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SHORT COMMUNICATION

J Rhinol 2022;29(2):96-100 | https://doi.org/10.18787/jr.2022.00402

pISSN 1229-1498 / eISSN 2384-4361
www.j-rhinology.org

Optical Analysis of Nasal Endoscopic Images From a Patient With Severe Acute Respiratory Syndrome Coronavirus 2

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Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has spread worldwide; a simple diagnostic test is becoming increasingly important. Polymerase chain reaction tests of nasal swab samples are expensive and time-consuming. Detailed observation of the nasal cavity is required. No nasal endoscopic study regarding patients with SARS-CoV-2 has been published. Here, we compared endoscopic images of normal subjects and patients with allergic rhinitis (AR) to images from a patient with confirmed SARS-CoV-2 infection. Nasal cavity endoscopic images (of the inferior turbinate) were compared using the hue, saturation, and luminance (HSL) color system of Matrox Design Assistant, version 5.0. The multiple allergen simultaneous test was used to distinguish normal subjects from patients with AR. HSL patterns were compared among images. We enrolled 14 normal subjects and patients with AR and 1 patient with confirmed SARS-CoV-2 infection. The inferior turbinates of normal subjects and patients with AR were smooth and uniform, while those of the patient with SARS-CoV-2 were scratched and stretched. Although additional data are needed, optical analysis of nasal endoscopy images may be useful to screen for SARS-CoV-2 infection. This imaging method is rapid, non-invasive, and inexpensive.

Keywords: SARS-CoV-2; Endoscopes; Nasal mucosa; Optical imaging; Turbinates.

INTRODUCTION

The coronavirus pandemic has spread worldwide. Polymerase chain reaction (PCR) testing is used for diagnosis; many countries seek to expand testing [1]. However, PCR testing is expensive and time-consuming [2]. The nasal cavity and pharynx are sampled. Nasal cavity samples are more informative, suggesting that detailed observation of the nasal cavity is necessary. Nasal endoscopy is commonly performed by otolaryngologists to evaluate the condition of the mucosa or to determine the effectiveness of treatment. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)-infected patients may have nasal symptoms such as a runny nose; nasal secretions may transmit the virus [3]. SARS-CoV-2 propagates more readily than SARS-CoV, particularly in aerosols [4]. We performed nasal endoscopy on an individual attending an outpatient clinic who had not been tested for the virus; he was later confirmed to have the virus. Here, we compare this patient's nasal imaging findings with the findings of normal subjects and patients with allergic rhinitis.

Received: January 19, 2022 **Revised:** June 7, 2022
Accepted: July 5, 2022

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METHODS

Nasal endoscopic images were analyzed using the hue, saturation, and luminance (HSL) method, which is an alternative to the red, green, and blue (RGB) color model. The HSL method was designed in the 1970s by computer graphics researchers to more closely reflect human color vision [5]. The colors of each hue are arranged radially. Saturation indicates various depths of brightly colored paint. Values refer to mixtures of such paints with varying amounts of black or white. Matrox Design Assistant, version 5.0 (Matrox® Imaging, Montreal, QC, Canada), was used for optical analysis.

Images were normalized using histogram equalization of the blue (B) band area; the mean brightness value of the B band in the RGB area of each nasal endoscopic image was approximately 20 to 30 (maximum possible value: 255). The min-

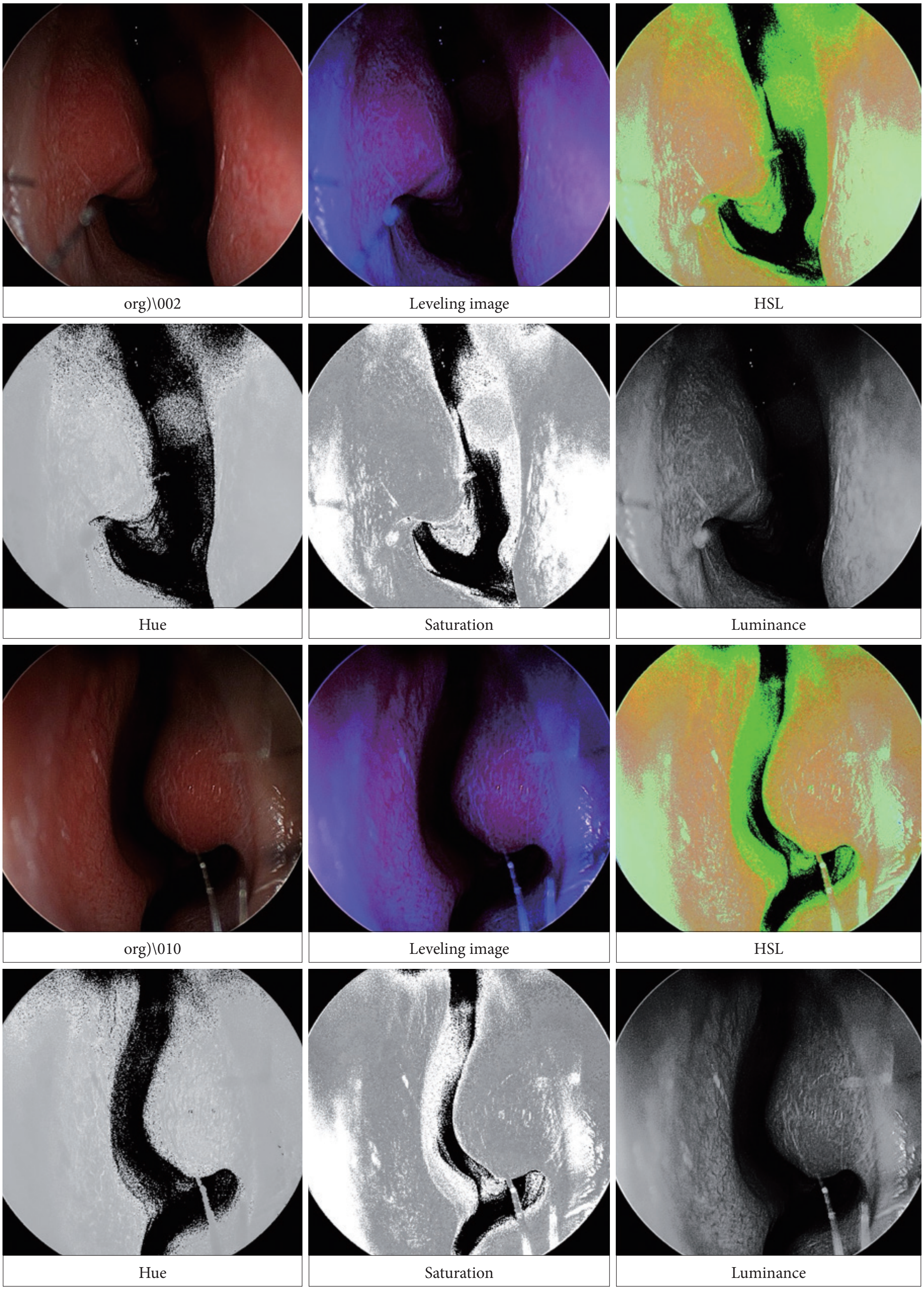

Fig. 1. Optical analysis of nasal endoscopic images from a patient with SARS-CoV-2. Upper six panels: right side, lower six panels: left side. The overall pattern was revealed by hue analysis. The scratch pattern was revealed by luminance analysis. The nasal mucosa of the patient with SARS-CoV-2 exhibited widespread spikes or scratches. SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; HSL, hue, saturation, and luminance.

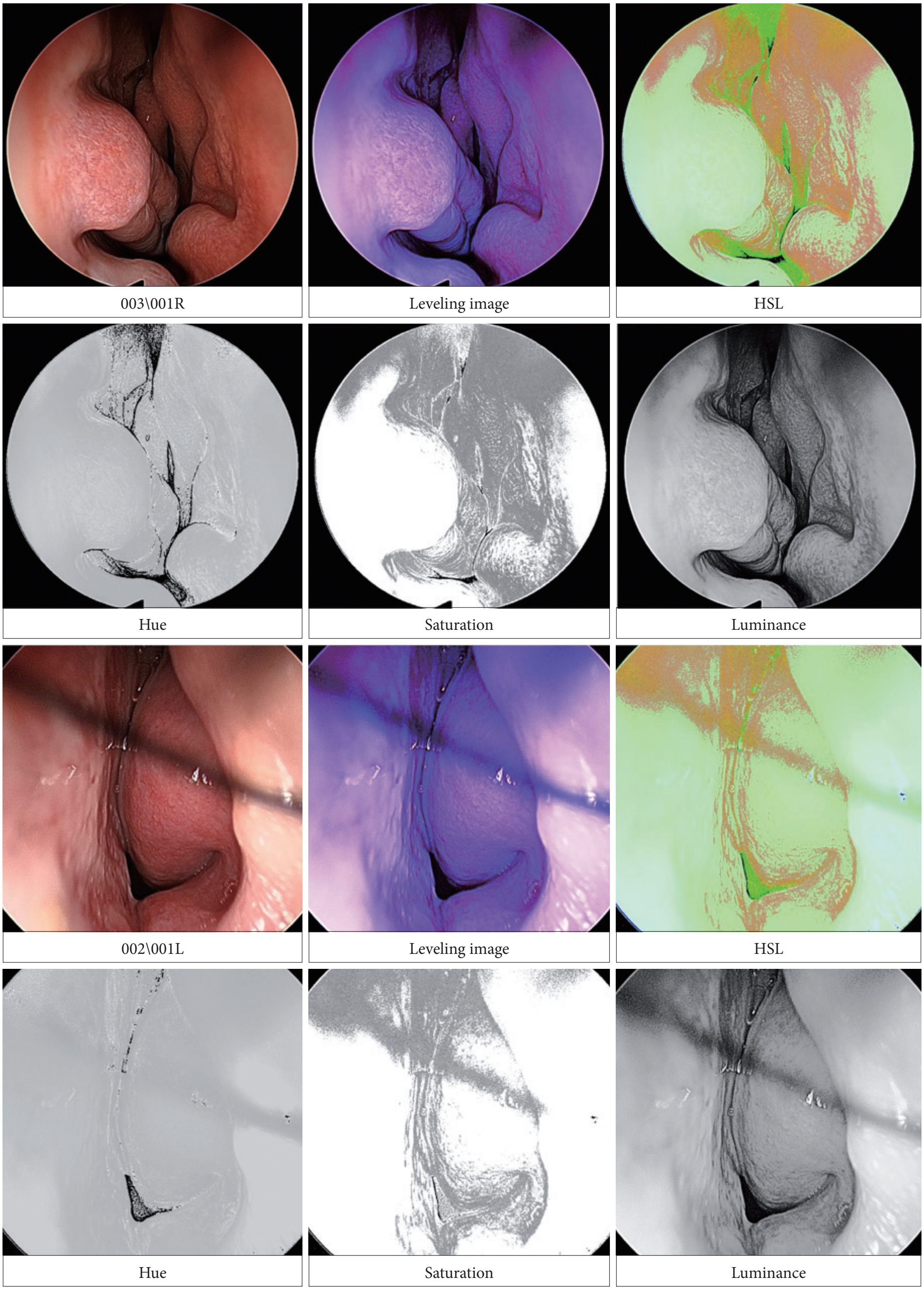

Fig. 2. Optical analysis of nasal endoscopic images from normal subject and patient with allergic rhinitis. Upper six panels: normal subject (right nasal cavity). Lower six panels: patient with allergic rhinitis (left nasal cavity). The surfaces are smoother and more even in these images, compared with the images from the patient with SARS-CoV-2. The inferior turbinate was paler and smoother in patients with allergic rhinitis than in normal subjects, but the surfaces were similarly uniform. SARS-CoV-2, severe acute respiratory syndrome coronavirus 2; HSL, hue, saturation, and luminance.

imum B band applied during histogram equalization was 0, and the maximum B band applied for image processing was 50. RGB-to-HSL conversion was performed for all images. At the time of nasal endoscopy, the patient had received no treatment nor manipulation; both inferior turbinates were analyzed.

Normal subjects and patients with allergic rhinitis were distinguished using the multiple allergen simultaneous test (MAST; an in vivo inhalation test). Normal subjects did not mount a substantial response to any antigens in MAST level I (the MAST features three levels). All subjects underwent nasal endoscopy and provided written informed consent for the MAST test prior to (possible) nasal surgery. The study was approved by the SoonChunHyang University Gumi Hospital Institutional Review Board (IRB no. 2019-22). All patients provided written informed consent.

A 29-year-old man presented with a runny nose and cough on February 18, 2020. He was diagnosed with SARS-CoV-2 infection on February 27. He had contracted the virus at a Sincheonji meeting (a religious gathering) on February 16 and had visited our clinic after the onset of symptoms. He had no history of any other illness, was not receiving any medication, and had not visited any hospital with symptoms. His body temperature during the visit to our clinic was 37.1°C and he exhibited no sinusitis on a paranasal sinus X-ray. We obtained a nasal endoscopic image during this visit.

RESULTS

Of the 15 subjects in this study, 6 were clinically normal, 8 had allergic rhinitis, and 1 had SARS-CoV-2 infection. The MAST test results confirmed the six normal subjects and eight patients with allergic rhinitis. Optical analysis of the nasal mucosa revealed differences in color and blood vessel distribution among groups. The inferior turbinate was paler and smoother in patients with allergic rhinitis than in normal subjects, but the surfaces were similarly uniform. Compared with patterning, smoothness is associated with different hue and luminance values. The nasal mucosa of the patient with SARS-CoV-2 exhibited widespread spikes or scratches (Fig. 1), and was thus not smooth (Fig. 2). The patterns of both inferior turbinates were similar in this patient. The luminance feature of HSL most clearly demonstrated these features. On hue analysis, the general appearance was rougher in the patient with SARS-CoV-2 than in normal subjects and patients with allergic rhinitis. Normal subjects had a total immunoglobulin E (IgE) grade of 1 (of a maximum of 3) on the MAST test, and no significant reaction to other antigens. Patients with allergic rhinitis exhibited total IgE grades of 1–3 and allergic reactions to various antigens.

DISCUSSION

The coronavirus binds to a host cell using a spike (S) protein, which features three segments, including a large ectodomain containing a receptor-binding S1 subunit and the membrane-fusion S2 subunit. The virus binds to the host cell via the S1 subunit and is then fused to the cell membrane by the S2 subunit [6]. The viral receptor is angiotensin-converting enzyme 2. Coronavirus membrane fusion is similar to membrane fusion mediated by the hemagglutinin glycoprotein of influenza virus [7]. The S protein is a trimeric class I protein involved in both prefusion and postfusion activities [8]. The receptor-binding domain of the S1 subunit behaves like a hinge when bound to the host cell receptor. S1 moves up and down, and thus appears unstable [8].

Earlier reports had found a close connection between infection and the market [9]. Virus was cultured in human airway epithelial cells; ciliary action ceased at 96 h after inoculation. Under the electron microscope, the virus exhibited distinctive spikes and a sun-like corona [10], perhaps explaining our hue data.

Joko et al. [11] reported that, when analyzed through RGB, the red value with a lot of blood flow was high in AR patients at the beginning, and then gradually became pale, and the red value was low in the perennial cedar group. In another RGB analysis, it was reported that green and blue were higher in AR patients, and that the cumulative RGB value was high [12].

In this study, HSL rather than RGB was used, which is a different point of view of color, and it is a method that can express subtle differences even in the same color.

Electron microscopy identifies viruses. However, prior culture is required. Furthermore, PCR analysis requires viral genomic amplification. Both techniques are associated with risks of viral spread. It is possible to detect the virus via nasal endoscopy. Millions of viral particles confer a distinct shape on the nasal mucosa, which presumably led to the scratches and stretching observed in this study. Shape changes can be highlighted by changing the background color or the color tone system. We found the HSL system useful in this respect. No normal subject or patient with allergic rhinitis (all of whom lacked fever and sinusitis) exhibited the pattern present in the patient with SARS-CoV-2. In patients with allergic rhinitis, the mucosal cells were more expanded than in normal subjects and thus absorbed more light.

Our test is macroscopic; it would be useful to investigate whether virus was adherent to the mucosa. However, ethical issues limited our ability to perform this investigation; noninvasive diagnosis is optimal. We studied only one patient with SARS-CoV-2; samples from additional patients are required. Variations in nasal endoscopy brightness may be of concern;

in this analysis, we normalized all images. The extents of inferior turbinate scratching require further investigation using hue and luminance analyses. Nasal endoscopy may be a useful viral diagnostic tool.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

Young Joon Jun who is on the editorial board of the *Journal of Rhinology* was not involved in the editorial evaluation or decision to publish this article. All remaining authors have declared no conflicts of interest.

Author Contributions

Conceptualization: Young Joon Jun. **Data curation:** Young Joon Jun. **Funding acquisition:** Young Joon Jun. **Methodology:** Sujeong Bae, Young Joon Jun. **Project administration:** Young Joon Jun. **Visualization:** Sujeong Bae, Young Joon Jun. **Writing—original draft:** Young Joon Jun. **Writing—review & editing:** Sujeong Bae, Young Joon Jun.

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Funding Statement

This research was supported by the Basic Science Research Program of the National Research Foundation of Korea (NRF) funded by the Ministry of Education (grant no. 2019R1I1A3A01063980).

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