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SHORT COMMUNICATION - IMAGING

Green light may improve diagnostic accuracy of nailfold capillaroscopy with a simple digital videomicroscope

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Abstract Nailfold capillaroscopy is a non-invasive and safe technique for the analysis of microangiopathologies. Imaging quality of widely used simple videomicroscopes is poor. The use of green illumination instead of the commonly used white light may improve contrast. The aim of the study was to compare the effect of green illumination with white illumination, regarding capillary density, the number of microangiopathologies, and sensitivity and specificity for systemic sclerosis. Five rheumatologists have evaluated 80 images; 40 images acquired with green light, and 40 images acquired with white light. A larger number of microangiopathologies were found in images acquired with green light than in images acquired with white light. This results in slightly higher sensitivity with green light in comparison with white light, without reducing the specificity. These findings suggest that green instead of white illumination may facilitate evaluation of capillaroscopic images obtained with a low-cost digital videomicroscope.

Keywords Nailfold capillaroscopy · Videomicroscope · Systemic sclerosis · Imaging

Introduction

Nailfold capillaroscopy (NFC) is a non-invasive technique for the analysis of microangiopathologies. NFC is primarily used to distinguish between primary and secondary Raynaud's phenomenon (RP) and is a valuable tool for early diagnosis and follow-up of systemic sclerosis (SSc) [1]. NFC is gaining popularity in rheumatological outpatient clinics. It requires both expertise and optimal equipment, which are rather costly. Therefore, many rheumatologists have used simple digital videomicroscopes. The resulting images are, however, often of poor quality, which limits their interpretation.

Nailfold capillaroscopies are usually performed with white light. In theory, green illumination, with a central wavelength of 530 nm, corresponds to an isobestic point in the absorption spectra of deoxy- and oxy-haemoglobin and therefore results in optimal contrast [2]. In a computerised videocapillaroscope, green light was used, but the specific advantages of green light compared with white light have not been studied [3]. In orthogonal polarisation spectral (OPS) imaging [4] and side-stream dark field (SDF) imaging [5], illumination with green light (wavelength 520–560 nm) was used to enhance contrast between capillaries and surrounding tissue [6, 7].

To improve NFC with a low-cost digital videomicroscope, we replaced the standard white LEDs by green light LEDs. The purpose of this study was to compare images made with green and white illumination.

Methods

We performed nailfold videocapillaroscopies with two digital microscopes (DigiMicro Profi) (Fig. 1). One was used with the standard ring of white LEDs (wavelength 500 ± 150 nm). In the other, we replaced these with green LEDs (wavelength 538 ± 20 nm). Both green and white LEDs had a maximum luminous intensity of 12,500 mcd

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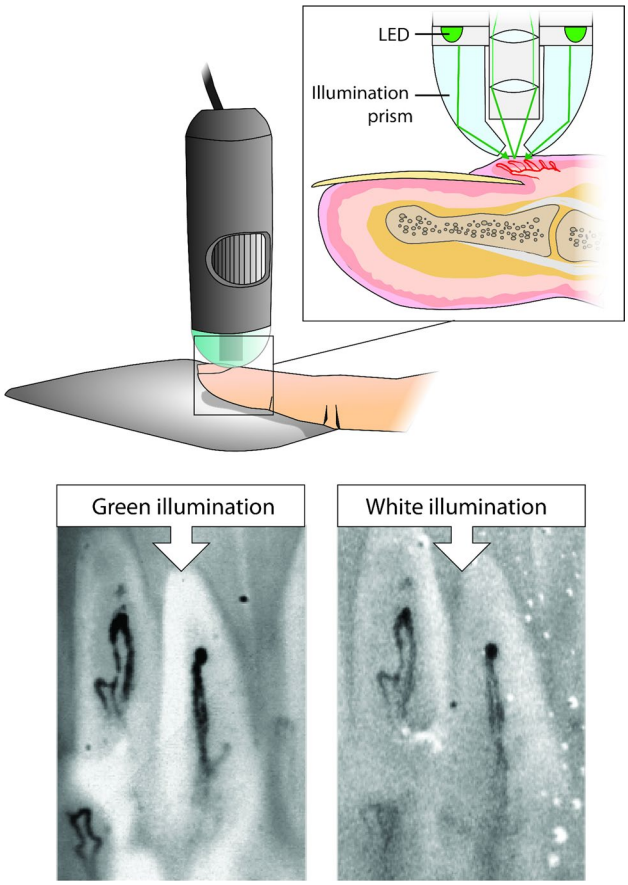

Fig. 1 Illustration of the capillaroscope and its position on the nailfold (*top*). Below, two cropped abnormal capillaroscopic images of the same capillaries, magnification 200×. *Left* acquired with green illumination. *Right* acquired with white illumination

and a viewing angle of 30°. All other properties of the microscopes were identical, including a specially designed illumination prism that fitted both microscopes.

Capillaroscopic images (using immersion oil and magnification 200×) of ten healthy subjects and five patients with SSc fulfilling ACR (1980 and 2013) criteria were obtained by a single observer (HW). All subjects were informed about the purpose of the study. In accordance with local ruling, no formal ethical approval was required. Nailfolds of four fingers (index and middle finger of both left and right hand) of each patient were imaged. In healthy subjects, only both index fingers were imaged. Each finger was imaged with green and white illumination in random order, resulting in 40 images with each light source equally divided over controls and patients.

The digitally stored true-colour RGB images were converted to greyscale intensity images, in order to blind the observer for the used illumination colour. Contrast was enhanced using contrast-limited adaptive histogram equalisation (MATLAB, version 8.0.0.783:R2012b). Typical abnormal capillaroscopic images are shown in Fig. 1.

The resulting 80 greyscale images were evaluated in a random (computer generated) order by five rheumatologists blinded to illumination method and subject characteristics. Evaluation included capillary density; numbers of microangiopathologies: giant capillaries, microhaemorrhages, neoangiogenesis, and avascular areas; and diagnosis: normal or SSc. A subjective assessment of image quality was given on a five-point scale: unsatisfactory (1), poor (2), average (3), good (4), excellent (5).

Statistical analysis was performed using Microsoft Excel and SPSS 18.0 (SPSS Inc., Chicago, IL, USA). Differences in the numbers of abnormalities between images made with white and green light were analysed with an independent samples *t* test, p values < 0.05 were considered significant.

Results

Capillary density in healthy subjects and in patients with SSc did not significantly differ between green and white light images (Table 1). In healthy subjects, no significant differences were found in the number of microangiopathologies between green and white illuminated images. In images acquired with green light in the four fingers of SSc

Table 1 Comparison of abnormalities scored in greyscale capillaroscopic images made with green and white light

	Green light	White light	*p* value
Capillary density in healthy subjects (number/mm)	8.58 (1.90)	8.15 (1.80)	0.05
Capillary density in patients with SSc (number/mm)	4.51 (1.66)	4.17 (1.67)	0.07
Number of microangiopathologies in healthy subjects	0.10 (0.52)	0.05 (0.33)	0.10
Number of microangiopathologies in patients with SSc	1.10 (1.64)	0.92 (1.37)	0.04
Diagnostic usefulness	3.6 (0.95)	3.0 (1.12)	<0.001
Sensitivity for diagnosis of SSc[a]	0.90 (0.80–0.95)	0.82 (0.75–0.90)	
Specificity for diagnosis of SSc[a]	0.95 (0.90–1.00)	0.93 (0.90–1.00)	

Capillary density and numbers of abnormalities are presented as average (SD) for all five observers

[a] Average (range) for the five observers

patients, the rheumatologists noted on average per patient: giant capillaries 2.2; microhaemorrhages 0.6; neo-angiogenesis 0.8; avascular areas 0.8. In images made with white light, these average numbers were 1.9, 0.3, 0.5, and 0.9, respectively. The diagnostic image quality acquired with green light as assessed by the five rheumatologists is better. White light images scored an average usefulness of 3.0 and the green light images of 3.6, which can be interpreted as 'above average'.

Illumination with green light and white light both resulted in high sensitivity and specificity with a mild increase in sensitivity for green light for all observers.

Discussion

The results of this small study support the theoretical advantage of green illumination in NFC. For experts in the field of capillaroscopy, this gain may be of small importance. However, many rheumatologists without access to expensive equipment introduce NFC in their outpatient clinics. The low-cost digital videomicroscopes that are provided to them have a moderate image quality, which limits the diagnostic quality of NFC in the hands of specialists without the experience of the experts. Improving digital videomicroscopes without substantial increase in the costs may therefore be valuable. It took one of us (BC) 3 h and €30 to replace the LEDs in a videomicroscope.

In this study, our primary aim was to demonstrate that green light improves image quality, as judged by rheumatologists. Their subjective assessment of image quality supports the use of green light. Oral comments of the observers stressed that the sharpness was important. Reduction of noise resulting in sharper edges is the theoretical and expected advantage of green light. For this reason, green light is used in various medical applications to visualise blood vessels. The strength of this study is the effective way of blinding images made with green and white light by converting them both to greyscale. The second aim was to explore if improved image quality increases sensitivity and specificity for SSc. Our results indicate that there indeed may be some improvement in this respect. However, the small numbers of patients and controls limit the strength of this finding. In view of our goal to assess image quality, we chose to study only two fingers of healthy controls and four fingers of a limited number of patients with long-standing SSc. Therefore, our conclusion must be interpreted with caution and requires confirmation in a larger population of patients with both long-standing and suspected SSC and RP. Further studies should address diagnostic performance in specific microangiopathologies, measurement of calibre variations, and the validity to recognise various scores and patterns in capillaroscopy. Interobserver variation of rheumatologists comparing videomicroscopy with for example the dermatoscope also merits evaluation [8].

Equipping a low-cost digital videomicroscope with green LEDs may help to improve its diagnostic accuracy. A disadvantage is that green light results in greyscale images that may be less appealing than coloured ones. However, morphology of capillaries is the primary goal of NFC, and therefore, increased contrast outweighs this limitation. Ideally, manufacturers will produce videomicroscopes with both green and white light sources.

In conclusion, our findings suggest that capillaroscopy with green instead of white light may be a modest improvement for evaluation of nailfold capillaroscopic images.

Conflict of interest The authors declare that they have no conflict of interest.

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