| REVIEW ARTICLE |

N95 mask and the dilemma of the ballistic trajectory of respiratory particles in COVID-19

Máscara N95 e o dilema da trajetória balística das partículas respiratórias na COVID-19

Respiradores N95 y el dilema de la trayectoria balística de partículas respiratorias en COVID-19

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ABSTRACT: Objective: To present theoretical elements about the transmission of SARS CoV-2 through respiratory particles, in addition to its aerodynamic diameter and ballistic trajectory, to support reflections on the adequacy of the use of masks by health professionals. **Method:** Academic essay using narrative review data from the literature. **Results:** Clarifies the confusion about the terms droplets, droplet nuclei, aerosols and particles, divergences that contribute to differentiated understandings about transmission mechanisms of this etiological agent, with the adoption of different intervention measures to control this virus. It shows data on the transmissibility of SARS-CoV-2 by air, despite the technical and methodological difficulties for detecting this agent in the air, a situation that hinders hard conclusions about the aerial transmission of this pathogen. **Conclusions:** It is believed to be an error to use the lack of sars-cov-2 identification conclusions in air samples, to question airborne transmission, also to recommend prevention measures depending on the aerodynamic size of viruses. Thus, the use of the N95 mask by health professionals during the pandemic should be a basic and unequivocal measure for the protection and safety of this population.
Keywords: Viral disease COVID-19. Aerosol. Disease transmission, infectious. Mask N95.

RESUMO: Objetivo: Apresentar elementos teóricos acerca da transmissão do SARS-CoV-2 por meio das partículas respiratórias, para além do seu diâmetro aerodinâmico e trajetória balística, a subsidiar reflexões sobre a adequação do uso de máscaras pelos profissionais de saúde. **Método:** Ensaio acadêmico com o uso de dados de revisão narrativa da literatura. **Resultados:** Clarifica a confusão acerca dos termos gotículas, núcleos de gotículas, aerossóis e partículas, divergências que contribuem para entendimentos diferenciados sobre os mecanismos de transmissão desse agente etiológico, levando à adoção de distintas medidas de intervenção para o controle do vírus. Apresenta dados da transmissibilidade do SARS-CoV-2 pelo ar, a despeito das dificuldades técnica e metodológica para a detecção desse agente em tal meio, situação que dificulta conclusões contundentes acerca da transmissão aérea do patógeno. **Conclusão:** Acredita-se ser um erro usar a falta de conclusões sobre a identificação do SARS-CoV-2 em amostras de ar para questionar a transmissão aérea e, igualmente, para recomendar medidas de prevenção segundo o tamanho aerodinâmico dos vírus. Assim, o uso da máscara N95 por profissionais de saúde durante pandemia deve ser medida basilar e inequívoca para a proteção e a segurança dessa população.
Palavras-chave: Doença viral COVID-19. Aerossol. Transmissão de doença infecciosa. Máscara N95.

RESUMEN: Objetivo: Presentar elementos teóricos sobre la transmisión del SARS CoV-2 a través de partículas respiratorias, además de su diámetro aerodinámico y trayectoria balística, para apoyar reflexiones sobre la adecuación del uso de mascarillas por parte de los profesionales sanitarios. **Método:** Ensayo académico utilizando datos de revisión narrativa de la literatura. **Resultados:** Aclara la confusión sobre los términos gotitas, núcleos de gotitas, aerosoles y partículas, divergencias que contribuyen a entendimientos diferenciados sobre los mecanismos de transmisión de ese agente etiológico, con la adopción de diferentes medidas de intervención para controlar ese virus. Presenta datos sobre la transmisibilidad del SARS-CoV-2 por vía aérea, a pesar de las dificultades técnicas y metodológicas para detectar ese agente en el aire, situación que dificulta duras conclusiones sobre la transmisión aérea del patógeno. **Conclusión:** Se cree que es un error utilizar la falta de conclusiones sobre la identificación del SARS-CoV-2 en muestras de aire para cuestionar la transmisión aérea e, igualmente, recomendar medidas de prevención según el tamaño aerodinámico de los virus. Así, el uso de los respiradores N95 por parte de los profesionales sanitarios durante la pandemia debe ser una medida básica e inequívoca para la protección y seguridad de esta población.
Palabras clave: Enfermedad viral COVID-19. Aerosoles. Transmisión de enfermedad infecciosa. Respiradores N95.

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INTRODUCTION

Since March 2020, the world has been living with a health crisis never before experienced: the pandemic caused by SARS-CoV-2 (COVID-19), which constitutes a global challenge to public health, responsible for more than 430 million people infected and over 6 million deaths[1-4].

This pandemic, in addition to physical, psychological, and social human suffering, has brought profound social disorganization at all levels. It has affected, in particular, health services, directly impacted by the avalanche of infected people and the need for quick responses despite the epidemiological, diagnostic, and therapeutic uncertainties related to the management of an emerging, unknown infectious agent with high transmissibility and pathogenicity[5].

Since SARS-CoV-2 was identified in China in December 2019 in patients with atypical pneumonia, knowledge about the transmission of this virus has evolved as new evidence accumulates. There is consensus that COVID-19 is a predominantly respiratory disease, whose clinical spectrum can range from asymptomatic infection to severe acute respiratory illness, sepsis with organ dysfunction, and death[1-4,6].

It is also widely known that an infected person can transmit this virus in the pre-symptomatic (48 hours before clinical illness) and symptomatic periods, and even without showing symptoms, so that infected and asymptomatic people account for 40 to 45% of cases of SARS-CoV-2 infections[6,7].

Thus, understanding the mode of transmission of this etiological agent and associated factors that contribute to its dissemination is a priority for the scientific society, regulatory bodies, and national health systems, given that this evidence is central to the development of effective strategies to prevent, contain, and mitigate COVID-19[4,6].

The risk of infection with SARS-CoV-2 varies according to the amount of virus to which a person is exposed, however the inoculum volume needed to cause infection has not yet been established[4]. To date, the main mode of transmission is exposure to respiratory fluids contaminated with the virus, and this exposure can occur through direct, indirect or close contact with infected people, through secretions such as saliva and respiratory secretions or respiratory droplets expelled when coughing, sneezing, talking or singing[6].

For the purpose of transmitting pathogens, respiratory fluids are classified by bodies such as the World Health Organization (WHO) and the American Centers for Disease Control and Prevention (CDC) according to the size of their particles, with a cut-off limit of 5 μm[1-4,6,8].

Droplets larger than 5 μm ("droplet transmission"), after being expelled, spread through the air in seconds to minutes and settle on surfaces close to the emitter (1 to 2 m). Small droplets (smaller than 5 μm) and aerosol particles ("airborne") are formed when these fine droplets dry quickly and are small enough that they can remain suspended in the air for minutes to hours[1-4].

Transmission of SARS-CoV-2 by respiratory droplets can occur when a person is in close contact (up to 1 meter away) with an infected person who has respiratory symptoms (coughing or sneezing) or who is talking or singing. Under these circumstances, respiratory droplets that contain the virus can reach the mouth, nose, or eyes of a susceptible person and result in infection. Indirect contact transmission, which involves contact of a susceptible host with a contaminated object or surface (transmission via fomite), is also possible[4,7,9].

For the WHO, airborne transmission of this virus can also occur during medical procedures that generate aerosols, and this body, together with the scientific community, has been actively evaluating whether SARS-CoV-2 can also be spread through aerosols even in the absence of these procedures[2,7-11].

SARS-CoV-2 can remain viable in the air for up to 3 hours (average of 1.1 hours)[7,12-15]. According to the CDC[4], its transmission by inhalation of air more than 6 m from an infectious source can occur, especially in closed and poorly ventilated spaces, with air with a concentration of expired respiratory fluids, due to the increased exhalation of respiratory fluids from an infected person when in physical exertion or increase in voice timbre, in prolonged exposure to these conditions, for a period longer than 15 minutes.

In health services, the rationale that this pathogen is transmitted essentially through respiratory droplets has determined the recommendation by regulatory bodies, including the National Health Surveillance Agency (*Agência Nacional de Vigilância Sanitária* – ANVISA), of the use of the surgical mask to "avoid contamination of the nose and mouth of professionals by respiratory droplets", when they "act at a distance of less than 1 meter from SARS-CoV-2 suspected or confirmed infected patients". The use of the N95 mask is recommended for healthcare professionals "during care procedures that may release aerosolized particles", such as intubation or tracheal aspiration, non-invasive mechanical ventilation, cardiopulmonary resuscitation, manual ventilation before intubation, collections of nasotracheal samples and bronchoscopies[1-4,6,16].

According to this recommendation, health professionals should wear a surgical mask during their work activities and reserve the use of the N95 mask for when the procedure with the patient has the potential to generate aerosolized particles of the virus and, thus, contaminate the professional.

It turns out that authors disagree with the 5 μm particle size limit adopted by public health authorities to define "droplet" or "aerosol" and report that particles much larger than the 5 μm limit can remain suspended in the air for many minutes, move depending on the air currents and ventilation conditions of the environment and significantly imply the prevention measures adopted in this pandemic[6-8,13].

Furthermore, according to the latest research in modern aerosol physics, 100 μm is considered the particle size limit between aerosols and droplets; Researchers therefore propose to refer to respiratory emissions as "respiratory particles", with the understanding that these include particles that are transmitted both through the air and in the form of droplets[7,8].

Given that the classification of oral fluid particles referred to as "droplets" or "aerosols" has been the subject of questioning in this pandemic and generated debates about their ability to remain suspended in the air over time, with implications for the recommendations of preventive measures and control, particularly the type of protective mask to be used against SARS-CoV-2, this academic essay seeks to answer the following question: *to what extent is the indication of using the N95 mask only when performing aerosol-generating procedures safe and protect healthcare workers from COVID-19?*

OBJECTIVE

To present theoretical elements about the transmission of SARS-CoV-2 through respiratory particles, in addition to their aerodynamic diameter and ballistic trajectory, in order to support reflections on the adequacy of the use of masks by health professionals.

METHOD

This is an academic essay carried out with data from a narrative review of the literature. The studies were obtained from the electronic databases of the Virtual Health Library and the Coordination for the Improvement of Higher Education Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* – CAPES), using the health descriptors "SARS-CoV-2", "aerosol", "droplet" and " mask N95", with the help of the Boolean operator AND. Searches were also carried out on the WHO, CDC, and ANVISA websites.

Inclusion criteria were: articles in English, Spanish, and Portuguese, which addressed the transmission mechanisms of SARS-CoV-2 and measures to prevent exposure to this virus, especially the type of mask, between the years 2016 to 2021.

Works that did not address viral transmission, preventive recommendations, that were outside the scope of the defined publication time and articles that were accessed via payment were excluded.

The data search was carried out online in May and June 2021, and initially 1,480 articles were identified. After reading the title and abstract, 1,460 works were excluded and the 24 that make up this essay were selected.

After selection, the articles were read in full and analyzed using a data collection instrument that included: article name, objectives, material and method, results and conclusion.

RESULTS

COVID-19 has once again revealed that healthcare professionals, due to their exposure to contaminated body fluids from patients, are much more exposed than the general population. Thus, the use of personal protective equipment (PPE) should be a basic measure within health services[2].

Therefore, it is important to clarify the authors' significant confusion about the definition of the terms "droplets", "droplet nuclei", "aerosols", and "particles", divergences that have contributed to different understandings about the transmission mechanisms of the etiological agent of COVID-19, leading to the adoption of different intervention measures to control this virus[8,9].

Respiratory droplets, formed by respiratory secretions and saliva, are emitted in speech, coughing, sneezing, and even through silent breathing. Their diameters cover the spectrum from < 1 μm to > 100 μm. Smaller droplets are rapidly reduced to 20-40% of their original diameter, leaving residues called "droplet nuclei" or "aerosols"[7,8,12-15].

Thus, respiratory droplets with a wide range of diameters can remain suspended in the air and are considered airborne vehicles. They cannot be statically classified with a cutoff diameter because the ability of these particles to remain suspended in the air depends on many factors in addition to their size, including when they are expelled and the characteristics of the surrounding airflow (velocity, turbulence, direction, temperature, and relative humidity)[8].

Thus, depending on airflow conditions, particles inappropriately classified as "large size" (diameter > 5 μm) can travel much farther than the "mythical" distance of 1 to 2 m at which such particles would fall to the ground. It must be considered that even "large particles" can behave like traditional "aerosols". Both "aerosols" and "droplets" should be analyzed as extremes of a size range for which the aerial pattern will vary depending on local environmental conditions[8].

The clinically relevant length of time for airborne particles to remain depends on ventilation. Hospital ventilation systems that perform air exchanges provide clean, filtered air, and exhaust any particles to the external environment in 10 to 30 minutes (systems that perform six air exchanges per hour) and 5 to 15 minutes (systems that perform 12 air changes/hour). In the absence of mechanical ventilation systems and in the absence of open windows or doors, airborne particles can potentially take hours to settle on the floor, posing an exposure risk to healthcare workers and patients, especially if they are close to the human source of infection and in the absence of the use of face masks[8].

DISCUSSION

For some authors, in the description of the pathogen transmission mode, the most rational threshold size to distinguish "droplets" from "aerosols", in terms of their physical behavior and exposure route, is 100 μm and not 5 μm, as described by the WHO and CDC[8]. For didactic purposes, they suggest the use of the terms "droplets" for particles that fall to the ground (or any surface, even vertical ones) under the influence of gravity and/or the impulse of the exhaled air of an infected person; and "aerosols" for particles that remain suspended due to size and/or environmental conditions. The term "respiratory particles" should, however, be used to refer to droplets and aerosols in general terms[8].

Evidence is growing to support airborne transmissibility of SARS-CoV-2, given that exposure to small airborne particles is equally, if not more, likely to result in infection than the more widely recognized transmission by larger droplets[8,17]. However, the detection of samples of this agent in the air has been hampered by technical problems (inefficiency in the collection of fine particles, dehydration, and viral damage during the collection process) and methodological problems (undefined sampling techniques, absence of validated methods), a situation that has hampered stronger conclusions about the air transmission of this pathogen[18-22].

In this sense, if an infectious virus spreads predominantly through large respiratory droplets that fall quickly and are deposited on surfaces, remaining suspended in the air for a short time, as reported by many authors and regulatory bodies, the main control measures are guided toward the reduction of direct contact, distancing and physical barriers, the use of masks as a droplet barrier, respiratory hygiene, strengthening hand hygiene and decontamination of surfaces. Such policies do not distinguish between indoors and outdoors, as the gravity-driven transmission mechanism is similar for both configurations[18].

However, if an infectious virus is primarily airborne, an individual can potentially become infected by inhaling aerosols produced when an infected person exhales, talks, screams, sings, sneezes, or coughs. Reducing airborne transmission of the virus requires measures to prevent the inhalation of infectious aerosols, which include the implementation of a ventilation and air filtration system, reduction of crowding and exposure time, the use of masks even indoors, attention to mask quality and fit and the highest degree of protection for healthcare staff and frontline workers[18].

Authors[18] list ten pieces of evidence that support the hypothesis of airborne transmission of SARS-CoV-2. Among which:

1. Viable SARS-CoV-2 was identified in air samples in rooms occupied by COVID-19 patients, in the absence of an aerosol-generating procedure;
2. Long-range transmission between people in adjacent rooms;
3. Asymptomatic or pre-symptomatic transmission from people who are not coughing or sneezing;
4. SARS-CoV-2 has been identified in air filters and building ducts in hospitals with COVID-19 patients, places that can only be reached by aerosols.

With these considerations, what are the implications of this knowledge specifically for health professionals? In addition to the obvious benefits of scientific knowledge about SARS-CoV-2 transmission by "respiratory particles", regardless of their aerodynamic size and ballistic range, there is a need to adopt measures that effectively minimize the risk of infection for healthcare professionals during their work activities, including the proper use of face masks.

Surgical masks protect the wearer by reducing exposure to incoming droplets and aerosols from infected people, however the filtering capacity of these masks varies depending on the micron size of the virus and the brand and, therefore, they are essentially intended to protect the wearer. against penetration of respiratory fluids. An N95 mask (also called N99, N100, PFF2 or PFF3) is a mechanical filter respirator designed to filter at least 95% of airborne particles up to 0.3 μm and is therefore designed for antimicrobial or antiviral protection or particulate filtration[23].

In this sense, based on the evidence that supports the aerial transmission of COVID-19, the use of N95/FFP2/FFP3 respirators by health professionals who directly assist patients is recommended regardless of the condition of performing procedures that generate aerosol, despite the contradictory recommendations even by regulatory bodies of excellence such as the CDC and the WHO[2,23,24].

It is necessary, however, that health professionals use the respirator fitted to the face and that they carry out sealing tests for adequate air filtration, considering that any leak leads to partial breathing of ambient air, without any filtration[23]. It is also important to know how to put on and take off masks when use is extended, and, in this situation, the regulation of the limit number of uses, as well as the conditions of packaging, must be part of the policy for the use of these equipment, in order to preserve its integrity and protect healthcare professionals.

CONCLUSION

This essay achieved its objective by discussing theoretical elements related to the transmission of SARS-CoV-2 through respiratory particles, in order to support reflections on the adequacy of the use of masks by health professionals.

It is confirmed that it is a scientific error to use the lack of direct evidence of the identification of SARS-CoV-2 in air samples to cast doubt on airborne transmission, as well as to recommend prevention measures based on the aerodynamic size of the viruses. In this sense, the present research demonstrates that the use of the N95 mask by health professionals who care for patients, suspected or confirmed, of COVID-19 can be considered a basic and unequivocal measure for the protection and safety of this population.

It is also necessary not only the acquisition of this equipment by the health services, but the training of professionals for its use and maintenance, with a view to protecting the health of these workers during their work care.

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CONFLICT OF INTERESTS

The authors declare there is no conflict of interests.

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