A novel approach to the diagnosis of pancreatic serous cystadenoma: needle-based confocal laser endomicroscopy

Background and study aims: The differential diagnosis of solitary pancreatic cystic lesions is frequently difficult. Needle-based confocal laser endomicroscopy (nCLE) performed during endoscopic ultrasound-guided fine-needle aspiration (EUS-FNA) is a new technology enabling real-time imaging of the internal structure of such cysts. The aim of this pilot study was to identify and validate new diagnostic criteria on nCLE for pancreatic cystic lesions.

Patients and methods: A total of 31 patients with a solitary pancreatic cystic lesion of unknown diagnosis were prospectively included at three centers. EUS-FNA was combined with nCLE. The final diagnosis was based on either a stringent gold standard (surgical specimen and/or positive cytology) or a committee consensus. Six non-blinded investigators reviewed nCLE sequences from patients with the most stringent final diagnosis, and identified a single feature that was only present in serous cystadenoma (SCA). The findings were correlated with the pathology of archived specimens. After a training session, four blinded independent observers reviewed a separate independent video set, and the yield and interobserver agreement for the criterion were assessed.

Results: A superficial vascular network pattern visualized on nCLE was identified as the criterion. It corresponded on pathological specimen to a dense and subepithelial capillary vascularization usually only seen in SCA. The accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of this sign for the diagnosis of SCA were 87%, 69%, 100%, 100%, and 82%, respectively. Interobserver agreement was substantial (κ = 0.77).

Conclusion: This new nCLE criterion seems highly specific for the diagnosis of SCA. The visualization of this criterion could have a direct impact on the management of patients by avoiding unnecessary surgery or follow-up.

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combination of these standard methods (morphological examinations, cytology, analysis of tumor markers, and pancreatic enzymes in the cyst fluid) enabled the correct diagnosis to be made in no more than 79% of cases [3]. Despite the improvement of imaging examinations and intracystic fluid analysis, the diagnosis of SCA often remains uncertain, and lesions larger than 2 cm are frequently surgically resected in asymptomatic patients [3]. In a large retrospective multinational study on 2622 patients with SCA, 36% of them underwent surgery for an uncertain diagnosis [11]. This approach remains inappropriate given the fact that surgery is associated with substantial morbidity and mortality [12] and that simple surveillance could be sufficient [13]. Probe-based confocal laser endomicroscopy is a novel imaging technology that enables in vivo and real-time imaging of the microscopic structures of tissue and surface epithelium during endoscopic procedures [14]. The miniaturization of the probe allows in vivo and real-time imaging of the inner wall of pancreatic lesions during the EUS-FNA procedure, by introducing the miniprobe through a 19-G needle (Fig. 1). This innovative technique has been termed needle-based confocal laser endomicroscopy (nCLE) [15, 16]. The first study to report on this technique demonstrated its feasibility and safety for in vivo imaging of pancreatic cysts [17]. A second study, INSPECT [18], enabled the characterization of IPMNs and correlated some identified nCLE structures with histological diagnostic features.

To date, no study has evaluated the value of nCLE for the characterization of benign pancreatic cystic lesions that could have a direct impact on patient management by avoiding unnecessary surgery. The aim of this pilot study was to describe and validate a diagnostic nCLE criterion for the characterization of SCA.

**Patients and methods**

**Study design**

This prospective study took place at three centers in France (Hôpital privé Jean Mermoz in Lyon, Institut Paoli Calmettes in Marseille, and Hôpital Saint-Philibert in Lille). The study was performed with the approval of the local Ethics Committee and the French Health Authority (ANSM), and was registered on clinicaltrials.gov (NCT01563133).

All consecutive patients (n = 43) who were admitted for EUS diagnosis of a pancreatic cyst of unknown origin were considered for inclusion. Inclusion criteria were a solitary cyst > 20 mm in diameter with at least one cavity ≥ 13 mm in size. Exclusion criteria were age < 18 years, known allergy to fluorescein dye, pregnancy, previous EUS-FNA procedure performed within the past 3 months, chronic calcifying pancreatitis, presence of a communication with the main pancreatic duct on MRI or EUS, presence of criteria for malignancy (tissue mass, metastases, ascites, vascular infiltration), and the usual contraindications to EUS-FNA. Written informed consent was obtained from all patients before the examination.

Preliminary analysis was conducted after 10 months of inclusion and included two steps (Fig. 2). Step 1 aimed at identifying a specific criterion for the characterization of SCA. The identification of specific features relied on side-by-side comparison of nCLE videos and corresponding histopathological pictures from a selected group of patients (n = 18) whose final diagnosis was based on a surgical specimen and/or positive cytopathology. For each patient, several sequences were initially available; one of them was arbitrarily selected and reviewed in this step. Step 2 consisted of the validation of the identified criterion and assessment of its reproducibility by an independent group of investigators on an independent video set of 66 sequences (including 6 for training purposes) from the 31 patients enrolled in the study.

**EUS-FNA and nCLE procedures**

All procedures were performed by the investigators (B.N., B.P., M.G., F.C., B.F., and D.L.) as follows. 1) Conventional gray-scale B-mode EUS (Olympus CF-H180 [Olympus Medical Systems Corp.,
Tokyo, Japan] or Pentax EG-3870 UTK [Pentax Corp., Tokyo, Japan]) to assess the EUS characteristics of the pancreatic cyst. 2) EUS-FNA with a 19-G needle [Boston Scientific Expect Flex [Boston Scientific Corp., Natick, Massachusetts, USA] or Cook Medical Echo Tip Ultra [Cook Medical Inc., Bloomington, Indiana, USA]). Prophylactic antibiotic therapy was given before each procedure (cefazoline 2g) and the AQ-Flex 19 confocal miniprobe (Cellvizio; Mauna Kea Technologies Inc., Suwanee, Georgia, USA) was pre-loaded into the needle (Fig. 1). The confocal miniprobe has the following characteristics: 10000 optical fibers, a diameter of 0.85 mm, a field of view of 320µm, a lateral resolution of 3.5µm, and a length of 4m.

After EUS imaging, the needle with the preloaded miniprobe was inserted into the cyst under EUS guidance via a transgastric or transduodenal approach. The probe was advanced and securely positioned using the locking device. An intravenous injection of a contrast agent (2.5 mL fluorescein, 10%), was administered simultaneously to optimize nCLE imaging. Video sequences of the inside structure of the cyst were recorded.

After image acquisition, the probe was retrieved from the needle, and the cyst was emptied as completely as possible (depending on the number of cavities). The fluid underwent cytopathological examination, and levels of carcinoembryonic antigen and amylase were assessed. Pathological examination was based on ThinPrep preparation for cytological analysis and cell blocks for histological interpretation. Data regarding clinical history, morphological examinations (MRI, CT, EUS), EUS-FNA samplings, and nCLE procedures, were prospectively recorded on a dedicated case report form.

**Final diagnosis**

The final diagnosis was described as stringent when based on histological analysis of the surgical specimen and/or when FNA results were undoubtedly positive on ThinPrep preparation, cell block sections, or both. A diagnosis of SCA was considered to be undoubtedly positive when stained slides from ThinPrep preparations and/or stained cell block sections showed sheets and small ribbon of mononuclear cuboidal epithelial cells with a clear cytoplasm and a small, round, and uniform hyperchromatic nucleus, and/or stained cell block sections showed microfragments of cyst wall with lining serous epithelium. A diagnosis of IPMN was made when stained cell block sections showed papillary projection with a vascular core and a mucinous epithelial border (Fig. 3). For the remaining cases, an adjudication committee made up of the six investigators and two pathologists reviewed all available information (including a systematic follow-up by MRI 3 months after the procedure) in order to make a final diagnosis by consensus. A systematic follow-up for 1 year was scheduled for these cases. Specifically, a final diagnosis of SCA was systematically proposed when all of the following characteristics were met: serous, clear, translucent fluid; absence of nodule, mural nodules or solid tumor on EUS; absence of cytopathological criteria suggesting a mucinous lesion; CEA < 5 ng/mL; amylase < 250 U/L. Patients without a final consensus diagnosis were excluded from the analysis.

**Step 1: Development of nCLE criterion for the diagnosis of SCA**

After 10 months of inclusion, four gastroenterologists (B.N., B.P., M.G., and F.C.) and two gastrointestinal pathologists (A.I.L. and B.M.M.) reviewed 18 nCLE videos from 18 patients with stringent final diagnoses in an unblinded manner. In addition, histopathological images of 24 cystic lesions (5 SCAs, 5 IPMNs, 7 MCNs, 4 pseudocysts, and 3 cystic neuroendocrine tumors [NETs]) extracted from an archive database, were reviewed simultaneously in order to identify a specific nCLE criterion for the diagnosis of SCA. Similarities in vascular structures were noted between nCLE videos of SCA and histopathology images. Based on the similarities observed, a common theme, the superficial vascular network, was formulated into an nCLE criterion, by consensus between the six investigators.

**Step 2: External validation of the criterion**

Four independent reviewers without previous nCLE experience (F.F., C.L., V.L., and L.P.) took part in the validation review. An independent set of 66 nCLE video sequences that were not used in Step 1 were selected, with one or several representative videos for each of the 31 included patients. The videos were obtained in the proprietary .mkt format and converted into .mpeg format without compromising the image ratio or the number of pixels. The investigators underwent basic training before the test, based on the review of six videos, three of which featured the newly defined criterion. The remaining videos (n = 60) were used for the test. The cases were presented in a different order for each participant, and viewed on their personal computers. The reviewers were blinded to all clinical data. For each case, reviewers noted the absence or presence of the criterion feature on a standardized scoring sheet. Following these evaluations, the four investigators conducted a consensus review of discrepant cases in order to propose a consensus diagnosis if possible.

**Statistical analysis and data management**

Data recorded on the case report forms were entered into OpenClinica software (Waltham, Massachusetts, USA) and used in this format for the reviews, definition, and accuracy evaluation. The diagnostic accuracy parameters and the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), of the criterion were calculated for each observer. The overall diagnostic accuracy was evaluated using the consensus review. The interobserver variability was calculated using multirater Fleiss’s kappa statistic. The results were as follows: poor < 0.2, fair 0.21 – 0.4, moderate 0.41 – 0.6, substantial 0.61 – 0.8, and excellent 0.81 – 1. In addition, the permutation test and the Matthews correlation coefficient were used to test for the significance of the test in Step 2.
All patients (n = 31)

Patients
Age, mean (range), years 57 (24 – 76)
Sex
Male 6
Female 25
Cyst morphology
Location
Head 14
Uncinate 1
Body 12
Tail 4
Lesion size, mean (range), mm 39 (20 – 120)
Wall thickness > 1 mm 8
Wall nodules / vegetation 3
Calcification
Yes 2
No 29
Intracystic concentrations
CEA, mean (range), ng/mL (n = 27) 1 070 (0.5 – 15 000)
Amylase, mean (range), U/I/L (n = 22) 28 887 (7 – 255 700)
Final diagnosis definition
Surgery 7
Positive cytology 11
Adjudication committee consensus 13

Results

Population
From June 2012 to March 2013, 43 patients were screened for inclusion in the study and provided consent. A total of 11 patients were excluded due to screening failure (n = 7) and absence of final diagnosis consensus (n = 5), leaving 31 patients included in the final analysis ( Fig. 2). Patient and cyst characteristics are listed in Table 1. The mean cyst size was 39 mm, and lesions were distributed throughout all areas of the pancreas. For patients with a stringent final diagnosis (n = 18), the diagnosis was based on the surgical specimen in 7 patients (6 MCNs and 1 pseudocyst) and cytopathological analysis of the cystic fluid in 11 cases (7 SCAs, 4 IPMNs). For the remaining patients (n = 13), the adjudication committee consensus diagnoses were 6 SCAs, 1 IPMN, and 6 pseudocysts.

Technical aspect of the procedure and safety
Technical feasibility was demonstrated in all 31 cases, with no technical failures reported. The choice of needle was at the discretion of each participating center. Needle probe manipulation was rated as “moderate” or “difficult” in two cysts (one in the head, one in the uncinate process); probe manipulation was evaluated as “easy” in all of the remaining cases. The mean duration of the nCLE procedure was 7 minutes (range 3 – 10 minutes). Fluorescein was well tolerated by all patients, with no complications identified following the procedure. A single event of mild acute pancreatitis was recorded, resulting in an overall complication rate of 3.2 %. In four patients with SCA, blood was identified within the imaged cavity, but no external bleeding or further clinical consequences were observed.

Step 1: Development of nCLE criterion for the diagnosis of SCA
The simultaneous review of the nCLE sequences and histopathological images enabled the identification of a particular pattern, which was observed repeatedly and exclusively in the sequences of patients with SCA. The pattern was present independently of the morphological presentation of the SCA (i.e. uni- or multicellular). This striking criterion was described as a densely woven network of tortuous blood vessels with intense and dynamic circulation of blood cells visualized.

To explain the visualization of this dynamic pattern, pathologists referred to reference specimens of SCA. Using an immunohistochemical vascular marker, the presence of a diffuse and homogeneous capillary network was noted all around the cavities. This network lay just under the serous epithelium at a depth of 10 – 40 µm, and was identified as a capillary necklace. On the five specimens analyzed, this feature was seen either on the outlying wall of macrocysts and/or on both sides of all the septa separating the microcystic cavities ( Fig. 4). As the depth of imaging permitted by the nCLE probe is 40 – 70 µm, findings from nCLE observation could be matched to this histological vascular organization. When looking at the histology of the other pancreatic cysts ( Fig. 4), this striking vascular organization was absent in the seven MCNs, five IPMNs, four pseudocysts, and three cystic NETs. Histologically, MCN are characterized by rare and large vessels located at various depths, IPMNs are characterized by the presence of intrapapillae fibrovascular cores, and in both cystic NET and pseudocysts, the presence of many vessels can be noted, at various depths and without a regular organization. In all these cases, the characteristic necklace observed in SCA is absent. This characteristic vascular organizational structure of SCA was consensually identified as the superficial vascular network. Its characteristics are: tightly connected tortuous blood vessels of variable width; intense blood circulation with a striking dynamic aspect and varying contrast, depending on the imaging duration; it can appear as white vessels on a dark or grey background, or as dark vessels on a clear background, depending on the density of blood cells within the vessels and fluorescein contrast; it can present a watermelon-shaped or tree-like aspect ( Fig. 5, Video 1, Video 2).

Step 2: External validation of the superficial vascular network criterion
In 81 % of the cases, the agreement between the four observers was complete. A final consensus was obtained in the remaining 19 % of cases. Compared with the final diagnosis, the overall accuracy, sensitivity, specificity, PPV, and NPV of the superficial vascular network criterion were 87 % (95 % confidence interval [CI] 69 % – 100 %), 69 % (95 %CI 44 % – 92 %), 100 % (95 %CI 100 % – 100 %), 100 % (95 %CI 100 % – 100 %), and 82 % (95 %CI 66 % – 98 %), respectively. 

A subanalysis was conducted on the two categories of patients. For patients with a stringent final diagnosis the accuracy, sensitivity, specificity, PPV, and NPV of the superficial vascular network criterion were 94 %, 86 %, 100 %, 100 %, and 92 %, respectively. For the remaining patients, these values were 77 %, 50 %, 100 %, 100 %, and 70 % respectively. The interobserver agreement was substantial (κ = 0.77; 95 %CI 0.55 – 0.99). This concordance was statistically significant, with the 95 %CI (kappa ± 1.96 SE) not crossing the zero value. In addition, the correlation between the consensus diagnosis and the final diagnosis was statistically significant (P < 0.01). Results are detailed in Table 2.
These are the first data reporting the yield of nCLE for the characterization of pancreatic SCAs. In this study, a new criterion for in vivo diagnosis of SCA was described and validated—the superficial vascular network. The correlation relies on three elements. First, the observation of circulating blood cells inside the opacified channels confirms the vascular nature of the network. Second, this structure is observed at a superficial depth of 50–70µm, which corresponds to the depth of imaging of the AQ-Flex probe. Third, the pathological examination of pancreatic cyst specimens including SCAs, MCNs, IPMNs, pseudocysts, and NETs showed that the only pancreatic cystic lesion featuring a dense, tortuous, and superficial capillary vascularization was the SCA.

Following the description of the superficial vascular network, postprocedural evaluation of the sign was conducted to assess the validity and reproducibility of this finding. In a validation vid-

**Video 1**

Needle-based confocal laser endomicroscopy of serous cystadenomas depicting the superficial vascular network.

**Video 2**

Needle-based confocal laser endomicroscopy of serous cystadenomas depicting the superficial vascular network.
The second limitation of this pilot study is that data are reported from a limited cohort of patients. Therefore, this analysis is best viewed as exploratory, with the aim of describing and validating a new nCLE diagnostic criterion for the characterization of SCA. Based on the results of this pilot study, future prospective studies with larger populations should be conducted in order to confirm the diagnostic yield and to assess the clinical impact.

Third, examinations were limited to cysts larger than 2 cm with at least one cavity larger than 13 mm. These inclusion criteria were proposed because cysts smaller than 2 cm are very rarely malignant [21], and for technical reasons, as a cavity of at least 13 mm of diameter is necessary to collect a sufficient amount of fluid (1 mL) for further cytological analysis. Moreover, on EUS, cysts with only microcystic components are most likely to be SCAs, and puncture is generally not even considered. Lesions featuring communication with the main pancreatic duct or criteria suggestive of malignancy were excluded, as they do not represent a diagnostic dilemma using conventional diagnostic methods. Finally, the superficial vascular network sign was observed in only 69% of SCA cases. Further series are needed to evaluate whether this sign is absent in 31% of cases or whether this criterion is more frequently observed on specific areas of the lesion (e.g., wall vs. septa).

In conclusion, this study has developed and tested a new diagnostic nCLE criterion that is present in SCA—the superficial vascular network. The examination of pathological specimens confirmed the specificity of this sign. Considering the specificity and PPV of the sign and the substantial interobserver agreement, the visualization of this feature could have a direct impact on the management of patients with pancreatic cystic lesions. The presence of the superficial vascular network during nCLE exploration should allow clinicians to confidently diagnose SCA, rule out unnecessary surgical resection, and limit systematic follow-up. The next phase of investigations should confirm the utility of nCLE by prospectively evaluating the accuracy of the technique for the characterization of mucinous vs. nonmucinous lesions, as well as the impact of the technique on patient management.

Competing interests: None

Institutions

1 Department of Gastroenterology, Hôpital privé Jean Mermoz, Générale de Santé, Lyon, France
2 Department of Biopathology, Centre Léon Bérard, Lyon, France
3 Department of Hepatogastroenterology, Institut Paoli Calmettes, Marseille, France
4 Medico-surgical Department of Hepatogastroenterology, Saint-Philibert Hospital Centre, Lomme-lès-Lille, France
5 Department of Digestive Surgery, Hôpital privé Jean Mermoz, Générale de Santé, Lyon, France
6 Department of Gastroenterology, Clinique du Trocadéro, Paris, France
7 Department of Biopathology, Institut Paoli Calmettes, Marseille, France

Table 2  Yield of SVN criterion in the two categories of patients.

<table>
<thead>
<tr>
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<th>All patients n = 31</th>
<th>Cases with final stringent diagnosis n = 18</th>
<th>Cases with less stringent final diagnosis n = 13</th>
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<tr>
<td>Final diagnosis, n</td>
<td></td>
<td></td>
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<tr>
<td>SCA</td>
<td>13</td>
<td>7</td>
<td>6</td>
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<td>MCN</td>
<td>6</td>
<td>6</td>
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<tr>
<td>IPMN</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Pseudocyst</td>
<td>7</td>
<td>1</td>
<td>6</td>
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<tr>
<td>Specificity</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Sensitivity</td>
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<td>86</td>
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<tr>
<td>NPV</td>
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<td>92</td>
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<tr>
<td>Accuracy</td>
<td>87</td>
<td>94</td>
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SCA, serous cystadenoma; MCN, mucinous cystic neoplasms; IPMN, intraductal papillary mucinous neoplasm; PPV, positive predictive value; NPV, negative predictive value.
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References