Editorial: World Health Organization Report Removes the Aerosol/Droplet Dichotomy But Does Not Move Us Forward in Infection Control Strategies

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Words, more specifically definitions, matter. This became all too apparent during the COVID-19 pandemic, particularly when robust decisions over the most appropriate infection control measures were required. For many decades, a dichotomy has been established between respiratory droplets and aerosols (often equated to dried droplet nuclei) and the roles that these two offenders play in the transmission pathways of respiratory pathogens (Randall et al. 2021). Epidemiological evidence that transmission preferentially occurs over short range was taken as confirming that ballistic droplets were nearly always the culprits and aerosol (or airborne transmission) could largely be ignored. This thinking arose from a fallacy: respiratory droplets were classified as everything larger than 5 μm in diameter, transmitting respiratory pathogens only over 1-2 m, while only particles smaller than 5 μm were designated as infectious aerosols, potentially leading to airborne transmission. Aerosol scientists challenged this dichotomy early during the pandemic, arguing that aerosol physics arrives at no such arbitrary demarcation of size when considering the transmission pathway and, if a size categorization was needed, a threshold of around 100 μm would be more appropriate and consistent with the pioneering work of Wells (Wang et al. 2021). After four years of deliberation and mounting evidence that the inhalation of infectious particles was the dominant mode of transmission, a recent report by the World Health Organization (WHO, 2024) has finally acknowledged that we must move on from this false dichotomy: particle size is not the only factor determining transmission of infections through the air.

The recognition by the WHO of the inadequacy of the particle size dichotomy and that infectious disease transmission "through the air" by *infectious respiratory particles* (IRPs) can occur over both short and long-

range is to be commended. IRPs are generated not only by coughing and sneezing but by infected individuals breathing, speaking and singing, and span a wide size range from sub-micrometers to millimeters in diameter, containing the pathogen, water and respiratory secretions. However, the report is identified as a "Global technical consultation report on proposed terminology for pathogens that transmit through the air", and it is just only that. It proposes terminology that is yet to be accepted by the scientific communities working on transmission pathways and mitigation strategies. Indeed, while it focuses on transmission mechanisms, it has little to say about infection control measures, recognizing that it represents: "…the first phase of the global scientific debate led by WHO", and requires "further technical and multidisciplinary research and exploration of the wider implications of the updated descriptors before any update on infection prevention and control or other mitigation measures guidance is issued by WHO." This latter guidance should be placed front and foremost in our ongoing endeavors; in the end, infection prevention and control measures save lives and mitigate the spread of diseases, and "transmission pathways alone are not sufficient to indicate which mitigation strategies are chosen". However, once again words matter. If we are to communicate to policy makers and the general public the degree of risk that an emerging pathogen poses, we must first reach a consensus on the language we use across the scientific and healthcare communities to ensure that the terminology we use in our scientific debates is aligned with clear interpretations for risk management and precautions in infection control.

So, where does the WHO report take us? The report seems unnecessarily limited to consideration of exhaled respiratory pathogens transmitted "through the air", a consequence of the singular focus on IRPs. Surely this is an arbitrary constraint that will lead to confusion; why introduce a false boundary between respiratory pathogens and a whole host of other airborne pathogens that transmit through inhalation and for which much of the terminology, most of the control measures and many of the research gaps are the same? Only the source of the aerosolised pathogen is different and can include water reservoirs (e.g. *Legionella*), vomiting or diarrhoea (e.g. norovirus originating in the gastrointestinal tract), flushing toilets (many microbes), skin fragments and blisters (e.g. *Staphylococcus aureus* and varicella zoster virus) and fungal spores (e.g. *Aspergillus*). Indeed, exhaled particles can also cause infection through routes other than inhalation, for example through the exposure of open wounds during surgery or eyes. In some instances, the boundaries are even more vague when processes such as the resuspension of deposited aerosolized pathogens are considered. The report also seems limited to considering that IRPs are generated solely by puff clouds, travelling independently of air currents before longer range dispersal and dilution by background air. Although appropriate for describing violent exhalation events such as coughs, the exhalation jet is less pronounced for activities such as breathing or talking, which are major contributors to exhaled pathogens and provide a constant source of emitted particles (for example, see Lindsley et al. 2016). Limiting consideration to exhaled respiratory pathogens transmitted "through the air" is a missed opportunity, providing terminology that is not comprehensive and cannot be used for other pathogens that can be aerosolized by other routes, inhaled through the respiratory tract and lead to infection. However, we must always be

cognizant that the same terminology may not always be applicable when considering the transmission of bacteria, fungi and respiratory viruses.

We question why new terminology, such as IRPs, is even needed? COVID-19 has led to wide recognition of the term *aerosol* in the context of infectious disease transmission, both by healthcare professionals and even in the general population. Why replace a term that has broad scientific meaning (with all the associated implicit understanding of the complexity in particle size, composition, transport properties, etc.) with a new term that is restricted in scope? At this time, IRPs cannot even be unambiguously identified. For instance, a particle could contain an inactivated pathogen, which would still be identified by molecular methods as containing a virus. Determining whether or not a pathogen sampled from the air can cause infection remains extremely challenging and the detection of virus genomic material does not imply inhalation risk. Furthermore, viral strains vary in their virulence and there are no exact measures regarding a virus' potential infectiousness that are fixed; instead, these change as viruses mutate.

Although the droplet-aerosol size dichotomy has been ousted by a recognition that IRPs span a continuum of sizes, it is replaced by a dichotomy between IRP transmission through *airborne* and *direct deposition* routes. The use of the term IRP seems to add very little to simply using *aerosol* in its broader sense, while generating additional terminology with no previous scientific validity. The report acknowledges "the goal is to prevent and/control microbial transmission. Control includes both limiting the spread of infection and limiting the morbidity and mortality resulting from infection. To prevent or limit the spread of infection, exposure must be addressed, prioritizing interventions according to the severity of the resulting diseases. This means that for the same transmission mode, different prevention and control measures may be selected." From an infection control perspective, it is necessary to know when a facemask and face shield may suffice, or when a respirator or airborne isolation room is deemed necessary. Resolving this dilemma is neither made more likely by the adoption of the additional IRP terminology nor by asserting the dichotomy of airborne versus direct deposition modes. The language of aerosol dispersal, sedimentation and dilution over an increasing range (from what is often loosely labelled as short to long range) surely captures the complexity of transmission pathways using established terminology from the aerosol science community. A reduction to dichotomous pathways, while removing the dichotomous sizes and attempting to simplify communication, seems to ignore the continuum in properties that always exists and, thus, does not achieve the ultimate aim of identifying robust control measures that must go way beyond this. At best, the new terminology may ensure that everyone starts with the same level of understanding, but it may distract and still be open to misinterpretation without careful and consistent adoption.

The reason for the WHO report's aversion to the use of the term *airborne* as a broad term to capture all relevant transmission pathways involving aerosols is unclear. While the authors state that other public health descriptors such as *waterborne*, *bloodborne* and *vectorborne* are commonly understood by scientists, clinicians, and the general public, it is unclear why the term *airborne* cannot just be used instead of the new

terminology of transmission “through the air”. This seems in conflict with accepted terminology in the medical and infectious diseases communities. Randall et al. (2021) have highlighted that the reluctance to use the term *airborne* in the early and mid-20th century, despite the assertion of Wells that aerosols could be an important mode of transmission, stemmed from the perception that it was regressive, reviving the discredited concept of miasmas or “bad air”. Perhaps because of this, or the perception that the term airborne is more frightening to the general population, the WHO report seems to persist with this reluctance to use it only for a particular aspect of the transmission pathway.

Adopting the single term *airborne* for what the WHO labels as both *airborne* and *direct deposition* in the context of respiratory disease transmission would simplify the picture, removing redundancy, while still having no bearing on what non-pharmaceutical interventions will be most effective. Simplicity is key in public messaging and, as it stands, the new terminology may be too confusing and redundant. It is true that particles or droplets hundreds of microns in size are not airborne from a traditional aerosol point of view and do not remain suspended for timescales longer than seconds, but there is no practical way of making a distinction to justify a separate term for these. Direct deposition has little difference from the aerosol deposition mechanism of impaction, making the term redundant. The size dependent droplet impaction efficiency (the inability of a particle to move around an obstruction and follow the gas streamlines) varies with Stokes number which is a function of **both** droplet size and velocity, and is a continuous function with no abrupt boundary. In addition, in real-world settings, large droplets rapidly decrease in size to reach the aerosol range and are almost always accompanied by a cloud of smaller aerosol particles. Retaining an ambiguous dichotomy between *airborne* and *direct deposition* risks us once again repeating the mistakes of infection, prevention and control guidance issued during the COVID-19 pandemic, with short-range transmission still equated solely with direct deposition and mitigated by precautions previously applied to prevent droplet transmission. Our contention is that the merging of these two transmission mechanisms within the single umbrella term *airborne* could avoid a dichotomy which is difficult to justify except in the extreme scenarios of the behaviour of very small particles (<1 μm) in a quiescent gas compared to very large ballistic droplets (>>100 μm) in an exhalation jet; the behaviour across the full spectrum of sizes is much more nuanced than the dichotomy recognises. Nevertheless, there are contexts (beyond respiratory disease transmission) where there remains a clear benefit of retaining the language of *direct deposition in communications of risk* such as where splashes of very large semi-ballistic droplets of infected blood or bodily fluids can be mitigated by face shields without the need for inhalation protection.

Of course, it is often the case that designating a pathogen as *airborne* crosses a threshold beyond which clinical practice and non-pharmaceutical interventions become difficult, expensive and burdensome. However, even using the new WHO terminology, many diseases should be categorised as *airborne* (e.g. seasonal flu) and yet the use of strict quarantine, isolation and full respiratory personal protective equipment is not required because they have available treatments and/or are not particularly virulent with relatively low mortality, thus avoiding a requirement for the highest level of protection. The new terminology does not

clarify this for health practitioners or policy makers. A further justification for avoiding the term *airborne* is apparent in the report, with the authors stating: “Most importantly, while discussions during the consultation were based on the available best science, it was agreed it was important to balance scientific insights with availability, access, affordability and other practical realities to minimize health inequity and avoid potential consequences such as the ability to access PPE.” This does not seem like an appropriate pathway to protecting vulnerable populations. Issues of health inequity and access to PPE should be addressed outside the scope of scientific inquiry or the definition of infection, prevention, and control guidance. If we allow the availability of PPE to influence the definition of how a disease is transmitted, we risk never being able to protect vulnerable populations adequately which could increase inequity of care. Instead, investing effort in recalibrating our understanding of the term airborne in the broadest sense seems most appropriate for informing the use of suitable infection control measures. As infection control mitigation strategies depend on situational risks and not exclusively on transmission mode, creation of a new, and easy to understand, terminology of adequate infection precaution "packages" corresponding to different transmission mode and risk scenarios is urgently needed (Leung and Milton, 2024).

Finally, the report is disappointingly incomplete when identifying key research gaps and next steps. There is little mention of the need for an improved understanding of the source; more specifically, what are the host factors that influence when, how much, and for how long an infected individual will shed a pathogen, knowledge that may be crucial for controlling transmission in future epidemics. Significant gaps also remain in our understanding of how differences in the site of deposition of a particle within the respiratory tract can alter the probability of infection due to tissue tropism and/or regional differences in protective mechanisms (e.g. mucus and mucociliary clearance in the upper respiratory tract) and pathophysiology. Importantly, as a community we must also attempt to better define the types of evidence needed to conclude that a pathogen transmits by the airborne route, with the aim of providing clear criteria to make a rapid and robust judgement on any future emerging pathogen. This must be complemented by information on disease severity and exposure risk (e.g. airborne infectious pathogen infectivity, indoor ventilation rates, levels of immunity) to guide communications about protection measures. Capturing these multifarious factors in a single metric, analogous to an Air Quality Index (AQI), could be a useful tool for providing guidance on infection prevention and control measures and be presented in a way that the general public, clinicians and policy makers can appreciate, linking the mode of transmission to the disease severity, and infectivity to the non-medical countermeasures to be implemented. Building managers should be able to rely on it to determine control technologies to be implemented, and infection control specialists could use it to decide on the mitigation measures that must be adopted.

In conclusion, the WHO report represents significant progress in collating our understanding of infectious respiratory disease transmission following our collective research efforts during COVID-19 and in proposing new terminology. It also highlights areas in which further clarification is needed. However, simplicity is the best approach to ensure general perception/acceptance of terminology and we suggest that further

refinements are still necessary. We argue for the explicit use of the term *aerosol* to provide a nuanced, accepted and scientifically rigorous term that implicitly captures the imprecise boundaries of, for example, the variability in particle mechanics with size. Specifying a prefix of, for example, *respiratory* can clarify the specific source of the aerosol containing a pathogen in particular context, and can ensure the broader framework can accommodate airborne diseases beyond just those originating in the respiratory tract. Adopting *aerosol* avoids the replacement of the previously misleading dichotomy in particle size (*droplet nuclei* vs *droplet*) with an unnecessary new dichotomy of *airborne* vs *direct deposition*, two terms which have little bearing on the choice or infection control measures and just add confusion. It also simplifies terminology avoiding the addition of new terms (such as *infectious respiratory particles*) that would need to be stringently policed in their usage if future confusion is to be avoided. A recalibration of our understanding of the terms *aerosol* and *airborne* in the broadest sense seems most appropriate for guiding the use of suitable infection control measures to mitigate *short-* and *long-range* exposure.

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