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Manual versus Automatic Classification of Laryngeal Lesions based on Vascular Patterns in CE+NBI Images

Abstract: Longitudinal and perpendicular changes in the blood vessels of the vocal fold have been related to the advancement from benign to malignant laryngeal cancer stages. The combination of Contact Endoscopy (CE) and Narrow Band Imaging (NBI) provides intraoperative real-time visualization of vascular pattern in Larynx. The evaluation of these vascular patterns in CE+NBI images is a subjective process leading to differentiation difficulty and subjectivity between benign and malignant lesions. The main objective of this work is to compare multi-observer classification versus automatic classification of laryngeal lesions. Six clinicians visually classified CE+NBI images into benign and malignant lesions. For the automatic classification of CE+NBI images, we used an algorithm based on characterizing the level of the vessel's disorder. The results of the manual classification showed that there is no objective interpretation, leading to difficulties to visually distinguish between benign and malignant lesions. The results of the automatic classification of CE+NBI images on the other hand showed the capability of the algorithm to solve these issues. Based on the observed results we believe that, the automatic approach could be a valuable tool to assist clinicians to classifying laryngeal lesions.

Keywords: Contact Endoscopy, Larynx, Classification

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1 Introduction

Laryngeal cancer is one of the most common tumors of the respiratory tract with a high incidence and mortality. Laryngeal lesions in a precancerous stage such as laryngeal dysplasia could develop to cancerous stage. Hence, early detection and diagnosis of suspicious laryngeal mucosal lesions is important to preserve the larynx and vocal fold function [1,2].

Changes in the organization and structure of the vocal fold's blood vessels are directly related to the development of benign and subsequent malignant lesions. The Endoscopic Laryngeal Imaging section of the European Laryngological Society proposed a guideline for the classification of these changes and divided them into two main categories, longitudinal and perpendicular vascular changes [3]. Longitudinal vascular changes (LVC) spread along the length and width of the vocal fold and can be observed in all kinds of benign or malignant lesions. On the contrary, perpendicular vascular changes (PVC) develop perpendicularly towards the mucosa intraepithelial and are associated to papillomatosis and malignant lesions. The evaluation of LVC and PVC therefore has a high diagnostic relevance [3,4].

Larynx endoscopy techniques can provide valuable information about the structural changes of the vocal fold's vessels in real time. Contact Endoscopy (CE) is one of these techniques that can be combined with other optical enhancement techniques such as Narrow Band Imaging (NBI) to provide a clear visualization of the vascular patterns of the larynx [5]. The first application of CE in the larynx was reported in 1995 and its efficiency was subsequently confirmed as a diagnostic tool in the evaluation of various pathologies in the larynx [6,7]. However, the evaluation of vascular patterns in CE+NBI images depends on the clinicians' experience as at the beginning of the training there is a risk of subjective evaluation causing difficulty in differentiation between benign and malignant lesions [8-10].

The main objective of this work is to present a preliminary comparison of multi-observer manual classification versus automatic classification of CE+NBI images into benign and malignant lesions. For that, a dataset of CE+NBI was generated. The classification scenario presented in [11] was used for the manual classification including three experienced and three less-experienced Otolaryngologist who visually evaluated CE+NBI images and subsequently classified them based on PVCs appearance in the images. For the automatic classification, we used the algorithm that was already proposed in our previous work [12] for automatic characterization of laryngeal lesions based on vascular patterns in CE+NBI images.

2 Material and Methods

2.1 Data Acquisition and Dataset Generation

Video scenes of 68 patients with histologically examined laryngeal lesions were acquired. An Evis Exera III Video System with a xenon light source plus integrated NBI-filter (Olympus Medical Systems, Hamburg, Germany) and a rigid 30-degree contact endoscope (Karl Storz, Tuttlingen, Germany) were used. 1632 high resolution CE+NBI images with unique vascular patterns were manually extracted from these videos. The images were labelled into benign and malignant groups based on histological diagnosis according to the WHO classification [13].
Table 1 shows the histopathologies with their number of patients and images used for the generation of the dataset.

2.2 Manual Classification

Based on [11], a series of four to five CE+NBI images were randomly selected for each patient from the previously extracted images. Three otolaryngology specialists (experienced observers) and three otolaryngology residents (less- experienced observers), blinded to the histologic diagnosis, independently visually evaluated the series of images to detect and classify lesions based on vascular patterns. PVC-positive lesions with the malignant histological diagnosis were considered true positives for the calculation of sensitivity and specificity. The calculation was conducted with the IBM SPSS Statistics software package (V-26), and the average value for each group of observers was presented.

Table 1: Histopathologies used for the generation of the dataset.

Type of Lesion	Histopathology	Number of Patients / Images
Benign	Cyst	3 / 90
	Polyp	5 / 71
	Reinke's edema	12 / 329
	Hyperkeratosis	4 / 82
	Squamous hyperplasia	3 / 75
	Papillomatosis	11 / 286
	Other lesions	5 / 88
Malignant	Dysplasia mild	3 / 77
	Dysplasia moderate	2 / 49
	Dysplasia severe	3 / 68
	Carcinoma in situ	9 / 249
	Squamous Cell Carcinoma (SCC)	8 / 168

2.3 Automatic Classification

An algorithm [12] was used for the automatic classification of CE+NBI images by characterizing the level of the vessel's disorder based on the consistency of gradient direction and the vessels' curvature.

For the image pre-processing and vessel segmentation step, the Jerman filter [14] was used as a new enhancement technique to overcome the observed deficiencies of the already used Frangi filter. Sigma (σ) and Tau (τ) are two main parameters of the enhancement function in Jerman filter. σ is a vector of scales on which the vesselness is computed. This parameter was set in the range of 0.5 mm to 2.5 mm with the step size of 0.5 mm to cover all the possible vascular structures. τ is a parameter that controls response uniformity. The empirical tests showed that a value between 0.5 to 1 is the proper value for τ. For that, in this study τ was set as 1. Figure 1 shows the outcome of this filter followed by the skeletonization process.

Five indicators were computed after image pre-processing and vessel segmentation based on direction-based and curvature-based characteristics of the vessels in CE+NBI images. Then 24 features were extracted based on the qualitative properties of these indicators as described in [12].

Features were fed into four supervised classifiers, including Support Vector Machine (SVM) with Polykernel and Radial Basis Function (RBF), k-Nearest Neighbor (kNN), and Random Forest (RF). The optimal hyperparameters for each classifier were set based on the results of hyperparameter tuning in [12]. For the classification scenarios, the same CE+NBI images selected for the manual classification were used as the testing set (336 images, ~20% of the dataset), and the rest of the images were used for training (1296 image, ~80% of the dataset). We used this training and testing set strategy to be able to compare the results of manual and automatic classifications. The sensitivity and specificity were calculated from a confusion matrix for each classification scenario.

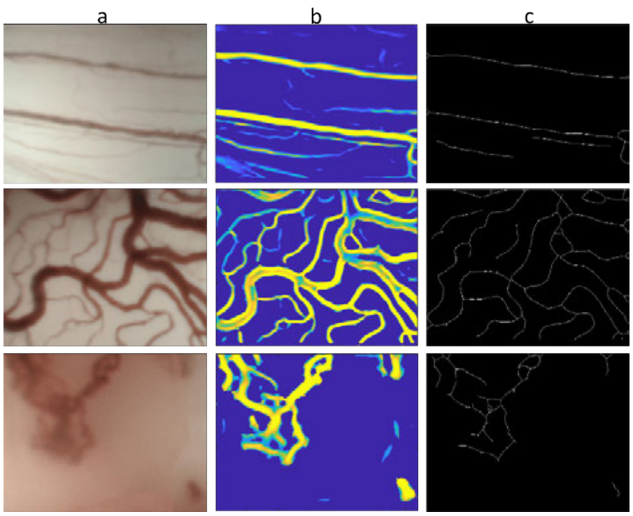

Figure 1: Imgae pre-processing: a) Original image, b) Jermann Filter, c) Skeletonization

3 Results and Discussion

Table 2 presents the results of manual classification performed by the clinical observers and automatic classification using four supervised classifiers.

The mean sensitivity value of manual classification showed a difference between experienced and less-experienced groups. Showing that the interpretation of vascular patterns in CE+NBI images is subjective and highly depends on the experiences of the clinicians. The mean specificity of 0.630 and 0.609 values in manual classification can be explained by the difficulty to visually distinguish between benign and malignant lesions based on vascular pattern. Papillomatosis is a benign histopathology that has similar vascular patterns to malignant lesions leading to misclassification of papillomatosis as malignant lesions. The automatic classification showed a sensitivity of 0.959 by SVM with RBF and specificity of 0.932 by kNN. These results emphasize the ability of the automatic approach to solve the problem of misclassification of laryngeal lesions such as papillomatosis and with that is valuable for all clinicians, experienced and less- experienced ones.

Table 2: Results of manual classification versus automatic classification of CE+NBI images.

		Sensitivity	Specificity
Manual Classification	Experienced Observers	0.955	0.727
	Less-experienced Observers	0.630	0.609
Automatic Classification	SVM with Polykernel	0.819	0.872
	SVM with RBF	0.959	0.853
	kNN	0.942	0.873
	RF	0.872	0.932

4 Conclusion

The results confirm the relevance of the vascular patterns as an evaluation parameter for benign or malignant lesions. The automatic approach has the potential to operate as assisting system to provide a confident way for clinicians to make the final decision about the stage of the laryngeal cancer in the routine surgical procedures.

Author Statement

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