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Minimum size of respiratory droplets containing SARS-CoV-2 and aerosol transmission possibility

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ABSTRACT

A short review of the important studies was conducted to evaluate the potential of aerosol transmission of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The minimum size of droplets potentially carrying the SARS-CoV-2 was newly estimated and discussed in this review.

Keywords: Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2); COVID-19; Middle East Respiratory Syndrome Coronavirus; bioaerosol; aerosol; aerosol transmission

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INTRODUCTION

The pandemic caused by the novel Severe Acute Respiratory Syndrome Corona virus 2 (SARS-CoV-2) that emerged in Wuhan city, China has spread globally, with more than hundreds of thousand infected cases reported worldwide.[1] There are more than ten thousand people infected with SARS-CoV-2 in Republic of Korea. [1] Aerosols are suspected to be a route of transmission for SARS-CoV-2, however, only a few review studies have been conducted on the aerosol transmission of the coronavirus.[2-4] In this study, a detailed review of important previous studies supporting the aerosol transmission of SARS-CoV-2 was conducted. Specific studies estimating and analyzing the minimum size of respiratory droplets containing SARS-CoV-2 were newly conducted for this review study. Various logical reasons were found to support the possibility of aerosol transmission of SARS-CoV-2 in 2020.

RESPIRATORY DROPLETS

SARS-CoV-2 is considered to be mainly transmitted via respiratory droplets.[5] Therefore, it is important to determine the size of the respiratory droplets for preventing the spread of COVID-19. In this study, 'respiratory droplets' and 'aerosol particles' were defined as particles of human respiratory fluid and airborne particles, respectively. Several experimental results support that respiratory droplets are sufficiently small for aerosol transmission of microorganisms inside droplets. In a study by Johnson et al. (2011), it was reported that healthy subjects (8 - 15 humans) generated aerosol particles, including respiratory droplets of three size modes, 1.6, 2.5, and 145 µm during speech and 1.6, 1.7, and 123 µm during voluntary coughing.[6] The generated particles contained large droplets with a size of more than 100 µm, which were bound to fall to the ground within a few seconds. However, small particles of approximately 2 µm were found to be generated simultaneously and could remain airborne for dozens of minutes. In another study by Lindsley et al. (2012), the sizes of the aerosol particles generated by patients (9 subjects) infected by influenza viruses were measured.[7] The size of the generated particles ranged from 0.35 to 9 µm. Among the particles generated by the influenza patients, the particles with a size range of 0.35 - 2.5 µm were of a higher number concentration. These particles could remain airborne for dozens of minutes to several hours. Although the measuring device has limitations of a size range in this study, the detected particles from influenza-infected patients are estimated to be mainly airborne for significant periods. The aerosol particles from patients (10 subjects) having an upper respiratory tract infection were measured by Lee et al. (2019) under clean air environment conditions.[8] The size of the generated particles from these patients ranged from < 100 nm to 10 µm. A significant number of particles of size < 1 µm were generated by coughing patients. The results of these studies conducted on healthy humans, influenza-infected patients, and upper respiratory tract infected patients demonstrated that a significant amount of respiratory droplets that are sufficiently small to be airborne for at least several minutes are generated. Therefore, airflow can transport these particles over time.

Additionally, the characteristics of the generated respiratory droplets were found to be related to human health conditions. For instance, in studies conducted with patients of influenza and upper respiratory tract infection, the amounts of generated aerosol particles decreased when human subjects recovered from the diseases.[7,8]

CORONAVIRUS BIOAEROSOLS

Two major studies have been conducted on aerosols carrying coronaviruses. In the first study, Middle East Respiratory Syndrome Coronavirus (MERS-CoV) was aerosolized for 10 min and its viability was measured under 40% and 70% relative humidity (RH) conditions.[9] It was found that MERS-CoV was considerably stable under 40% RH. However, the virus viability was significantly lost under 70% RH. Therefore, it can be concluded that the artificially generated

MERS-CoV usually spreads in dry conditions.[10] In the second study by van Doremalen, et al. (2020), SARS-CoV-2 was aerosolized for 3 h and its viability was analysed. It was found that the virus was viable even after 3 h with limited loss of viability.[11]

Two major studies have been conducted to detect coronaviruses in air. In one, the genome of MERS-CoV was detected at a camel barn air sample of an MERS infected patient. [12] In the other, SARS-CoV-2 nucleic acid tests conducted on air samples gave positive results at an intensive care unit of a hospital in Wuhan (China). [13]

ESTIMATED MINIMUM SIZE OF RESPIRTORY DROPLETS CONTAINING SARS-COV-2

The size of SARS-CoV-2 ranged from 70 to 90 nm.[14,15] If respiratory droplets sized 0.09 µm contain a single SARS-CoV-2 (maximum size case), it can be estimated that 1 mm sized droplets can contain viruses up to the order of 10^{12}. In other words, it can be assumed that 100% of the respiratory fluid droplet is full of viruses. If only 1% of the respiratory fluid droplet is occupied by SARS-CoV-2, the minimum size of the respiratory droplet that can contain SARS-CoV-2 is approximately 0.4 µm. If only 0.01% of the respiratory fluid droplet is occupied by SARS-CoV-2, the minimum size of the respiratory droplet that can contain SARS-CoV-2 is approximately 1.9 µm. If only 10^{-4}% of the respiratory fluid droplet is occupied by SARS-CoV-2, the minimum size of the respiratory droplet that can contain SARS-CoV-2 is approximately 9 µm. Furthermore, if only 10^{-6}% of the respiratory fluid droplet is occupied by SARS-CoV-2, the minimum size of the respiratory droplet that can contain SARS-CoV-2 is approximately 42 µm. Previous studies stated that these particles of minimum size could practically be respiratory droplets.[6-8] Figures 1 and 2 show the calculated estimates in a schematic diagram and in a graph, respectively. The ratio of viruses in the released respiratory fluid droplets is not known. If the respiratory droplets are larger than 50 µm, they can remain airborne only for a few seconds, therefore, the possibility of aerosol transmission is limited. However, if the respiratory droplets are smaller than 9 μm (10^{-4}% condition, probability of one in a million), they can be airborne for more than minutes or even hours. In such a case, the aerosol transmission of viable SARS-CoV-2 could be possible. [11]

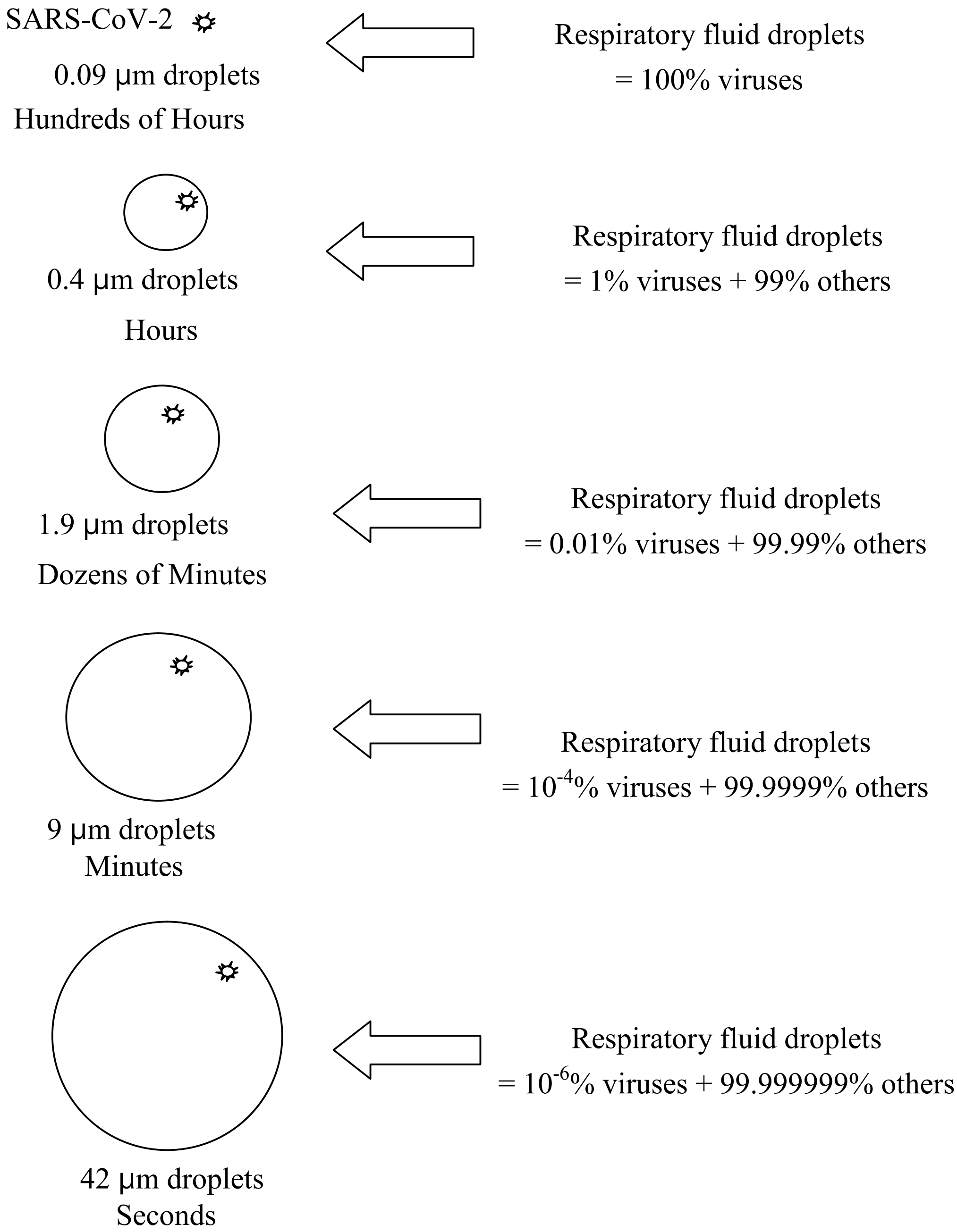

Figure 1. The estimated minimum size of droplets (the homogeneity assumption; virus size 90 nm assumption) potentially carrying SARS-CoV-2 and the aerosol levitation time (BUL's theory).

The above calculations of the minimum sizes and aerosol levitation times were based on the homogeneity assumption, considering a maximum size of 90 nm for SARS-CoV-2, a falling time of 1 meter, and the balance between gravity and the Stokes' law to determine the air friction on the aerosol particles. [16]

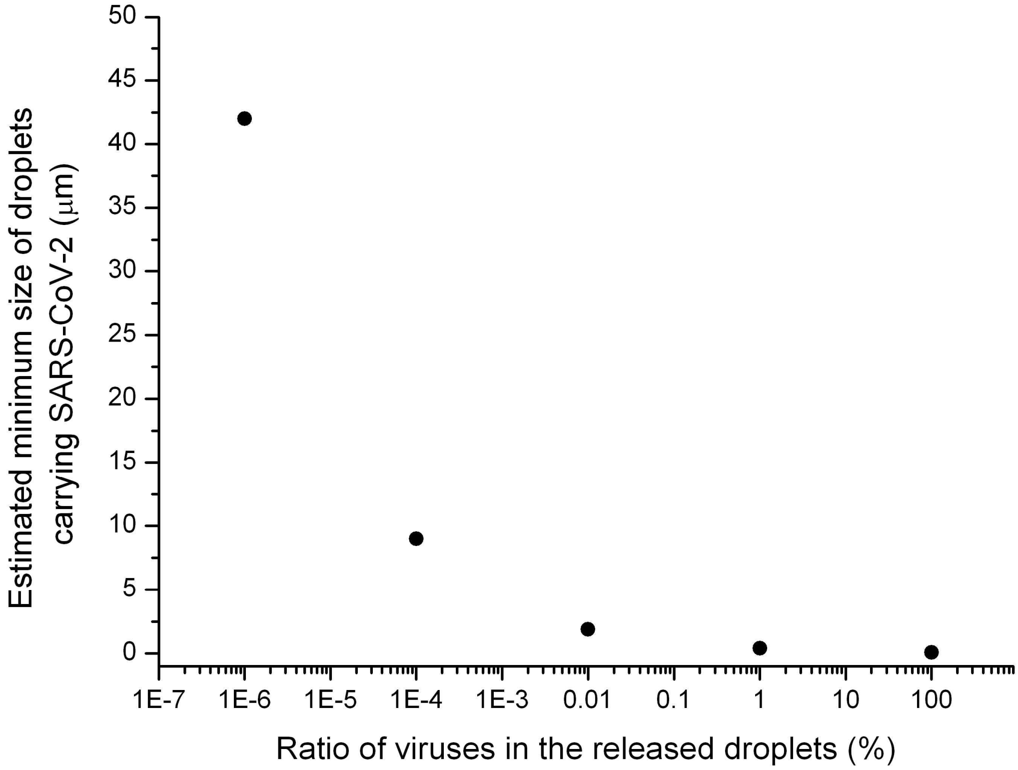

Figure 2. The estimated minimum size of droplets (homogeneity assumption; virus size 90 nm assumption) potentially carrying SARS-CoV-2 (BUL's theory)

CASES OF INFECTION AND CONCLUSIONS

There have been several clusters of infections in Republic of Korea. [17] More than 100 people were infected by SARS-CoV-2 at a hospital. At a telephone call service center inside a building, more than 80 employees were infected by SARS-CoV-2. More than 40 people were infected by SARS-CoV-2 at a church. Other additional cases have been reported. Although the infectious dose of SARS-CoV-2 for COVID-19 is unknown, the cases where more than dozens of people were infected by the virus in closed environments, the size of the respiratory droplets, and the viability of SARS-CoV-2 bioaerosols indicate that the aerosol transmission of SARS-CoV-2 can be possible in confined environments. Thus, it can be concluded that SARS-CoV-2 bioaerosols can be considered to play an important role in the pandemic infections occurring in 2020.

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Conflicts of Interest: The author declares no conflicts of interest.

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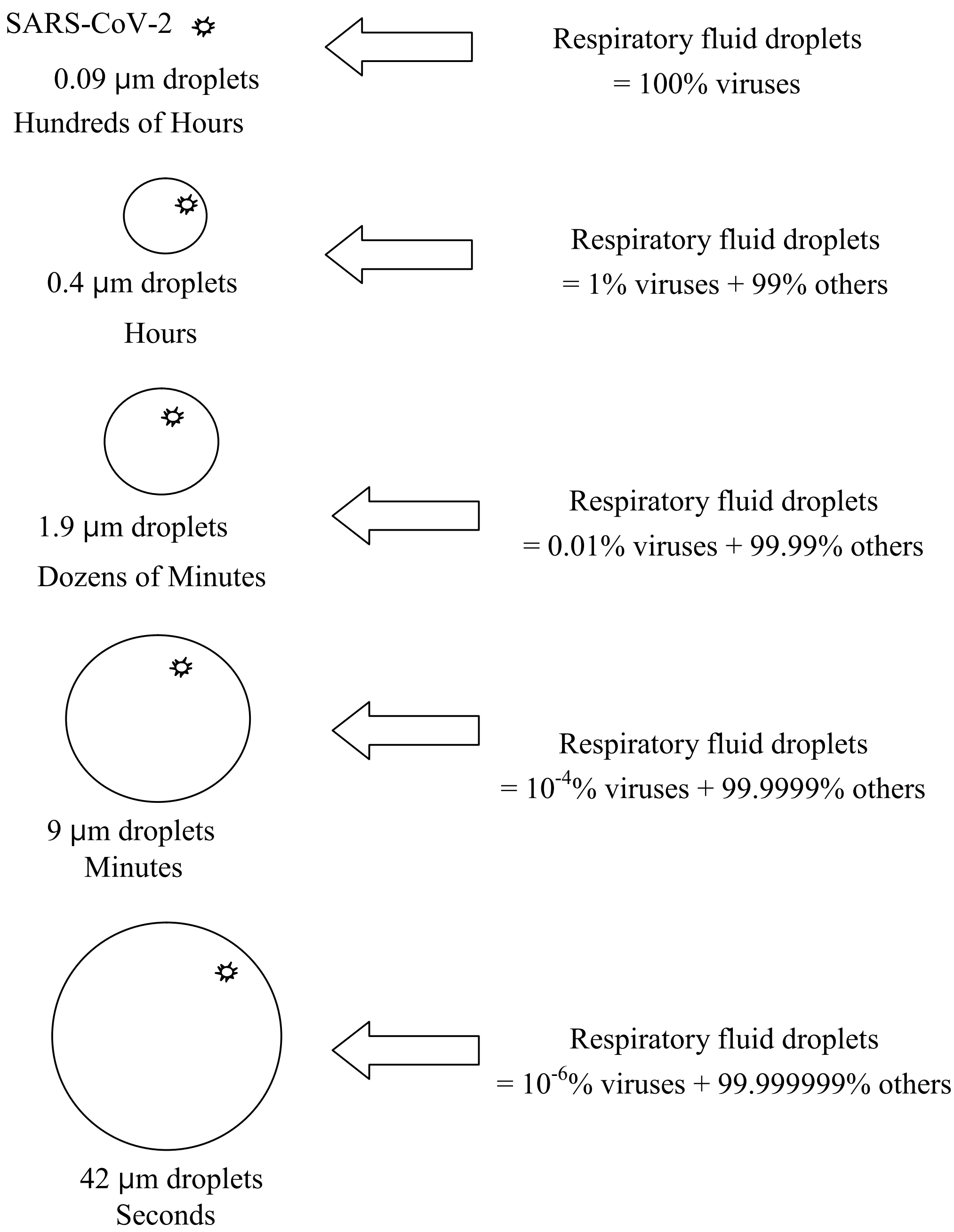

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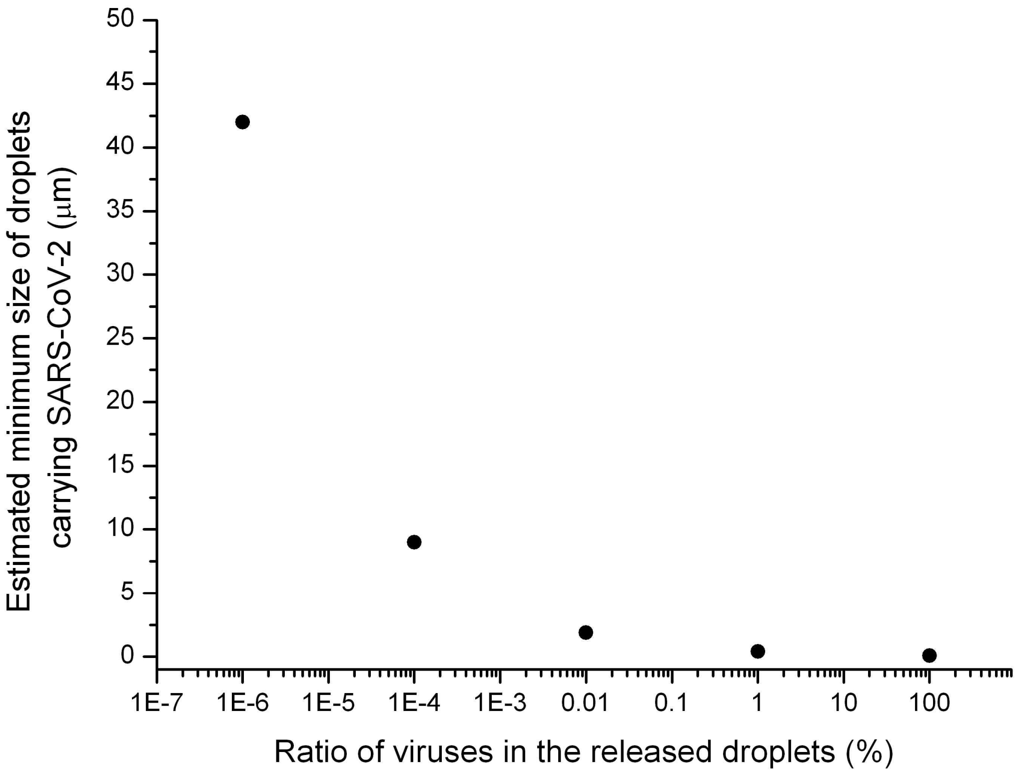

Figure 2. The estimated minimum size of droplets (homogeneity assumption; virus size 90 nm assumption) potentially carrying SARS-CoV-2 (BUL's theory)