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Prediction and prevention system for Severe Acute Respiratory Syndrome CoronaVirus 2 infection by preempting the onset of a cough

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***Abstract*—The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection is fast becoming one of the most significant infections worldwide. Of all the causes of SARS-CoV-2 infection, airborne-droplet infection via coughing is the most common. Therefore, if predicting the onset of a cough and preventing infection were possible, it would have a globally positive impact. Here, we describe a new prediction and prevention system for SARS-CoV-2 infection. Usually, air is inhaled prior to coughing, and the cough, which contains droplets of the virus, then occurs during acute exhalation. Therefore, if we can predict the onset of a cough, we can prevent the spread of SARS-CoV-2. At Tohoku University, a diagnosis system for evaluating swallowing motions and peripheral circulation has already been developed, and our prediction system can be integrated into this system. Using three-dimensional human body imaging, we developed a prediction system for preempting the onset of a cough. If we can predict the onset a cough, we can prevent the spread of SARS-CoV-2 infection, by decreasing the shower of virally active airborne droplets. Here, we describe the newly developed prediction and prevention system for SARS-CoV-2 infection that preempts the onset of a cough.**

***Clinical Relevance*— If predicting the onset of a cough and preventing infection were possible, it would have a globally positive impact. Here, we describe the newly developed prediction and prevention system for SARS-CoV-2 infection.**

I. Introduction

The novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic poses a great threat to the world. The SARS-CoV-2 infection is fast becoming one of the most significant infections worldwide. Of all the causes of SARS-CoV-2 infection, airborne-droplet infection via coughing is the most common. Therefore, if predicting the onset of a cough and preventing infection were possible, it would have a globally positive impact. Here, we describe a new prediction and prevention system for SARS-CoV-2 infection. Usually, air is inhaled prior to coughing, and the cough, which contains droplets of the virus, then occurs during acute exhalation (Fig. 1).

Therefore, if we can predict the onset of a cough, we can prevent the spread of SARS-CoV-2. At Tohoku University, a diagnosis system for evaluating swallowing motions and peripheral circulation has already been developed, and our prediction system can be easily integrated into this system. Using three-dimensional (3D) human body imaging, we developed a prediction system for preempting the onset of a cough [1-10]. If we can predict the onset of a cough, we can prevent the spread of SARS-CoV-2 infection, by decreasing the shower of virally active airborne droplets. Here, we describe the newly developed prediction and prevention system for SARS-CoV-2 infection that preempts the onset of a cough[1-18].

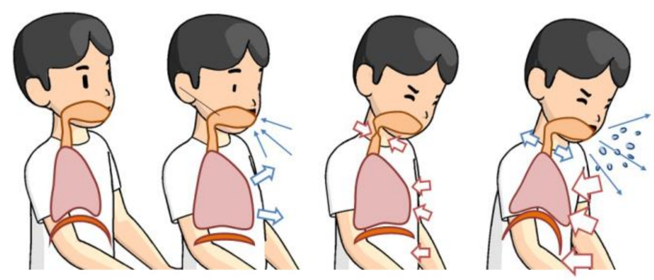

Fig.1 Pressure mechanisms and human neck motions during a cough

In this study, we aimed to develop a prediction and prevention system for SARS-CoV-2 infection that preempts the onset of a cough.

Fig. 2 If a cough can be predicted, the transmission of infection can be largely avoided.

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Therefore, we focused on the four phases of a cough as follows: the inhalation, holding, glottal closure, and cough phases. With the ability to measure the motions of these four phases, we will be able to predict the onset of a cough from outside the human body.

For doctors working in outpatient clinics, if a patient coughs, there is a risk of infection (Fig. 2). Thus, if a cough can be predicted, the transmission of infection can be largely avoided.

Fig. 3 As part of the newly developed prevention system (Jpn Pt. Appl. 2021-045978), this figure shows the use of a transparent partition actively blocking the airborne cough droplets.

Transparent partitions were installed in some rooms in the outpatient clinics of the hospitals (Fig. 3). However, these were not installed in every room. In some emergency situations, partitions cannot even be used. Every doctor and nurse comes in direct contact with human bodies. Therefore, if we are able to predict the onset of a cough, we will be able to prevent the spread of SARS-CoV-2 infection by decreasing the shower of virally active airborne droplets. Since this system may be useful in preventing SARS-CoV-2 outbreaks, the patent applications were submitted (Jpn Pt. Appl. 2021-045978).

This study is clinically relevant because predicting the onset of a cough and preventing infection would have a globally positive impact. Here, we describe the newly developed prediction and prevention system for SARS-CoV-2 infection..

II. MATERIALS AND METHODS

Newly developed prediction and prevention system for SARS-CoV-2 infection.

After obtaining ethical approval for this study from the relevant Ethics Committee (20191707), we tested the ability of the newly developed prediction and prevention system to identify selected areas of the human body (Fig. 4).

First, the human face was automatically detected using a commercially available signal processing system with a 3D camera (Logocol 4k) and a sampling rate of 30 fps.

Clinical application

Following identification of the human face, the neck was identified and evaluated using 3D reconstruction.

Thereafter, we used the 3D camera and a personal computer system to identify and evaluate areas of the human body in normal healthy volunteers, aged 23 to 49 years, after the ethical committee allowance.

Fig. 4 Testing the ability of the newly developed prediction and prevention system to identify selected areas of the human body, namely the face and neck

III. RESULTS

After obtaining ethical approval, quantitative evaluation of the human body areas was integrated into the system. For example, Fig. 5 shows the 3D reconstruction of the human neck using time-series data.

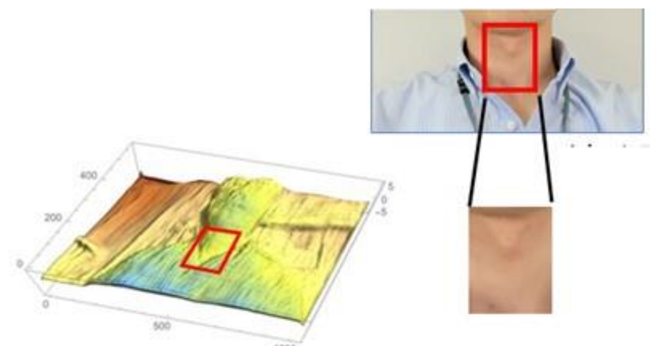

Fig. 5 Three-dimensional reconstruction of the human neck using time-series data.

Fig. 6 shows an example of the time-series data of the summation of the horizontal and longitudinal lines, and the real-time diagnosis of a cough was demonstrated by this system.

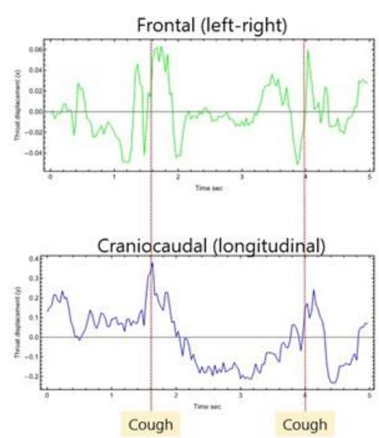

Fig. 6 Time-series data of human neck motions during a cough.

Furthermore, by using the horizontal line, the onset of a cough could be predicted. In addition, we can evaluate peripheral circulation using images from the human body (Fig. 7).

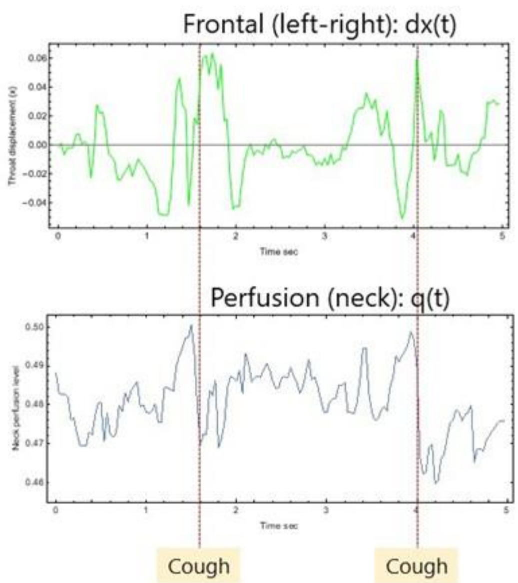

Fig. 7 Skin surface motions and peripheral circulation before, during and after coughing.

When interacting with human skin, light is scattered and absorbed in the subcutaneous tissue. Part of the light is then reflected and returned to the surface of the skin. The intensity of the returned light changes in accordance with the amount of blood under the skin because light is strongly absorbed by the plasma hemoglobin. The light-absorption characteristics of plasma hemoglobin exhibit a high peak at approximately 500–600 nm, which corresponds to the frequency band of green light signals captured by a video camera.

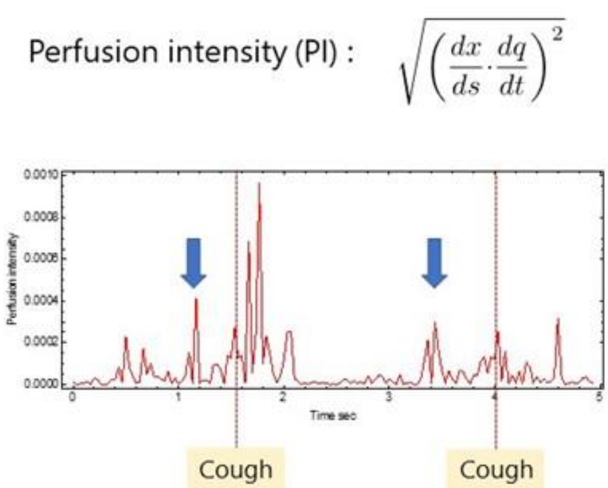

Fig. 8 Prediction wave using skin surface motion and peripheral circulation to predict coughs

Therefore, we can evaluate both the skin motions and peripheral circulation beneath the surface of the skin during a cough. Figure 8 showed the Prediction wave using skin surface motion and peripheral circulation to predict coughs

Using the time-series data of the human skin surface motion and peripheral circulation, the prediction wave for the onset of a cough was calculated.

Prediction waves were calculated for every healthy volunteer prior to coughing.

IV. DISCUSSION

The SARS -CoV-2 infection is becoming increasingly significant, not only in Japan, but globally. When aiming to predict a cough, and thereby prevent infection, it is imperative to focus on the four phases of a cough, which includes the inhalation, holding, glottal closure, and cough phases.

Here, a prediction wave was detected in the horizontal slice of the 3D image of the human neck during coughing. If the ability to predict a cough is integrated into the existing system, the prevention system will be realized, which can even be used in elderly care facilities in future. By the use of this invention, the elderly care facility with the ability to prevent the transmission of the severe acute respiratory syndrome coronavirus 2 infection, that is spread via a shower of virally active airborne droplets will be easily embodied in near future as shown in fig.9.

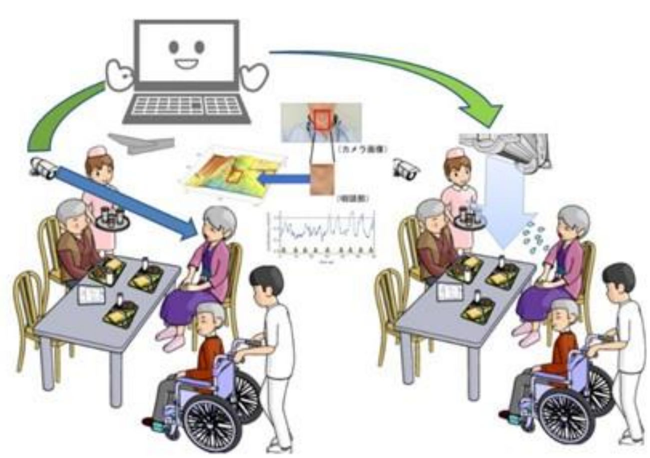

Fig. 9 Elderly care facility with the ability to prevent the transmission of the severe acute respiratory syndrome coronavirus 2 infection, that is spread via a shower of virally active airborne droplets.

Using an actuated acrylic partition to actively block a shower of virally active airborne droplets will also be useful during outbreaks of other diseases.

The SARS-CoV-2 pandemic is one of the most significant problems worldwide. Therefore, implementing prevention strategies in only hospitals, outpatient clinics, and elderly care facilities is inadequate.

Prevention strategies should be implemented in every relevant environment within society. When considering future generations, schools are one of the most important places.

Unfortunately, there have been cases of students having the SARS-CoV-2 infection without any symptoms.

This not only places those at the school at risk of contracting the virus, but also their family members, particularly those who are elderly.

Fig. 10 showed a prevention system plan being used in a future school in this invention. Using an actuated acrylic partition to actively block the shower of virally active airborne droplets, may be of use not only for the SARS-CoV-2 pandemic, but also during outbreaks of other diseases.

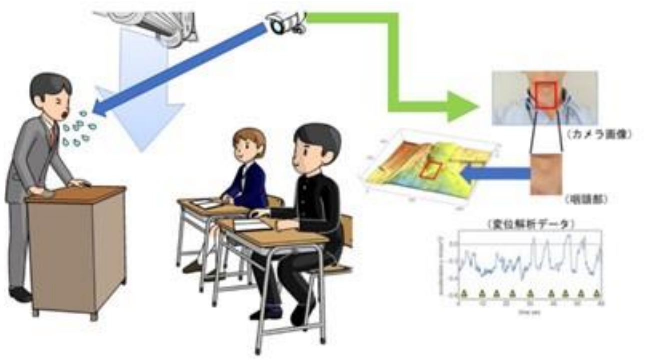

Fig. 10 An example of the prevention system being used in a school.

Eradicating the SARS-CoV-2 infection will have a positive impact worldwide.

V. Conclusion

The SARS-CoV-2 infection is becoming increasingly significant, not only in Japan, but also globally. When aiming to predict a cough, and therefore prevent infection, it will be imperative to focus on the four phases of a cough, which includes the inhalation, holding, glottal closure, and cough phases. Here, we identified a prediction wave using time-series data of motion and peripheral perfusion waves. If the ability to predict a cough is integrated into the existing system, the prevention system will be realized, even in elderly care facilities. Using an actuated acrylic partition to actively block a shower of virally active airborne droplets, may be of use not only for the SARS-CoV-2 pandemic, but also during outbreaks of other diseases. Eradicating the SARS-CoV-2 infection will have a positive impact worldwide.

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