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**Appraisal of needle-based confocal laser endomicroscopy in the diagnosis of pancreatic cysts**

Krishna SG *et al* nCLE diagnosis of pancreatic cysts

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**Abstract**

Nearly 2.5% of cross-sectional imaging studies will report a finding of a cystic pancreatic lesion. Even though most of these are incidental findings, it remains very concerning for both patients and treating clinicians. Differentiating and predicting malignant transformation in pancreatic cystic lesions is clinically challenging. Current evaluation of suspicious cystic lesions includes a combination of radiologic imaging, endoscopic ultrasound (EUS) and cyst fluid analyses. Despite these attempts, precise diagnostic stratification among non-mucinous, mucinous, and malignant cystic lesions is often not possible until surgical resection. EUS-guided needle based confocal laser endomicroscopy (nCLE) for evaluation of pancreatic cysts is emerging as a powerful technique with remarkable potential. Though limited imaging data from 3 large clinical trials (INSPECT, DETECT and CONTACT) are currently the reference standard for nCLE imaging, nonetheless these have not been validated in large studies. The aim of this review article is to review the evolving role of EUS-guided nCLE in management of pancreatic cystic lesions in terms of its significance, adverse events, limitations, and implications.

**Key words:** Pancreatic cyst; Needle-based confocal laser endomicroscopy; Endoscopic ultrasound; Intraductal papillary mucinous neoplasm; Mucinous cystadenoma; Serous cystadenoma; Pancreatic cancer

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**Core tip:** Differentiating and predicting malignant transformation in pancreatic cystic lesions is clinically challenging. Endoscopic ultrasound-guided confocal laser endomicroscopy for evaluation of pancreatic cysts is emerging as a powerful technique with remarkable potential. The feasibility of visualization at the microscopic level enables in differentiating cystic pancreatic lesions, but with certain challenges. In keeping with the gastroenterologist’s motto of ‘seeing is believing’, this technology is poised for continued and expanded research.

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**INTRODUCTION**

Approximately 2.5% of cross sectional imaging studies will detect pancreatic cysts[1,2]. In patients over the age of 70, this number can be as high as 10%[1]. Even though most of these are incidental findings, nevertheless it remains very concerning for both patients and the clinicians. This is in large part due to the fact that pancreatic cancer being the 4th leading cause of cancer-related death in the United States has dismal treatment outcomes with 5-year survival being less than 5%[3]. The foremost reason for the low survival is difficulty in detection of its earliest stages.

The scenario has changed in the last two decades. Benign inflammatory pancreatic pseudocysts were the most common pancreatic cysts, however with advent of sophisticated imaging techniques and discovery of mucinous neoplastic pancreatic lesions, cysts with neoplastic potential at small (< 2 cm) sizes are frequently detected. In addition, endoscopic ultrasound (EUS)-guided fine needle aspiration (FNA) has evolved and established its role as the diagnostic procedure of choice for pancreatic lesions (solid and cystic). The overall complication rate remains low (1%-2%), which is similar to radiology assisted FNA biopsies[4].

The common differential diagnoses for incidental cystic pancreatic lesions include pseudocysts, serous cystadenomas (SCA), mucinous cystic lesions [categorized into mucinous cystic neoplasms (MCN), branch-duct (BD)- intraductal papillary mucinous neoplasm (IPMN), and main-duct (MD)-IPMN], and cystic-neuroendocrine tumors. Current guidelines recommend surgical resection for all large (> 4 cm) MCNs (malignancy risk of 17.5%), all patients with MD-IPMN (malignancy risk of 61%) and BD-IPMNs with worrisome features (≥ 3 cm, thick cyst wall, mural nodules and positive cytology; malignancy risk of 25%)[5]. To evaluate cysts, a combination of clinical history, demographics, imaging and endosonographic features, cytology, and cyst fluid carcinoembryonic antigen (CEA) and amylase are used to identify mucinous cysts[5]. Further sub-typing of mucinous cysts is also possible with some limitations. Distinguishing MCN from BD-IPMN can prove to be difficult. Unusual cysts like, macrocystic SCA, atypical pseudocysts and lymphoepithelial cysts can pose challenges[6]. A solitary CPL begins as a diagnostic challenge and sometimes remains so after completion of available investigations. Cyst fluid molecular analyses involving KRAS and GNAS mutations, and micro-RNAs have been studied, but there is no recommendation for routine use[7-10]. While surgical resection is the choice of treatment for symptomatic cysts, frequently, a decision for surgical approach is taken for asymptomatic cysts where either a conclusive diagnosis was not reached or where a BD-IPMN lacking ‘worrisome features’ was still concerning[5]. Pancreatic surgery for cystic neoplasms is a major operative procedure that carries significant morbidity. Even at high volume specialty centers, the morbidity rate remains high at 20%-40%[11,12].

There is a problem of resource utilization that involves patients seeking specialized care for all types of pancreatic cysts while some undergo premature and unrequired surgery. This is compounded by significant differences in technique and elucidation of cross sectional imaging, and inter-operator variations in technique, practices, and interpretation of endosonographic studies. At the crux of these issues involving pancreatic cysts, the challenge of achieving an accurate diagnosis and when diagnosed, risk stratification of mucinous pancreatic cysts, makes management difficult. A recent comprehensive technical review by the American Gastroenterology Association (AGA) reviewed all the available literature with an inference that there was insufficient evidence to make decisive recommendations based on patient risk versus benefit[10]. The low quality of evidence due to the dynamic and evolving science of pancreatic cysts contributed to the fact that seven of the ten AGA guidelines were conditional (low quality of evidence)[13].

The technical review summarized the pooled data from available studies where surgical histopathology was available: For predicting malignancy, a cyst size of > 3 cm had a sensitivity and specificity of 74% and 49% respectively, a dilated pancreatic duct reached a sensitivity and specificity of 32% and 80% respectively, and presence of an intracystic solid component had the most specificity of 91% but at the cost of a low sensitivity of 48%[10]. For EUS guided cyst aspiration, the review summarized data from 12 studies where histopathology was available: Cyst amylase concentration of < 250 U/L indicated either a SCA or mucinous cyst with a sensitivity of 44% and specificity of 98%. A CEA level < 5 ng/mL predicted pseudocyst or SCA with a sensitivity of 50% and a specificity of 95%[10]. While no absolute value of CEA predicted malignancy, values exceeding 800 ng/mL reached a high specificity of 98% (sensitivity 48%) in predicting a mucinous lesion. Cytology of the cyst fluid also performed poorly. In 11 studies utilizing histopathology as final diagnosis, the pooled sensitivity and specificity to differentiate mucinous from non-mucinous lesions were 63% and 88% respectively. Further cytology detected malignancy in only 48% of mucinous cancers[10].

While the current guidelines recommend resection of symptomatic cysts, the evidence however continues to remain unclear. The AGA technical review and guidelines does not support symptom based surgical resection, although symptoms should be considered with other cyst features in the decision making process[10,13].

Although there are multiple studies involving CPLs, most of these investigations do not provide histopathology as the standard for comparison in evaluating sensitivities and specificities. The overall trend including the recent AGA guidelines is more conservative management of CPLs. This might further limit the availability of ‘gold-standard’ histopathology for CPLs; thus relying on ‘expert consensus.’ A majority of the data involving the novel technology of confocal laser endomicroscopy in evaluating CPLs is hence gleaned from consensus rather than diagnostic histopathology.

**CONFOCAL LASER ENDOMICROSCOPY**

Confocal laser endomicroscopy (CLE) is a real-time laser-assisted microscopic imaging of tissue where the system provides tissue-sequences with a high resolution (1 μm–3.5 μm) facilitating *in vivo* histopathology. A low power laser illuminates the tissue through optical fibers in a miniprobe, this light is absorbed by fluorophores (either naturally occurring or applied), and the reflected fluorescence is transferred back to the laser-scanning unit through the miniprobe. These miniprobes come in various sizes with differing resolutions and field of view. The CLE probes are currently manufactured by Cellvizio, Mauna Kea Technologies, Paris, France. A fluorescent contrast is necessary for CLE imaging of tissue that does not contain naturally occurring fluorophores. Intravenous fluorescein is the most commonly used contrast agent for CLE imaging. Fluorescein stains vessels and delineates tissue structures. Since the nuclei are not stained, they appear as dark spots. By providing *in vivo* microscopic-resolution images of mucosal glands, goblet cells, and capillary patterns that may highlight dysplastic changes, CLE has the potential to replace the role of biopsies in specimen acquisition[14].

Initially, there were two CLE systems, an endoscope-integrated system and a probe-based system. Following several proof-of-concept studies, the former endoscope-based CLE is no longer commercially available. The more recent probe-based confocal laser endomicroscopy (pCLE) uses a separate unit outside the endoscope, which emits the laser required for the imaging. This miniprobe can be introduced through the working channel of any endoscope, and thus we have the GastroFlexTM, CholangioFlexTM, and ColoFlexTM high-definition probes for respective parts of the gastrointestinal tract. For imaging using pCLE, inter-or intra-observer agreement has been largely favorable in the esophagus and colon[15,16].

A novel needle-based CLE (nCLE) miniprobe (AQ-Flex 19; Mauna Kea Technologies) has been developed that can be used during endoscopic ultrasound (EUS). It is compatible with the 19-gauge (g) FNA needle. The AQ-Flex miniprobe has 10000 optical fibers, a diameter of 0.85 mm, a field of view of 320 μm, a lateral resolution of 3.5 μm, and a length of 4 m.

Cystoscopy and direct visualization of the pancreatic cyst has also been achieved using through-the-needle SpyGlass fiberoptic probe (Boston Scientific, Natick, Mass)[17]. Compared to the AQ-Flex nCLE probe, cystoscopy imaging using a Spyglass probe produced a suboptimal image that was further compromised by thick or cloudy fluid in some cysts. The cyst size was also an issue since the focal length of the Spyglass fiber (4 to 7 mm) was much larger than that of the nCLE probe (40 to 70 μm)[17].

**PROCEDURE OF ENDOSCOPIC ULTRASOUND AND NCLE IMAGING**

Patients who are referred for EUS evaluation of large (≥ 2 cm) pancreatic cysts can undergo EUS-guided nCLE before the standard process of EUS-FNA. A 19-g FNA needle is preloaded with the AQ-Flex miniprobe. At least 2 mm to 3 mm of the nCLE probe should be advanced beyond the needle tip during pre-loading. The probe position is then secured by using a locking device that attaches the probe to the inlet of the needle biopsy channel.

After a comprehensive EUS examination of the pancreas, the cyst of interest is oriented for interrogation. A single pass of the preloaded 19-g FNA needle is then performed into the pancreatic cyst. The tip of the AQ-Flex miniprobe is advanced with the needle under EUS-guidance until there is contact with the intracystic epithelium. Fluorescein (2.5 mLl to 5 mL of 10% fluorescein sodium) is intravenously injected immediately prior to CLE imaging.

The nCLE probe is gently positioned against the cyst wall (making contact without pressure) and multiple areas of the cyst wall are imaged in a fan-like distribution by using the elevator. The location of the cyst, position of the echoendoscope, and the size of the cyst limit the area covered. Aggressive maneuvering of the needle should be avoided to minimize risk of pancreatitis. While transitioning from one area of the cyst to another, it is preferable to withdraw the probe away from the cyst wall instead of grazing the cyst epithelium. Intracystic endomicroscopic videos are then captured for 2 to 5 min with permissible angulation of the 19-g fine needle aspiration (FNA) needle. Anecdotally longer video acquisition with excessive manipulation can increase risk of pancreatitis. Following this the AQ-Flex probe is gently withdrawn from the 19-g FNA needle. A syringe with negative suction is then attached to the proximal end of the needle for cyst aspiration. As per standard practice, the cyst fluid is sent for fluid analysis (CEA and amylase) and cytology. Prophylactic antibiotics are administered during and after the procedure.

**IMAGE INTERPRETATION**

All nCLE images are reviewed during the procedure (real time interpretation). However, comprehensive evaluation is feasible during post-procedure review of nCLE video files where representative images and video sequences can be selected for extraction and storage. Due to the high resolution of nCLE, real time video appears fast paced with rapid shifting of image sequences. A post-procedure play and pause approach counters this and allows for detailed review. A dedicated software provided by Mauna Kea Technologies (Cellvizio Viewer) can be downloaded from their website (compatible with both Mac and Windows operative software). This application provides multiple tools including measurement of structures, editing, and video format conversion.

**REVIEW OF PUBLISHED LITERATURE**

The feasibility of EUS-guided nCLE was first demonstrated in animal models with depiction of in-vivo histology from various abdominal organs (pancreas, spleen, liver and lymph node) after intravenous injection of fluorescein[18]. In this study, a total of 10 porcine models were examined with nCLE where the probe was inserted through the EUS-FNA needle. Organ biopsies were obtained for histologic evaluation and confirmation. Technical feasibility was demonstrated with *in vivo* image acquisition of histology grade resolution and suitable quality.

The first human pilot study demonstrated feasibility of EUS-guided nCLE for pancreatic lesions. A nCLE probe was used through a 19-gauge EUS-FNA needle in 16 cysts and 2 solid lesions of the pancreas. Technical feasibility was demonstrated in 17 of 18 cases[19]. A final diagnosis was established on either histologic analysis of a surgical specimen or positive cytology of a FNA specimen. Images of adequate quality were acquired in 10 patients. Post-procedure pancreatitis (requiring hospitalization) as an adverse event was observed in two patients (11.1%), tentatively attributable to longer nCLE image acquisition time.

The next study involving nCLE targeted development of descriptive criteria for image interpretation and classification of the nCLE findings for pancreatic masses and lymph nodes. The study included 11 patients (pancreatic masses: 4, CPLs: 3, and lymph nodes: 4)[20]. A non-malignant IPMN lesion was observed to display finger-like projections representing villous changes. Pancreatic malignancy demonstrated large dark clumps and leakage of fluorescein. Malignant lymph nodes were also noted to have large dark clumps and significant leakage of dye. In both the pancreatic mass and malignant lymph node, dye leakage was correlated with neovascularization characteristic of malignancy.

An international, multicenter pilot trial using *in vivo* CLE in the pancreas with endosonography of cystic tumors (INSPECT) was the next study to evaluate diagnostic potential and establish a safety profile[21]. A total of 66 patients with pancreatic lesions were evaluated of which 14 (21.2%) had surgical histopathology for confirmation (Table 1). Epithelial villous structures as revealed by nCLE were associated with neoplastic cystic lesions [sensitivity 59%, specificity 100%, positive predictive value (PPV) 100%, negative predictive value (NPV) 50%]. The study arrived at a few conclusions including the complementary role of nCLE imaging in diagnosis of cystic lesions and that the finding of villous or finger like structures is suggestive of IPMN type lesion. The rate of acute post procedural pancreatitis was 3% (one mild and the other moderate severity), a decrease compared to the author’s prior study mostly due to the limitation of imaging time to 10 min. Sampling error was recognized either due to mixed type of IPMN or imprecise probe placement. There were no reported adverse events to intravenous fluorescein.

Following this, the next clinical trial was DETECT (Diagnosis of Pancreatic Cysts: Endoscopic Ultrasound, Through-the-Needle Confocal Laser Endomicroscopy and Cystoscopy Trial)[17]. The objective of this study was to assess the feasibility, safety, and diagnostic yield of a combination of cystoscopy using Spyglass and nCLE in the diagnosis of CPLs. This was a single center study where a preceding ‘cystoscopy’ was performed using Spyglass followed by cyst interrogation with a nCLE probe. A total of 30 patients with pancreatic cystic lesions were studied where 2 (6%) had surgical histopathology. The authors studied the association of Spyglass-assisted cystoscopy and nCLE imaging with clinical diagnosis. In 18 high-certainty cases (2 independent investigators strongly agreed on the concordant diagnosis based on clinical presentation, image findings on EUS, CT, or MRI, fluid analysis, and cytology), nCLE alone had a sensitivity of 80%, specificity of 100%, PPV of 100%, NPV of 80%, and accuracy of 89% for diagnosis of mucinous cysts (Table 1). The sensitivity reached a 100% with the combination of Spyglass assisted cystoscopy and nCLE imaging. Rate of post procedure pancreatitis was 6.6% (2 of 30) and these patients required 4 to 5 d of hospitalization. No intravenous fluorescein-related adverse events were observed.

The most recent published results come from the Clinical evaluation of nCLE in the lymph nodes along with masses and cystic tumors of the pancreas (CONTACT) study. This is a multi-center study from France and was conducted in two phases[22]. The first phase involved identification of specific criteria for the characterization of cystic lesions in the pancreas, and retrospective validation of these criteria. Phase 2 (ongoing CONTACT 2 study) involves prospective validation of nCLE criteria for pancreatic cysts. During phase 1 of the study, a new nCLE pattern called ‘superficial vascular network’ was identified which was a unique feature of SCA[22]. For nCLE-based diagnosis of SCA, the sensitivity, specificity, PPV and NPV were 69%, 100%, 100%, 82% and 87% respectively (Table 1). The criterion of superficial vascular network was validated in 31 patients. Among these 7 (22.5%) had surgical histopathology for confirmation of diagnosis. Rate of procedure related pancreatitis was 3.2% (1 of 31 patients). This adverse event was of mild severity. There were no complications related to intravenous fluorescein.

**REVIEW OF CLINICAL ABSTRACTS**

The data from CONTACT study was utilized to investigate the technical feasibility of EUS-guided nCLE[23]. The study aims also included assessment of EUS-nCLE related complications. The procedure was feasible in 131 (93% of 141) of patients. Significant technical limitation was observed for lesions in the head and uncinate process of the pancreas necessitating interrogation of the pancreatic cyst from the second portion of the duodenum. This being the largest number of patients evaluated by EUS-guided nCLE, post-procedural acute pancreatitis was observed in 2 (1.45%) patients. This is equal to current risk of acute pancreatitis following routine EUS-FNA with smaller caliber needles (22 g or 25 g)[24].

Multiple other studies with limited number of patients have validated common criteria for diagnosis of IPMNs, SCAs, MCNs and pseudocysts (Table 2). Notably, the overall specificity for diagnosis of IPMN type lesion when finger like papillae were observed was 100% in four of these studies[25-28]. The general consensus from these abstracts was that EUS-guided nCLE was safe, feasible, and impacted management of pancreatic cysts; albeit, the authors from various abstracts suggested that multicenter and/or studies with larger number of patients are necessary for validation of representative nCLE images.

**CURRENT EVIDENCE FOR EUS-NCLE GUIDED DIAGNOSIS OF PANCREATIC CYST**

Based on currently published literature[17,19,21,22,29] and our experience, Table 3 summarizes the pancreatic structures visualized during EUS-guided nCLE examination of pancreatic cystic lesions. Table 4 summarizes the most common types of pancreatic cysts and the associated nCLE findings. Figure 1 A-D are examples demonstrating the different types of pancreatic cysts. While the evidence for nCLE guided diagnosis of BD-IPMN and SCA has accrued in recent studies, further substantiation with larger studies and *ex vivo*[29] modeling is desired. The specificity for diagnosis of either BD-IPMN or SCA is high (nearing 100%) when finger like papillae or ‘superficial vascular network’ pattern (respectively) are visualized. In the absence of visualizing these recognized image patterns, the sensitivity for diagnosis of the cystic lesion remains low (60% to 80%). For BD-IPMN lesions, distribution of the papillary epithelium is patchy and the limited intra-cystic mobility might restrict and prevent imaging the involved area of the cystic lesion. For SCA, the pattern of superficial vascular network was not observed in nearly 1/3rd of the cases. This could again be due to the limited range of movement of the nCLE probe, which is further compromised by absence of the vascular network in certain area of the cyst.

The criteria for diagnosis of pseudocysts have not been formally validated in published literature. Our experience and current available evidence is summarized in Table 4. A detailed history, prior episodes of pancreatitis, review of prior cross-sectional imaging studies, fluid analysis, and cytology might augment diagnostic suspicion for suspected pancreatic pseudocysts. It is typically rare that a pseudocyst presents as a solitary cystic lesion in the absence of a suggestive history.

Diagnosing MCN also needs validation with clinical trials. The small number of patients identified in currently published studies and meeting presentations suggest that the presence of a single band like epithelium could be indicative of MCN. The characteristic ‘ovarian stroma’ seen on histopathology has not been characterized by EUS-nCLE. Like pseudocysts, MCNs also demonstrate large caliber blood vessels, albeit without the distinctive vascular network of SCA.

Endomicroscopy features of other rare types of cystic lesions including lymphoepithelial cysts, cystic neuroendocrine tumors, retention cysts, and cystic degeneration of metastatic lesions need continued exploration.

**LIMITATIONS**

***Limitations of current studies***

A surgical histopathology as diagnostic gold standard was not universally available. Combining all three trials (INSPECT, CONTACT, and DETECT), only 20% (23 of 115) patients underwent surgical resection of the pancreatic lesion. With recent guidelines[5,13] stressing the role of watchful waiting in otherwise operative candidates (as per prior guidelines)[30], surgery for non-malignant pancreatic cystic lesions is not as frequently performed. A confirmatory diagnosis was thus not available and investigators had to resort to FNA cytology, imaging studies, patient follow-up, and consensus of experts.

***Adverse events***

Combining all three major trials (INSPECT, CONTACT, and DETECT), the rate of post-procedural pancreatitis was 4.3%. The highest risk was with the DETECT study (6.6%) especially since the procedure involved longer needle access time for Spyglass cystoscopy and nCLE imaging. The latest update from the CONTACT study evidences a much lower risk of acute pancreatitis. For the largest number of patients evaluated by EUS-guided nCLE (*n* = 141), post-procedural acute pancreatitis was observed in only 2 (1.45%) patients[23]. The prior reported risk of pancreatitis for 22-g and/or 25-g needles in cystic lesions is 2.4%[24]. The current nCLE miniprobe requires a 19-g needle. The outer diameter of a standard 19-g needle is 1.067 mm. Comparatively; a standard 22-g needle has an outer diameter of 0.718 mm. Thus a 19-g needle represents an approximate 48.6% increase in outer diameter over a 22-g needle. Although, prior studies comparing a 19-g to 22-g and 25-g needles for FNA of solid pancreatic lesions have not shown any increase in the risk of post-procedural pancreatitis, yet this doesn’t reflect the same risk when aspirating cystic lesions[31,32]. Furthermore, manipulation of the needle with the elevator of the linear echoendoscope combined with possible friction induced effect by the impact of the tip of the probe grazing the intracystic epithelium can also, theoretically increase risk of pancreatitis. The authors of the DETECT study recommended limiting both the needle access time as well as the amount of needle movement within the cyst[17].

***Technical limitations***

In a randomized trial, the technical success rate for sampling pancreatic head masses was significantly lower for the 19-g needle than for the 22-g needle (80.8% *vs* 100%)[32]. In contrast, a recent study comparing the 19-g and 25-g needles (Expect, Boston Scientific Corporation, Natick, MA) demonstrated that solid pancreatic lesions were successfully sampled irrespective of location, including patients crossed over from the 25-g cohort[31]. In the INSPECT and CONTACT trials, there were a total of 3 patients with cysts in the uncinate process. These can be technically challenging with a 19-g needle since this location necessitate access through the second part of the duodenum. In the latest update from the CONTACT study[23] involving evaluation of technical feasibility among 141 patients, 3 lesions were located in the uncinate and 64 in the head of the pancreas. Needle access through the second part of the duodenum was required in 4% of the patients. There were 3 (2%; 1 lesion in uncinate, 2 in head of the pancreas) technical failures of needle puncture and all of these involved attempts for needle access through the second part of the duodenum. In effect, FNA of the uncinate lesions with a 19-g needle from the second duodenum could represent a limitation.

**INTEROBSERVER VARIATION**

Both the INSPECT and DETECT studies did not have independent observers and thus lacked testing for interobserver variability. In the phase I of the CONTACT study, four blinded independent observers underwent a training session and independently reviewed the recorded nCLE video sets. The interobserver agreement for the criterion of superficial vascular network was significant (κ = 0.77, 95%CI: 0.55–0.99)[22]. In the recently concluded DDW meeting, investigators utilized the data from CONTACT study for external retrospective validation of diagnostic nCLE criteria for pancreatic cysts[33]. Five independent gastroenterologists underwent a teaching session by an nCLE expert. Following this 31 nCLE sequences were reviewed. Interobserver agreements were kappa values of 0.71 (for SCA), 0.65 (for MCN), and 0.9 (for pseudocysts) respectively. Our experience with nCLE reveals that there is a short learning curve to facilitate image interpretation. There are two aspects for image analysis. The first, is that the endosonographer should get comfortable with maneuvering the 19-g needle for appropriate ‘image acquisition’. Following this, the endosonographer should interpret the recorded nCLE video. Familiarity with known patterns facilitates image acquisition since every minute expended during nCLE examination is ‘precious’ in terms of exposing the patient for higher risk of procedure related pancreatitis. Our personal experience relates to improved and accelerated learning after listening to multiple sessions by nCLE experts at local and national level conferences.

**FURTHER AREAS OF RESEARCH IN EUS-NCLE**

While we need larger studies to validate nCLE findings for IPMNs, SCAs, MCNs and pseudocysts, the focus should also be on identifying additional image patterns or improve nCLE-imaging techniques to increase the sensitivity of diagnosis. *Ex vivo* examination of pancreatic cysts by higher resolution CLE probes might provide reference image patterns for *in vivo* image interpretation[29]. The images thus acquired will serve as reference standard (image atlas) for future EUS-based AQ-flex nCLE evaluation. This could potentially lead to identification of patterns suggestive of higher grades of dysplasia in IPMN and MCN. Furthermore, identification of subtypes of IPMN by nCLE imaging can lead to additional risk stratification given the fact that the morphological type is an independent predictor of patient prognosis[34]. Enhanced CLE probe technology providing for a possible 22-g needle based device resulting in an approximate 49% reduction in needle outer diameter might improve needle maneuverability thus increasing sensitivity. This may also facilitate larger studies with wider acceptance among endosonographers. More importantly, the decreased size of the needle can hopefully reduce the risk of procedure-associated pancreatitis.

In our opinion, nCLE probe compatibility with a 22-g needle would perhaps provide the utmost advance in terms of diagnostic capability and patient safety. Identification of safe, additional fluorescent markers with preferential binding to areas of higher grades of dysplasia that can be detected by the nCLE probe might also provide a big impetus to further nCLE research[35].

In conclusion, EUS-guided nCLE appears to be a convincing minimally invasive process to diagnose and risk stratify pancreatic cystic lesions. In keeping with the gastroenterologist’s motto of ‘seeing is believing’, this technology is poised for continued and expanded research. The feasibility of visualization at the microscopic level enables in differentiating cystic pancreatic lesions, but with certain challenges. These include sampling error, interobserver variability, technical limitations, risk of pancreatitis, and the attendant learning curve. The usage, currently, is still limited to select tertiary referral centers with expectations of a broader acceptance among endosonographers with growing evidence of clinical applicability and technical progress.

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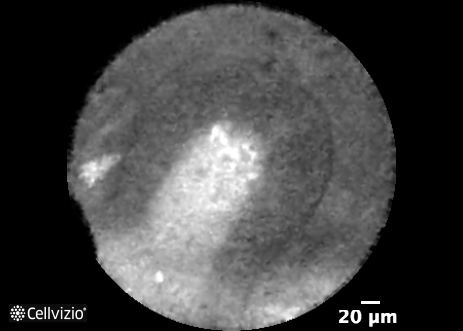
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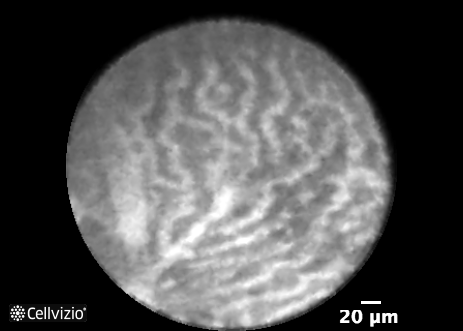
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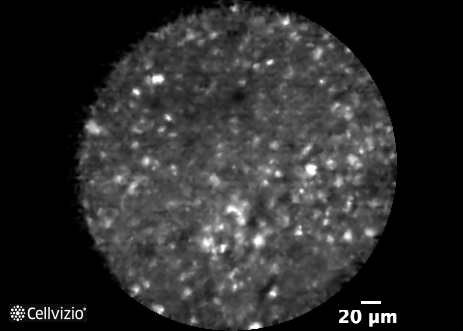
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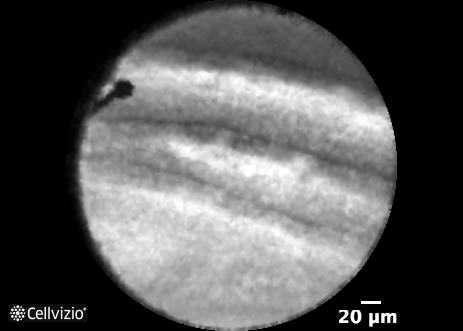


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 **Figure 1 Different types of pancreatic cysts.** A: Intraductal papillary mucinous neoplasm. A single papilla is visualized with a central fibrovascular core and overlying epithelium; B: Serous cystadenoma: Branching and tortuous network of multiple blood vessels in a ‘fern like’ pattern. This is has been termed as ‘superficial vascular network’[22]; C: Pseudocyst: Clusters of bright, floating particles with a background which is nondescript and lacks blood vessels; D: Mucinous cystic neoplasm: Solitary epithelial bands without formation of papillae.

**Table 1 Outcome, diagnostic accuracies, and risk of pancreatitis for major trials investigating role of endoscopic ultrasound-guided needle based confocal laser endomicroscopy needle based confocal laser endomicroscopy in diagnosis of pancreatic cystic lesions**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Outcome** | **Patients, *n*** | **Surgery**  ***n* (%)** | **SN** | **SP** | **PPV** | **NPV** | **Accuracy** | **Pancreatitis rate (%)** |
| INSPECT[21] | Neoplastic cystic lesions | Total: 66 | 14 (21.2) | 59 | 100 | 100 | 50 | 71 | 3 |
| DETECT[17] | Mucinous cystic lesion | Total: 30  High certainty: 181 | 2 (6) | 80 | 100 | 100 | 80 | 89 | 6.62 |
| CONTACT[22] | Serous cystadenoma | Total: 31 | 7 (22.5) | 69 | 100 | 100 | 82 | 87 | 3.2 |

1High-certainty patients included in analysis of diagnostic accuracy; 2Patient underwent both, needle based cystoscopy and confocal endomicroscopy. SN: Sensitivity; SP: Specificity; PPV: Positive predictive value; NPV: Negative predictive value.

**Table 2 Developing role of endoscopic ultrasound guided needle based confocal laser endomicroscopy in diagnosis of pancreatic cystic lesions: Review of recently presented abstracts at international gastroenterology conferences (DDW and ACG scientific meeting)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Study objectives** | **Patient, *n*** | **Pancreatitis and other complications** | **Accuracy data** | **Conclusions** |
| Napoleon *et al* CONTACT study[23]  DDW 2015 | To evaluate feasibility and assess complication rate of nCLE in CPLs.  Prospective study. | Total: 141  Technical feasibility: 93% (131 patients) | Minor pancreatitis: 2 (1.45%).  Intracystic bleeding without extravasation - 10% | NA | Main technical limitation observed when cyst interrogation requires approach through second part of the duodenum. |
| Kadayifci *et al* [28]  DDW 2015 | To assess the safety, feasibility and diagnostic value of EUS guided nCLE for CPLs.  Retrospective. | Total: 11  Procedure successful: 10 | No pancreatitis reported | The sensitivity, specificity, and accuracy for mucinous cyst (findings of papillae) were 57%, 100%, and 70% respectively. | nCLE for pancreatic cysts was safe and feasible. nCLE has low sensitivity but high specificity for mucinous cysts. |
| Bertani *et al*[26]  DDW 2015 | To validate prior described nCLE findings typical of IPMN lesions  Retrospective. | Total: 9 | No pancreatitis reported | Finger-like projections were observed in 7 of 7 IPMN lesions. | nCLE imaging identified common criteria for diagnosis of IPMN |
| Krishna *et al***[25]**  DDW 2015 | To validate prior described diagnostic nCLE imaging patterns  Retrospective. | Total: 32  Inclusion: 26  Surgery: 7 (27%) | Pancreatitis: 3.1% (1 patient) | Sensitivity, specificity, and accuracy for IPMN were 89%, 100%, and 96% respectively  Sensitivity, specificity, and accuracy for SCA were 90%, 100%, and 96% respectively | Promising technology providing diagnosis of mucinous cysts. |
| Sejpal *et al*[27]  DDW 2015 | To validate prior described nCLE findings for diagnosis of pancreatic cysts.  Retrospective. | Total: 19 | No pancreatitis reported | Sensitivity, specificity, and accuracy for IPMN were 80%, 100%, and 95% respectively | Possibly treating pseudocysts after nCLE examination bypass fluid analysis. |
| Joshi *et al*[36]  ACG 2014 | To validate available nCLE criteria for diagnosis of CPLs. | Total: 16 | No pancreatitis reported | Improved confidence in diagnosing type of cyst in 80% of patients. | Can impact in management and avoiding unnecessary surgeries for pancreatic cysts |
| Napoleon *et al*[37]  CONTACT  study  DDW 2014 | To investigate and describe nCLE characteristics of CPLs.  Prospective. | Total: 31  Inclusion: 16 | No pancreatitis reported | NA | nCLE images could help in the differentiation of IPMNs, MCN and SCA |

DDW: Digestive Disease Week; ACG: American College of Gastroenterology; CPL: Cystic pancreatic lesions; NA: Not available; IPMN: Intraductal papillary mucinous neoplasm; MCN: Mucinous cystic neoplasm; SCA: Serous cystadenoma.

**Table 3 Summary of endoscopic ultrasound-guided needle based confocal laser endomicroscopy findings: INSPECT[21], DETECT[17], and CONTACT[22] trials**

|  |  |
| --- | --- |
| Parenchymal structures | |
| Blood vessels | Thin or thick white bands; networking of blood vessels |
| Acinar cells | Dark lobular structures |
| Adipose cells | Grey oval structures |
| Pancreatic ductal epithelium | Thin grey bands |
| Fibrous strands | Ultrathin bright bands |
| Epithelial structures |  |
| Villous structures | Finger-like papillary projections, dark ring with white core (cross section) |
| Wall (fibrous) | Paucicellular, avascular wall |
| Neoplasia | Dark aggregates of cells |
| Cyst luminal structures | |
| Inflammatory cells | Clusters of bright, floating, heterogeneous particles |
| Red blood cells | Small black particles |
| Debris | Bright white fixed spots or large dark round floating particles with varying sizes |

**Table 4 Proposed criteria for diagnosis of pancreatic cystic lesions and correlative histology**

|  |  |
| --- | --- |
| Intraductal papillary mucinous neoplasm (Figure 1A) | |
| Finger like projections | Central fibrovascular core and overlying epithelium viewed in parallel |
| Dark rings | Central fibrovascular core and overlying epithelium viewed in transection |
| Parallel thick bands | Alternating papillae with central fibrovascular core and overlying epithelium |
| Absence of ‘superficial vascular network’ |  |
| Absence of ‘bright, floating, heterogeneous particles’ |  |
|  |  |
| Serous cystadenoma (Figure 1B) |  |
| ‘Superficial vascular network’ | Dense and tortuous appearing network of multiple blood vessels under cuboidal epithelium. Observed in both macrocystic and septa separating microcysts. |
| Multiple blood vessels |  |
| Absence of finger like projections |  |
|  |  |
| Pseudocyst1 (Figure 1C) |  |
| Clusters of bright, floating, heterogeneous particles |  |
| Absence of finger like projections |  |
|  |  |
| Mucinous cystadenoma1 (Figure 1D) |  |
| Solitary epithelial bands | Epithelium (columnar, tall cells) lining the cysts |
| Large caliber blood vessels |  |
| Clusters of bright particles | Epithelial cells and inflammatory elements |

1Needs validation.