technical success rate than the 19G Tru-Cut needle group. The second generation of FNB needles, Procore needles (Cook Endoscopy, Limerick, Ireland), were created with a reverse bevel design. More than 10 years after the Tru-Cut needle was introduced, the third generation EUS-FNB needles for core biopsy were developed. They could collect more tissue than the conventional FNA needle, thus improving diagnostic results. Various types of needles have been developed, including the fork type (SharkCore; Medtronic, Minneapolis, MN, United States), flanged type (Acquire; Boston Scientific, Marlborough, MA, United States) (Top-gain; Medi-Globe, Achenmühle, Germany), and 20G FNB needles with forward-facing core traps (ProCore 20G; Cook Medical)[27] (Figure 1). A meta-analysis demonstrated the diagnostic performance of the new generation FNB needles, namely the crown and fork tip needles. They showed a remarkable diagnostic accuracy of 96% for solid pancreatic lesions, with no significant difference between the crown and fork-tip needles (97% and 95%, respectively, $P = 0.8$)[29]. Renelus *et al*[7] conducted a meta-analysis of RCTs published between 2012 and 2019; they found that FNA demonstrated significantly reduced diagnostic accuracy compared with FNB (81% and 87%, respectively, $P = 0.005$). In addition, FNA required an increased number of mean passes compared with FNB (2.3 and 1.6, respectively, $P < 0.0001$). Furthermore, there was no significant difference in the rate of adverse events between FNA and FNB needles (1.8% and 2.3%, respectively, $P = 0.64$)[7].

An RCT analysing cost-effectiveness found that pancreatic mass EUS-FNB (two passes without on-site cytopathology evaluation) was more cost-effective than EUS-FNA (number of passes dictated by on-site cytopathology evaluation). Variables with the largest impact were EUS procedure and sedation cost, specimen adequacy, and diagnostic yield associated with EUS-FNB[30].

THE ERA OF PERSONALIZED AND PRECISION MEDICINE

Several studies have reported increased tissue volume with EUS-FNB samples compared with EUS-FNA. One study reported a 20-fold increase in tissue volume[9,31,32]. Elhanafi *et al*[10] reported that FNB resulted in a higher proportion of sufficient samples for targeted next-generation sequencing (NGS) than FNA (90.9% *vs* 66.9%; P = 0.02). In multivariable modeling, only FNB [odds ratio = 4.95, 95% confidence interval (CI): 1.11-22.05, and P = 0.04] was associated with sufficient sampling capacity for genomic testing[10].

Pancreatic ductal adenocarcinoma is anticipated to become the second leading cause of cancer-related mortality by 2030, with high mortality considering the incidence. Given the low median survival time of 12 mo for patients with advanced metastatic pancreatic cancer (ductal adenocarcinoma in particular)[33,34], urgent new treatments are warranted. Molecular profiling data has recently revealed that up to 25% of pancreatic cancers have actionable molecular changes[35-42], defined as changes with strong clinical or preclinical evidence suggesting specific treatment efficacy[34]. Actionable molecular changes were found in 5.5%-21.7% of EUS-FNA/B specimens from pancreatic ductal adenocarcinoma patients[39,43]. Pishvaian *et al*[34] reported that patients with actionable molecular alterations treated with matched therapy (n = 46) had significantly longer median overall survival times than those treated with unmatched therapies [n = 143; 2.58 years *vs* 1.51 years; hazard ratio (HR) 0.42 (95%CI: 0.26-0.68), P < 0.001][34]. Therefore, EUS-TA can improve diagnostic accuracy and help ensure successful personalized medicine, with EUS-FNB expected to be particularly useful.

Advances have been made in both tissue collection methods and devices, and genetic analysis technology. The most common genomic alterations noted in

metastatic pancreatic cancer specimens are in the *KRAS, TP53, CDKN2A*, and*SMAD4* genes. The first genetic analysis reported using EUS-FNA samples was KRAS mutation analysis. This driver mutation is found in more than 90% of pancreatic cancers, and drugs targeting KRAS mutations, such as Sotrasib, may be effective for pancreatic cancer[27,44]. The DNA mismatch repair (MMR) pathway is an important function that identifies and corrects base pair mismatches in DNA. Loss of MMR function leads to elevated microsatellite instability (MSI)-high, making the MSI test useful for evaluating pembrolizumab response. Sugimoto *et al*[45] reported that in unresectable pancreatic ductal adenocarcinoma, EUS-FNB with the Franseen 22G needle had a higher success rate in MSI analysis than EUS-FNA [FNB, 88.9% (8/9) *vs* FNA, 35.7% (5/14); $P = 0.03$].

Targeted genome sequencing (TGS) applies polymerase chain reaction technology to construct and sequence a library of specific regions. Currently available multigene NGS systems, such as MSK-IMPACT (Memorial Sloan Kettering Cancer Center, New York, NY, United States) and FoundationOne CDx (F1CDx; Foundation Medicine, Cambridge, MA, United States), screen several hundred cancer-related genes simultaneously as companion diagnostic tests[46,47]. Whole genome sequencing (WGS) can detect various genomic structural alterations (translocations, inversions, duplications, chromosomal aberrations, chromosomal breaks) by obtaining sequence information of the entire genome, including non-coding regions. WGS may be more useful than TGS, but it is significantly more costly, requires more samples, and its superiority in therapeutic selection has not yet been proven[48]. RNA sequencing is a newly developed technology that can identify fusion genes faster, with greater sensitivity, and more efficiently than DNA panels. It can also detect new genes and genetic mutations.

Agents for actionable molecular changes are still being investigated. For example, evidence suggests trametinib in GNAS alterations[49], sotorasib in KRAS G12C alterations[44], olaparib in germline *BRCA1/2* mutation[50], entrectinib in *NTRK* gene fusion[51], pembrolizumab in MSI-high[52,53], and afatinib in NRG1 fusions[54,55] may be effective treatment options. In malignancies such as pancreatic cancer, it is likely that multiple genomic drivers may be present. A combination of compatible drugs

with targeting multiple genomic alterations at once may overcome this; however, evidence is lacking, and further studies are needed[56,57]. The application of precision medicine for treating pancreatic ductal adenocarcinoma has just begun, and further development of genetic testing equipment, drugs, and tissue collection devices is required[27].

EUS-FNB FOR THE ERA OF PERSONALIZED AND PRECISION MEDICINE

FNB needle type and caliber

Since EUS-FNB is more suitable than EUS-FNA for personalized medicine, further investigation into needle size and type has been conducted. The abovementioned meta-analysis evaluating crown and fork-tip needles, showed equivalent sample adequacy, diagnostic accuracy, optimal histological core procurement, mean number of needle passes, pooled specificity, and sensitivity of these two FNB needles[29]. Oh *et al*[58] compared 22G with 25G Franseen needles in the three needle passes technique, with suction using 10 mL syringe, and movement within the target lesion at least 10 times using the fanning technique. They reported no diagnostic accuracy difference between the two needles; however, the 22G Franseen needle was superior to the 25G needle in histologic core facilitated easier collection of appropriate specimens for the OncoGuide NCC Oncopanel System [70.0% (49/70) *vs* 28.6% (20/70), respectively; $P < 0.001$]. The 19G FNB needle was reported to have the potential for easier collection of appropriate specimens for the OncoGuide NCC Oncopanel System compared with the 22G FNB needle, however, concerns were expressed about risks such as bleeding and pancreatic juice leakage[59,60]. For successful personalized medicine, 22G FNB needles are better than 25G ones. However, usage of 19G FNB needles raises concerns regarding accidental injury and harder to manipulate compared with 22G ones.

Negative pressure during EUS-FNB

A randomized controlled trial of tissue samples from patients with pancreatic masses on imaging compared collection techniques using Menghini-tip, reverse-bevel, Franseen, and fork-tip needles. A second randomized control, patient-by-

patient analysis, compared the use of suction, no suction, and stylet retraction during biopsies. The biopsy samples collected by fork-tip or Franseen needles had significantly higher cellularity than those collected by Menghini-tip needles or reverse-bevels ($P < 0.001$). The predictors of high cellularity for pancreatic masses showed that Franseen needles, fork-tip needles, not applying suction, stylet retraction, and pancreatic mass size of > 3 cm were associated with high cellularity. Therefore, they recommended using a negative pressure technique with every EUS-TA needle for an optimal outcome, as shown in Table 2[61]. Stylet retraction and standard suction technique may be equivalent when using the 20G reverse-beveled needle[62]; however, the stylet retraction technique is considered equally or more useful than the standard suction technique when performing EUS-FNB.

EUS-FNB puncture technique

Sample quality scores were significantly higher when obtained by the torque and fanning techniques rather than the standard one ($P < 0.001$)[63]. The new torque technique consists of turning the echoendoscope counterclockwise or clockwise while repeated to-and-fro movements are performed to reach multiple areas within the lesion; this is obtained by maneuvering the "up-down" articulating dial of the echoendoscope. Conversely, in the standard technique, the mass is pierced by the tip of the needle in a unidirectional movement. Studies on FNA needles suggest that the DKM may be useful for increasing cell volume[25]; however, there are no specific studies on DKM in FNB.

The European Society of Gastrointestinal Endoscopy recommends that 2-3 needle passes are sufficient to ensure a sensitivity of at least 90% for the diagnosis of malignancy[16]. However, evidence on the number of needle passes required for successful personalized medicine is lacking. In a few recent retrospective studies, a median number of 3 FNB needle passes (interquartile range 3-4) yielded sufficient tissue for targeted NGS in 91% of patients[10].

Based on these findings, we believe that the EUS-TA strategy with three or more punctures, the stylet retraction method, the torque or fanning technique, and a 22-G

or thicker FNB needle may be effective in patients with solid pancreatic tumors scheduled for treatment, including personalized medicine.

RAPID ON-SITE PATHOLOGIST EVALUATION AND MACROSCOPIC ON-SITE QUALITY EVALUATION

It is unclear whether an on-site pathologist improves the diagnostic accuracy of EUS-FNA for solid pancreatic lesions; however, Rapid On-Site Pathologist Evaluation (ROSE) can reduce the number of needle passes required to obtain a pathological diagnosis[64,65]. The subsequent introduction of the FNB needle has made it possible to collect large quantities of macroscopic white samples. A recent global, randomized trial showed that ROSE did not affect the diagnostic accuracy of EUS-FNB (96.4% with ROSE *vs* 97.4% without ROSE, $P = 0.396$)[66]. In addition, the application of ROSE is limited by the availability and additional cost of trained cytopathologists at each facility; therefore, ROSE is unlikely to be recommended for future diagnostic practice[67].

Direct observation of specimens obtained by FNA/B, macroscopic on-site evaluation (MOSE), is more feasible and readily available alternative to ROSE[68,69]. Kaneko *et al*[70] showed that the macroscopic visible core (MVC) length and histological sample quantity were positively correlated in EUS-FNB using a 22G Franseen needle. Multivariate analysis showed that MVC length ≥ 30 mm on MOSE was a significant factor affecting suitability for NGS (odds ratio 6.19; 95%CI: 2.72-14.10).

NEEDLE TRACT SEEDING

Theoretically, cancer seeding through the needle tract may occur more frequently in the body or tail of the lesion when using the transgastric approach, than in the head of the lesion using the transduodenal approach[71]. This is because the EUS-FNA tract of pancreatic head cancers is later resected in a blocked fashion along with the pancreatic head in curative surgery. In contrast, the EUS-FNA tract of lesions in the body or tail lies beyond the surgical resection margin[72,73].

Ngamruengphong *et al*[73] reported that EUS-FNA for pancreatic head, body, and tail cancers was marginally associated with improved overall survival (HR 0.84, 95%CI: 0.72-0.99) but did not affect cancer-specific survival (HR 0.87, 95%CI: 0.74-1.03). Park *et al*[74] reported 528 patients with distal pancreatic cancer who underwent distal pancreatectomy. Among these, 193 were treated using EUS-FNA, and 335 were not. The between-group recurrence rates were comparable (EUS-FNA, 72.7%; non-EUS-FNA, 75%; $P = 0.58$) at follow-up (median, 21.7 mo), with similar cancer-free survival ($P = 0.58$), showing that preoperative EUS-FNA does not reduce cancer-specific or overall survival[74]. However, as gastric wall recurrence only occurred in patients treated using EUS-FNA ($n = 2$), clinicians must consider the potential risks of needle tract seeding, and patients should be carefully selected[74]. Yane *et al*[75] also reported that the 5-year cumulative needle tract seeding rate, estimated using Fine and Gray's method, was 3.8% (95%CI: 1.6%-7.8%). They concluded that, although preoperative EUS-FNA for pancreatic body and tail cancers has no negative effect on recurrence-free survival or overall survival, needle tract seeding after EUS-FNA was observed to have a non-negligible rate[75]. Sakamoto reported that among the six cases with needle tract seeding occurred, it was revealed by upper gastrointestinal endoscopy in four. They suggested upper gastrointestinal endoscopy follow-up, as well as computed tomography, in patients who undergo gastric EUS–FNA before distal pancreatectomy to identify needle tract seeding at soon as possible[76].

CONCLUSION

Since pancreatic cancer treatment is highly invasive and EUS-TA does not worsen cancer-specific prognosis, histological diagnosis should be made to establish effective treatment options. Furthermore, with genomic profiling, a large volume of tissue are needed from each biopsy; Franseen and Fork-tip needles should be the first choice for this purpose. EUS-TA involving three or more punctures using the stylet retraction method and the torque or fanning technique with a 22-G FNB or thicker needle is the most effective tissue-sampling method for patients with solid pancreatic tumors scheduled for treatment, including those receiving personalized medicine. The prediction of MOSE histological specimen volume by measuring

MVC length may have clinical significance, especially when submitting specimens for NGS. The application of precision medicine for treating pancreatic ductal adenocarcinoma has just begun, and further development of genetic testing equipment, drugs, tissue collection devices, and puncture technique is required.

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