

Chapter 83

Detection of Rarefaction of Capillaries and Avascular Region in Nailfold Capillary Images

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ABSTRACT

Reduction in the capillary density in the nailfold region is frequently observed in patients suffering from Hypertension (Feng J, 2010). Loss of capillaries results in avascular regions which have been well characterized in many diseases (Mariusz, 2009). Nailfold capillary images need to be pre-processed so that noise can be removed, background can be separated and the useful parameters may be computed using image processing algorithms. Smoothing filters such as Gaussian, Median and Adaptive Median filters are compared using Mean Squared Error and Peak Signal-to-Noise Ratio. Otsu's thresholding is employed for segmentation. Connected Component Labeling algorithm is applied to calculate the number of capillaries per mm. This capillary density is used to identify rarefaction of capillaries and also the severity of rarefaction. Avascular region is detected by determining the distance between the peaks of the capillaries using Euclidian distance. Detection of rarefaction of capillaries and avascular regions can be used as a diagnostic tool for Hypertension and various other diseases.

INTRODUCTION

Capillaries form a very crucial component of circulatory system. Capillaries are the actual sites where the exchange of gases, nutrients and waste products occur in a tissue. They are very thin vessels of micrometer diameter and are imaged at the finger nailfolds since they are placed parallel to the skin at the nailfolds. There are various features of the capillaries such as capillary density, capillary dimensions

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and capillary architecture. Capillaroscope is a non-invasive imaging device that captures the capillary distribution in the nailfold and the images so obtained are processed to obtain various capillary features. Cutolo et al (2010) specify that the capillary features are then interpreted to conclude about the presence/absence of diseases, identify the severity of the disease and sometimes, even as an early biomarker in the detection of diseases much earlier than the actual symptoms. Capillary density refers to the number of capillaries present in the given length. This parameter is a crucial parameter in diagnosis of diseases such as hypertension. It is observed that hypertensive subjects have a rarefaction of capillaries i.e., the capillary density is low. An avascular area on the image is an area with capillary loss. H J Anders et al (2000) define avascular areas as a lack of more than three capillary loops. Extended avascular areas are defined by Mariusz et al (2009) as absence of capillaries in an area longer than 500 μ m. This can be identified by finding the distance between capillaries. If this distance is three times or more than the distance in healthy controls, then an avascular area is said to be detected.

The commercially available capillaroscope is very expensive; instead, a USB Digital microscope is used which has a magnification of 200x. Researchers have worked on the video sequences obtained from a capillaroscope. But there is a need for research in processing of images obtained from a digital microscope. The image quality is far inferior compared to the high resolution video sequences from a commercial capillaroscope. Filtering is a fundamental signal processing operation, and often a pre-processing operation which can be used for de-noising, image enhancement and edge detection. Smoothing filters are averaging filters which can be applied for noise removal. These low pass filters can be improved by using weighted averaging over the image. Linear filters are associated with blurring and are incapable of removing certain types of noise such as impulsive noise (Eg: Gaussian filters). Nonlinear filters such as Median filters can be useful to remove impulsive noise. F Isgro et al [2013] preprocess the video sequences by extracting the frames followed by green channel extraction, edge preserving smoothing and contrast stretching. Then frame registration is done followed by conversion to gray scale. Segmentation includes coarse segmentation by selecting the areas that are likely to contain capillaries followed by a battery of automated thresholds. Isgro reports a true positive rate of 0.96 and a true negative rate of 0.99. Niraj P Doshi et al [2012] evaluates ten image enhancement techniques for nailfold capillary images as a precursor to edge detection aimed at identifying capillaries. They consider Gaussian, alpha trimmed, median and wavelet filters among others. Yogamangalam and B Karthikeyan discuss various segmentation techniques such as region based, edge based, threshold based, feature based clustering and model based segmentation. They mention that compared to other methods, thresholding is the simplest and computationally fast.

Initially, the capillary images are cropped manually to retain only the upper row of capillaries which are used for the analysis. The cropped images are then pre-processed using filters and then Otsu's thresholding is used to convert into a binary image. The capillaries are extracted using connected component labeling (Lun-chien, 2011) and then, quantitative calculations are carried out. Interpretation of rarefaction of capillaries and avascular areas is based on the values of the quantities, namely, capillary density and distance between capillaries.

MOTIVATION

Capillaroscopy has huge potential as a diagnostic and prognostic clinical tool. In Indian subcontinent, nailfold capillaroscopy is yet to gain popularity (Bakuni, 2012). The reasons could be the cost of the

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