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VIEWPOINTS

Coronavirus Disease 2019 and Airborne Transmission: Science Rejected, Lives Lost. Can Society Do Better?

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This is an account that should be heard of an important struggle: the struggle of a large group of experts who came together at the beginning of the COVID-19 pandemic to warn the world about the risk of airborne transmission and the consequences of ignoring it. We alerted the World Health Organization about the potential significance of the airborne transmission of SARS-CoV-2 and the urgent need to control it, but our concerns were dismissed. Here we describe how this happened and the consequences. We hope that by reporting this story we can raise awareness of the importance of interdisciplinary collaboration and the need to be open to new evidence, and to prevent it from happening again. Acknowledgement of an issue, and the emergence of new evidence related to it, is the first necessary step towards finding effective mitigation solutions.

Keywords. airborne transmission; airborne infection spread; coronavirus; COVID-19; SARS-CoV-2 virus.

The events described here happened during the first months of the pandemic; however, we continue to be asked by the public and the media about them, and so we think that this account should be made public to serve as a warning about what happens when scientific evidence is rejected in favor of beliefs that have become dogma without a firm evidence base. One can say that these disturbing events are in the past; let's move on. Yet, the consequence of this "past" was the loss of many lives, along with huge economic consequences. Equally important, how can we safeguard society in situations when those in power, with responsibility for our health and well-being, opt to base their decisions on embedded beliefs or narrow ways of interpreting evidence that seriously misdirect policy-making? This is another reason why we believe that this story is worth telling as a contribution to retrospective assessments and future resilience planning.

THE BEGINNING—THE PANDEMIC UNFOLDS

In January 2020, we all watched the news about a virus causing a rapidly increasing number of respiratory cases and deaths in Wuhan, China. Many asked: "Can it be controlled?"

In the minds of natural scientists, medical professionals, engineers, and experts from numerous related fields, who have devoted their careers to studying the many elements of airborne infection transmission and to developing solutions to control it [1–5], the early reports left no doubt that this was a respiratory virus. As such, curtailing airborne transmission had to be on

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the table as one of the key elements in controlling the epidemic before it became a pandemic.

The first signs of a serious problem were detected by China. Professor Junji Cao from the Chinese Academy of Sciences was worried that the airborne transmission route of the virus might not be well recognized. He shared his concerns with Professor Lidia Morawska of Queensland University of Technology, Australia, on 7 February 2020. This communication raised the question of what could be done. Should we contact the authorities and alert them to this situation?

The situation was rapidly changing. Cao and Morawska collaborated on a commentary entitled "Airborne transmission of SARS-CoV-2: the world should face the reality" [6]. They aimed as high as they could, contacting the editors of 2 top journals in turn and argued for the need to spread this message, but to no avail. The response from one of the editors on 1 April 2020 was, "We appreciate that it is important to take into consideration long-distance airborne transmission by COVID-19. However, we feel that this possibility is acknowledged by authorities and by the scientific community alike, and is being considered in different publications."

It became clear that it would not be easy to get this message across as a publication (the paper was eventually published by *Environment International* on 7 April 2020 [6]).

The virus continued to spread and dark clouds were gathering. By March 2020, Italy was the epicenter of the disease spread outside China, with an unprecedented number of lives lost. Professor Giorgio Buonanno from the University of Cassino and Southern Lazio was among the first to raise the alarm that the critical element of control—airborne transmission—was not being taken into account. The Italian medical community knew how to apply relevant personal protective equipment and did so "by the book." But "the book" did not acknowledge that this virus was in the air, and that measures to protect against airborne transmission, such as protective respirators and adequate ventilation, should be used. Discussing this Saturday evening 28 March 2020 with Morawska, Buonanno suggested contacting the Italian Public Health Authorities directly to tell them about the significance of airborne infection transmission of the virus. We knew that it was unlikely that the voices of 2 scientists contacting the authorities directly would have any influence. If at all, our voices are heard within the scientific community via publications in scientific and professional journals.

The next day, the World Health Organization (WHO) tweeted: "Fact check: COVID-19 is NOT airborne" (https://twitter.com/WHO/status/1243972193169616898); and on 29 March 2020, the Executive Director of the WHO Health Emergencies Program stated to CNN: "There is no specific evidence to suggest that the wearing of masks by the mass population has any potential benefit" (https://edition.cnn.com/2020/03/30/world/coronavirus-who-masks-recommendation-trnd/index.html). This broadcast statement made us realize that the authority of WHO was necessary to convey the critical message and provide guidance to countries around the world. That evening a decision was taken to assemble a group of experts to help convey the vital message to the WHO. Time was of the essence as the pandemic was intensifying and people were dying.

THE FOCUS ON THE WHO: SCIENCE REJECTED

On 29 March, Morawska drafted a message in the form of a petition to the WHO director general (DG) and compiled a list of experts—colleagues of high international standing from around the world—whom she knew had been working on airborne transmission for many years from various angles, including aerosol physics, virology, public health, clinical medicine, infection prevention and control, building engineering, and facility management. She had worked on this broad topic over the years with several of these individuals. The next day she contacted all of the identified experts, explaining the problem, presenting the draft, and asking if they would like to support the petition. Every one of them did so, and some suggested names of additional experts to include. The list expanded to 36 names, a sizable group; although we knew that many more experts could have been enlisted given more time this was a manageable group who represented a breadth of expertise from around the world. This is how "Group 36" was born.

On 1 April, Morawska e-mailed the petition directed to the WHO DG to his management team in the Geneva WHO Health Emergencies Program (Supplementary Appendix 1). There was an agreement within Group 36 not to engage with the media at this stage. The hope was that the WHO would consider and act upon this message, without the need for any additional pressure, such as that created by the media.

Within just an hour, Morawska received a phone call from a member of the WHO Health Emergencies Program wanting to talk to her about the petition. There was some tension during the conversation; Morawska thought that the WHO was reacting defensively rather than constructively to the arguments that were being presented. The conclusion from that call was that another call would be organized, this time open to the participation of the entire Group 36; this call took place 2 days later, on 3 April.

That call was even more uncomfortable for Morawska, and indeed for all of the participating members of Group 36. It is described in the first paragraphs of Molteni, 2021 [7]: "The 60-Year-Old Scientific Screwup That Helped COVID Kill." In addition to the members of the WHO Health Emergencies Program and Group 36, several other expert participants were invited by the WHO. The overwhelming impression was that these experts and the WHO team were trying to undermine or reject the message of our petition. We were backed into a defensive position during the call, while we tried to make our

points. After the call was finished, disappointed and frustrated, we wondered, Why are they acting like this? Why are they so bluntly rejecting our arguments? Nevertheless, the WHO undertook to provide a response to our petition. Before the response was received, on 6 April, we sent extended comments/clarifications on many points touched upon during the teleconference, saying, "During the teleconference a number of points were raised, to which we were not able to respond, as time was limited. To address these points, and to clarify our explanations and recommendations, we have prepared a new document, please see attached." (Supplementary Appendix 2).

A written response from the WHO was provided on 16 April (Supplementary Appendix 3), which stated: "In conclusion, we recognize that this is a complex and evolving area. Supported by many independent international experts, we maintain our view expressed above that the role of airborne transmission for SARS-CoV-2 is predominantly opportunistic and mainly limited to aerosol generating procedures."

We replied on 17 April (Supplementary Appendix 4), expressing our disappointment: "As you may have seen in the initial reactions from colleagues who signed the petition, we are disappointed that WHO will not consider airborne spread of SARS-CoV-2 as one of the routes of infection transmission and will not recommend measures to mitigate this. Of course, we are keen to continue the discussion with your team and look forward to possible collaboration on this important topic. Please let us know how you would like to proceed. At the same time, we believe that the matter is so important and urgent that we will have to consider any avenues available to bring it to the attention of the general public, the medical community and authorities in charge of public health."

In response, a member from the WHO Health Emergencies Program commented on the same day: "I'm afraid that you have misunderstood. We have always considered the possibility of airborne transmission in the context of health care settings where aerosol generating procedures are conducted. Our guidance clearly reflects this, and has included this since the first version that was published on 10 Jan. I will let the IPC team respond directly to the questions from the group."

Time was passing, and while there was an appearance of a dialogue, it became clear to Group 36 that direct communication with the WHO was not going to achieve anything. What could we do? One option we discussed was to go directly to a top media outlet in an English-speaking country, so the message would be published in English. But it turned out that doing it this way would exclude many of our Group 36 medical colleagues who, as government employees, could not participate in a campaign through the media. We decided to recast the petition in a slightly longer form, and to direct it not only at the WHO but also to national public health authorities by approaching a top international scientific journal. In addition, we decided to extend the group supporting this message by including other experts as co-authors or supporters. Members of Group 36 identified additional internationally acclaimed experts, and we established an online platform through which the invited experts could sign their support. Because we wanted to submit the petition—an open letter, as it came to be called—as soon as possible, we asked these experts to sign if they agreed with the text in its current form, and if they wanted to be part of this initiative. The immediate and overwhelmingly positive response to support the open letter was a demonstration of consensus on the topic within the global expert community.

The submitted paper was rejected on 28 May by a top journal following a review by 2 advisors. Subsequently, the paper was submitted to a second international journal on 5 June, and again was rejected after review on 17 June, with comments that the manuscript "raises fear by warning against a mode of SARS-CoV-2 transmission for which the evidence so far is very weak. In numerous countries around the globe, COVID-19 cases are now decreasing without taking any measures to prevent virus spread through the air over several meters. Most countries recommend 1, 1.5, or 2 meters of physical distance between people and several do not recommend facemasks or only under specific conditions, let alone facemasks that filter small droplets or aerosol. Despite the limited measures that have been taken (and are currently advised by the WHO) the case counts are dropping rapidly in many of these countries, thus providing reasonable assurance that COVID-19 is predominantly transmitted via direct or indirect contact and perhaps via large droplets over short distances. I would object to several arguments used by the authors as follows." We now know how wrong this reviewer was.

The paper was submitted a third time, to *Clinical Infectious Diseases* on 26 June and, after editorial comments were addressed, it was accepted on 1 July and published online on 6 July [8]. This was a full 3 months after the first petition had been sent to the WHO. The paper was made available to the media under embargo and attracted a global media blitz after the embargo was lifted. Just before publication of the paper we sent a second petition to the WHO (Supplementary Appendix 5), saying, "We appeal again for WHO to join these scientists and national healthcare organizations to acknowledge the new data and update their stance, by acknowledging that aerosol spread is one of the main modes of transmission of SARS-CoV-2. This will provide urgent and much needed global leadership to unify the multiple and varied approaches required to control the spread of SARS-CoV-2, as new clusters continue to break out across the world."

The WHO reacted during a media conference the next day on 7 July, accepting airborne transmission: "The World Health Organization acknowledged 'evidence emerging' of the airborne spread of the novel coronavirus, after a group of scientists urged the global body to update its guidance on

how the respiratory disease passes between people" [9]. The WHO modified its brief on 9 July 2020: "This section briefly describes possible modes of transmission for SARS-CoV-2, including contact, droplet, airborne, fomite, faecal-oral, bloodborne, mother-to-child, and animal-to-human transmission" and "Airborne transmission is defined as the spread of an infectious agent caused by the dissemination of droplet nuclei (aerosols) that remain infectious when suspended in air over long distances and time." The brief, however, used much more certain language for droplets and a much more uncertain description for aerosols.

As cases grew, new variants emerged, more data appeared showing poorly ventilated spaces were associated with transmission and, in particular, superspreading events, and the wider scientific community started to accept evidence more readily from those who studied respiratory aerosols, there were further modifications to the brief. The one posted on 23 December 2021 made the wording more complicated by separating inhalation of the virus in close proximity to an infected person ("this is often called short-range aerosol or short-range airborne transmission") and inhalation elsewhere in the room ("this is often called long-range aerosol or long-range airborne transmission"). This flags a wider challenge around terminology. Airborne infection transmission occurs by inhalation of an infectious pathogen from the air; the mechanism is the same regardless of the location of a susceptible person in relation to the infectious person. However, in medical fields, the word "airborne" is typically reserved for transmission over longer distances, leading to incorrect assumptions that close-range transmission is only by large droplets. Intervention opportunities to control airborne transmission overlap but are not coincident between the short-range and longer-range transmission paths.

The WHO did publish several documents on ventilation—in particular, the "Roadmap to improve and ensure good indoor ventilation in the context of COVID-19" [10], which was released on 1 March 2021, and sought the expertise of Group 36 to review this document. However, by not directly connecting "ventilation" with "airborne transmission," the message to national public health authorities and the public was not clearly delivered.

Group 36 continues to be an active force to combat airborne infection transmission and to shift the paradigm of the approach to clean and healthy indoor air in general, with an influential paper published in 2021 [11] and a total of 45 collaborative papers about the pandemic (Supplementary Appendix 6). However, our voice was ignored by WHO at the beginning of the pandemic, which was the most critical time for action.

CAN SOCIETY DO BETTER?

What course would the pandemic have taken if airborne transmission had been recognized at the beginning of April 2020 and guidelines on the mitigation of airborne transmission had been provided? How many cases would have been prevented, how many long-COVID cases and how many lives would have been saved? Of course, we will never know for sure as there is no reliable counterfactual; yet, it is clear that there was a delay in messaging to manage airborne exposures and that funding was prioritized for other measures. And why, after 3 years, is acceptance of the science of airborne infection transmission still a challenge? Several historical reasons are discussed by Jimenez et al [12], but historical errors should not shape the future.

One may say that the delay was only 3 months; perhaps that is only a short interval considering that we are now in the third year of the pandemic. However, those early 3 months were critical, because this was when control measures were being developed and introduced in countries around the world. This was also the time when public interest was most acute and messages around transmission were embedded into the actions that millions of people took in their daily lives. The "hygiene theatre" (as it was later called) was established [13], and for at least the next 12 months, hands were disinfected countless times during the day; surfaces in public spaces were deep cleaned; groceries from supermarkets were disinfected; and gloves were worn to avoid surface virus. But the virus was principally in the air, with even now limited evidence that fomites or hard surfaces play a significant role in transmission. The initial misguidance and subsequent mixed messages have delayed practical implications from being implemented as vigorously as they should have been, from recognizing the importance of airborne transmission to implementing controls demonstrated to be effective. Two and a half years later, in November 2022, the then WHO Chief Scientist admitted, "We should have done it much earlier [calling SARS-CoV-2 airborne], based on the available evidence, and it is something that has cost the organization" [14].

Can the consequences of this misguided history be quantified, not only to provide an account of the past but to help set the right course for respiratory infection control in the future? Such knowledge would motivate the use of existing technologies and knowledge to minimize future loss of life due to airborne infection transmission and to reduce morbidity, economic costs, and other impacts.

It is a tragic situation for our society that scientific fact is not timely adopted in public health decision making. We recognize that, when setting policy, decision-makers must weigh numerous considerations: scientific, economic, social, ethical, and others. However, science must not be sidelined in the process, which unfortunately is the case in many other decisions critical to the well-being of our society. We believe that, as a society, we can and should do much better and we recommend how to do it.

Recommendations

1. Multidisciplinary mechanisms should be created by which decision-makers should be accountable for using or rejecting science, in a transparent and timely manner.
2. Decision makers should use the best available science and not contort the science in order to fit a decision that may hinge on multiple factors.
3. Decision-makers should acknowledge scientific realities and explaining how they, along with numerous other factors, drive policy. Such transparency would build public trust.
4. Concentrated effort should be made to use the massive body of data and the evidence amassed during the COVID-19 pandemic to assess the protective impact of control measures against the airborne transmission of the virus, should they have been implemented since the beginning of the pandemic.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

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Multi-partner project with Universities of Manchester, Cambridge, Newcastle, Imperial, UKHSA, Dstl, Department for Transport and multiple transport stakeholders, CECAM, Engineering and Physical Sciences Research Council (EPSRC) £950 K funding to support a new bioaerosol chamber (2021–2025); Centre for Doctoral Training in Fluid Dynamics (Co-Director, PI Prof P. Jimack), 2019–2027, EPSRC, £4.2 M; Cross-faculty programme to train 50 PhD students over 8 years; and EPSRC National Fellowships in Fluid Dynamics coordination hub (CoI), 2022–2025. C. N. also reports honoraria for Royal Institution Christmas Lecture; payment from BBC Life Scientific; accommodation and registration fees for Indoor Air June 2022, Kuopio, Finland, and BOHS annual conference, June 2022, Belfast; travel expenses for the International Symposium on Stratified Fluid, August 2022; travel and registration fees for IHEEM annual conference (October 2022). C. N. served as co-chair for SAGE Environment and Modelling Group (April 2020–May 2022) and participated in multiple UK government advisory groups during COVID, serves as Chair for HSE Science Quality Assurance Group, is a member of the UKRI SPF clean

air programme steering board, a member of the WHO Environment and Engineering Control Expert Advisory Panel (ECAP) on ventilation and WHO European High Level Expert Group on COVID-19 leading the ventilation subgroup, and as a Member of the Royal Academy of Engineering COVID-19 Working Group on Infection Resilient Buildings and co-author of reports in July 2021 and May/June 2022. C. N. also received 3 Aranet CO_2 sensors from Naltic Industrials. S. M. reports a leadership role as the Vice President for the Academy of Fellows, International Society for Indoor Air Quality and Climate, and on the Aerosol Science and Technology Journal advisory board (both of which are unpaid positions). W. B. reports an unpaid role as chair of the ASHRAE Epidemic Task Force. P. M. B. serves in a leadership or fiduciary role on the KNAW Commission and the Pandemic Disaster Preparedness Centre (both unpaid positions). All other authors report no potential conflicts. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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