Vascular pattern detection and recognition in endoscopic imaging of the vocal folds

Abstract: At present transoral laryngeal interventions are mainly observed and controlled by an external two dimensional direct microscopic view. This modality provides an overall view on the surgery situs in a straight line of sight. For treatment planning and appropriate documentation, an endoscopic inspection is mandatory prior to surgery. Nowadays a detailed endoscopic work-up of laryngeal lesions can be performed by contact endoscopy in combination with structure enhancement like Narrow Band Imaging. High resolution and magnification of up to 150 times provide detailed visualization of vascular structures and pathological changes of the tissue surface. In these procedures it is difficult however to localize the evaluated areas on large scale scenes like the microscopic view used for surgery. To provide a fast and easy image matching an automated vessel pattern recognition and allocation is presented. Endoscopic images depicting representative vessel structures of the vocal folds are selected out of contact endoscopy video scenes. These images are pre-processed for background homogenization. A Frangi Vessel Segmentation filter and morphological operations are used to extract the vessel structure and match it to the microscopic image. Using this method 4 detailed contact endoscopy images could be allocated in different scenes of the microscope video.

This method can be used to simplify treatment planning and to prepare image data for documentation.

Keywords: Endoscopy, Vocal folds, Larynx, Surgery, ENT, Image analysis, Pattern recognition, Pattern allocation.

https://doi.org/10.1515/cdbme-2018-0019

1 Introduction

0.7% of surgeries in Germany per year are dealing with the treatment of diseases of the upper digestive and respiratory tracts [1]. Treatment strategies include open surgery or transoral micro surgery to avoid an open transcervical procedure [2]. For diagnosis and treatment planning, an endoscopic inspection has to be performed prior to surgery. This procedure is regularly done using white light imaging. Additionally, it and can be combined with enhancement technologies like Narrow band imaging (NBI) or Fluorescence Imaging. NBI uses blue (415nm) and green (540nm) wavelength light to highlight features from the mucosal surface like the haemoglobin of the capillary vessels. The shorter wavelength penetrates the superficial layers of the mucosa while the longer one penetrates deeper into the tissue [3]. Changes in the structure of vasculature can be an indicator for early stage diseases like cancer. These changes appear first on a microscopic level. To depict them, a high resolution and high magnification imaging technique is necessary. Contact endoscopy (CE) can show these early changes especially in combination with NBI [4]. But unfortunately only small regions can currently be covered by CE.

During the micro laryngeal intervention for treatment of diseases of the vocal folds, an external microscopic imaging (MI) is used. This provides an overall view on the surgery situs in a straight line of sight [5]. To automatically identify structures depict by CE + NBI in this overall view, we show an automated vessel structure recognition and allocation method.
2 Materials and Methods

2.1 Image acquisition and selection

To develop an automated algorithm for vessel pattern recognition and allocation, video scenes of CE + NBI were acquired during inspection of the vocal folds. This data collection was part of the regular surgery preparation. A contact endoscope (KARL STORZ, Tuttingen, Germany) in combination with an endoscopic imaging system (VISERA 4K UHD, Olympus, Japan) was applied. Additionally video scenes of the overall vocal folds were captured from the surgery microscope (OPMI NC4, Zeiss, Germany) using the same 4K camera system.

Out of the CE video scenes 4 different images depicting vessels of the right vocal cord were selected. Scenes presenting an overall view of the vocal folds were selected from the microscope video.

2.2 Image processing

An algorithm to find the vessel patterns in the CE image and to match it with the MI image needed to be developed. First, the vessel structures have to be extracted from the CE and MI images. Therefore, the MI images with HD resolution (1008x1280) are divided into patches of 80 x 80 pixels. The resulting number of patches $P$ is 201.

For CE a pre-processing step is applied first. The objective of pre-processing is to attenuate the low trend frequency inhomogeneity’s in the image in order to better differentiate vessel from background information. For that, a Discrete Wavelet Transform filter is applied to each line profile of the CE and of its transposed.

The resulting homogenized image and each patch of the MI then passes through a Frangi Filter [6], a multiscale vessel enhancement filter. A Canny edge detection is applied to the resulting images for obtaining a first segmented image version. For final vessel structure extraction, a morphological operation is applied in order to connect pieces of vessels and eliminate over-segmented structures.

Figure 1 displays the main steps of the proposed approach for vessel structure extraction.

2.3 Image matching

After vessel structure extraction a matching procedure is performed in order to localize the CE vessel patterns in the overall MI image. To perform the matching process, the vessel structure extracted from the CE image has to be compared with the vessel structures extracted from the 201 cropped patches of the overall MI image. The extracted vessel contour can be considered as a template that is matched with each one of the patches by looking for the highest similarity in the MI image.

The block diagram of Figure 2 summarizes the approach for comparing the vascular structures of CE to the MI one.

In order to estimate the similarity between the contours, a method, based on polynomial fitting of contours, was adopted. It starts by finding the best polynomial function fitting the contours of the CE image. Then, contour points from each of the 201 patches were evaluated in the polynomial function extracted from the MI image. The matching vessel structure can be found in the patch with contour points, which produce the least error in the polynomial evaluation process (see eq 1).
\[ E_{\min} = \min(E(I_p)), \forall p = 1, 2, ..., 201 \] (1)

E: Error of polynomial evaluation
P: Patch ID
Ip: Particular patch

3 Results and discussion

Figure 1 and 3 are showing the extracted vessel structures of four CE images after each step of the proposed approach. It is possible to observe that the main vessel structures are correctly segmented even under high inhomogeneity conditions, for example when high intensity light reflections are present in the image. These extracted structures show enough information about the vessel shape for automatic localization in the MI image.

Using this method 4 detailed CE images could be allocated in 5 different scenes of the MI video (Figure 4).

Figure 2: Matching procedure for detection of vessel crop in the microscopic image

Figure 3: Vessel contour extraction obtained for three different endoscopic vessel images.

Figure 4: MI overall scene of the vocal folds with the 4 CE scenes and their location.

4 Conclusion

The method proposed in this paper provides an automated vessel structure allocation in CE and MI endoscopic images. It has the potential to be used to support
treatment planning and preparation of image data for
documentation. The algorithm runs stable for the images
included in this first test. Future steps should include a real-
time data acquisition and processing. The algorithm can be
trained to speed up the allocation process. A stitching method
for the single CE images can help to identify borders of
structures of interest.

Author Statement
Research funding: This research was financially supported by
the Federal Ministry of Education and Research (BMBF) in
context of the 'INKA' project (Grand Number 03IPT7100X).
Conflict of interest: Authors state no conflict of interest.
Informed consent: Informed consent has been obtained from
all individuals included in this study. Ethical approval: The
research related to human use complies with all the relevant
national regulations, institutional policies and was performed
in accordance with the tenets of the Helsinki Declaration, and
has been approved by the authors' institutional review board
or equivalent committee.

References
[1] „Publikation - Gesundheit - Operationen und Prozeduren der
vollstationären Patientinnen und Patienten der
Krankenhäuser (4-Steller) - Statistisches Bundesamt
(Destatis)“.  
„Objective quantification of the vocal fold vascular pattern:
comparison of narrow band imaging and white light
Oto-Rhino-Laryngol. Soc. EUFOS Affil. Ger. Soc. Oto-Rhino-
Laryngol. - Head Neck Surg., Bd. 273, Nr. 9, S. 2599–2605,
[3] K. Gono u. a., „Appearance of enhanced tissue features in
narrow-band endoscopic imaging“, J. Biomed. Opt., Bd. 9,
Stimmlippen in Kombination mit Narrow-Band-Imaging
(Kompaktendoskopie)“, Laryngo-Rhino-Otol., Bd. 94, Nr. 03,
S. 150–152, März 2015.  
tumors“, GMS Curr. Top. Otorhinolaryngol. Head Neck