Smart Atlas for Supporting the Interpretation of probe-based Confocal Laser Endomicroscopy (pCLE) of Biliary Strictures: First Classification Results of a Computer-Aided Diagnosis Software based on Image Recognition

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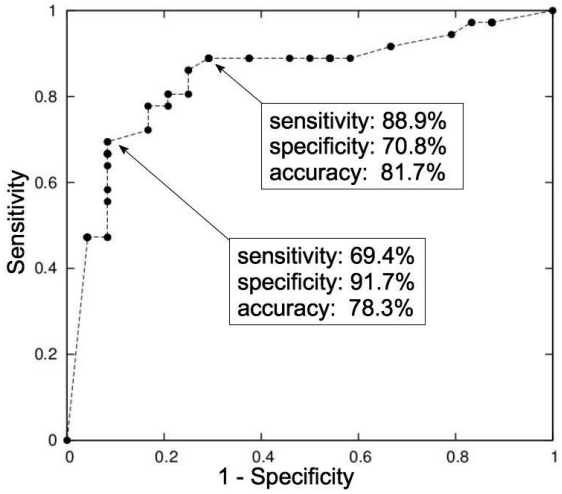
BACKGROUND AND AIMS:
pCLE enables microscopic imaging of biliary strictures, in vivo and in real time, during an ERCP procedure. Results of a multicentric study (Meining et al., GIE 2011) have shown that pCLE allows endoscopists to differentiate benign from malignant strictures in real time with high sensitivity and NPV. A computer-aided diagnosis software called Smart Atlas has been developed to assist endoscopists with the interpretation of pCLE sequences. This study aims at evaluating the performance of this software for the differentiation of benign and malignant strictures.

METHODS:
Several high quality pCLE sequences were retrospectively collected from pCLE procedures performed in multiple clinical centers. These sequences, along with their annotated final diagnosis, were used to train a classification software that uses a content-based image retrieval algorithm to predict the diagnosis of a query video based on the diagnoses of the most visually similar atlas videos. For all cases, final diagnosis was based on histology, positive tissue sampling, or one year follow-up. All evaluations were performed using leave-one-patient-out cross-validation to avoid bias. To evaluate binary classification, a receiver operating curve was generated, allowing optimization of the trade-off between false positives and negatives.

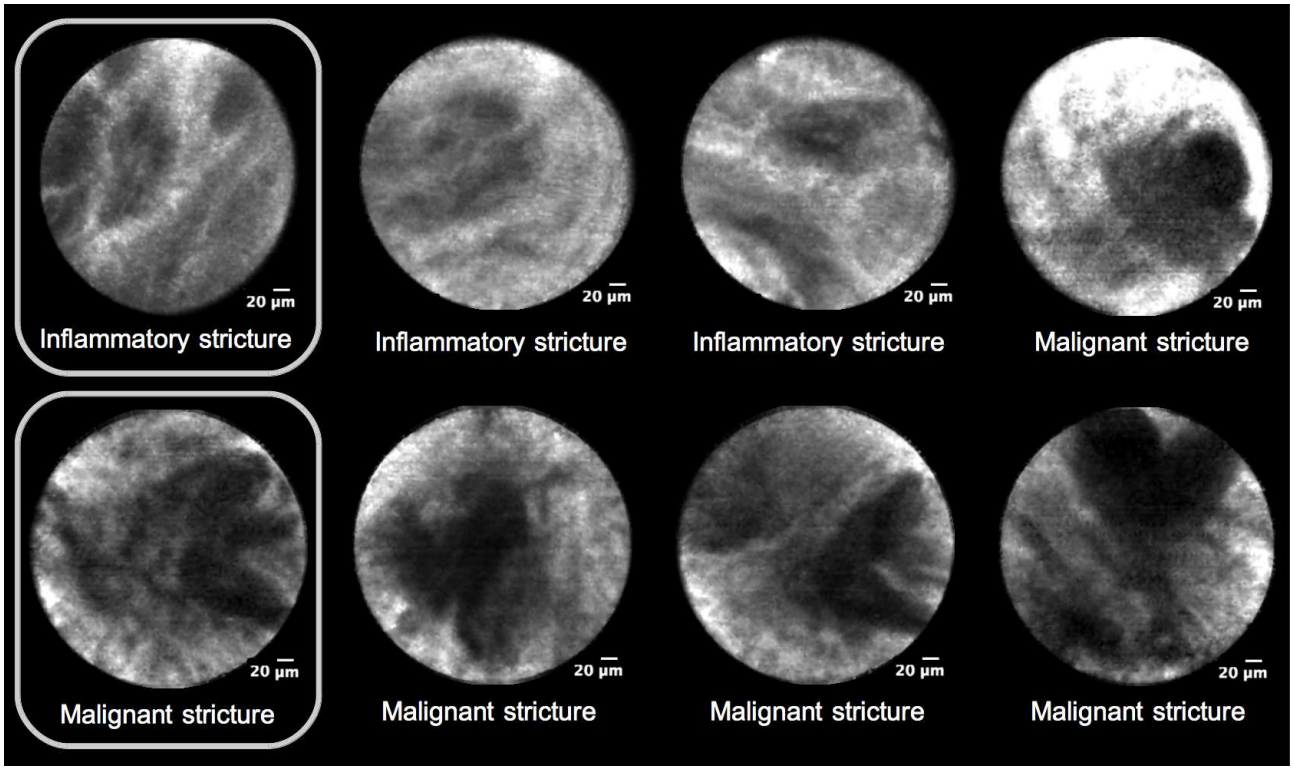
RESULTS:
Among the 60 pCLE sequences collected from 30 patients, 14 were representative of healthy bile duct, 10 of inflammatory strictures and 36 of malignant strictures. The resulting receiver operating curve shows two points of interest: the first (reps. second) point has a high sensitivity of 88.9% (reps. high specificity of 91.7%), an acceptable specificity of 70.8% (reps. acceptable sensitivity of 69.4%), an accuracy of 81.7% (resp. 78.3%), a PPV of 82.1% (resp. 92.6%) and a NPV of 81.0% (resp. 66.7%). In comparison, Meining et al. reported that, for in vivo pCLE diagnosis of malignant stricture, endoscopists achieve overall sensitivity, specificity, accuracy, PPV and NPV of 98%, 67%, 81%, 71% and 97%, respectively.

LIMITATIONS:
Small and unbalanced sample size, restricted to high quality videos.

CONCLUSIONS:
These first results demonstrate that benign and malignant strictures can be automatically discriminated by the Smart Atlas software using only the image content of pCLE sequences of high quality, with an accuracy comparable to that achieved in real-time by endoscopists. The software is also able to achieve high specificity and PPV to help reduce false positives caused by inflammatory strictures. Future work will focus on improving the software to handle pCLE sequences of various quality. The resulting case-based reasoning software could be used as an educational tool to train non-expert endoscopists, but also as a second-reader tool to assist any endoscopist in real-time diagnosis of biliary strictures using pCLE.



Receiver operating characteristic curve for the binary classification between benign and malignant biliary strictures.



On each line: pCLE image representative of a query video (framed image on the left), followed by 3 pCLE images representative of the 3 atlas videos which have been automatically recognized by the Smart Atlas software as the most visually similar to the query video. Each pCLE video is annotated with final diagnosis.