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In the late 1850s Louis Pasteur discovered organisms seen only through a microscope cause putrefaction of dead biological materials and also infectious diseases. On the basis of these findings, the medical profession at the time concluded; when people get exposed to decaying organic matter, microbes therein gain access to human body, making them sick. Their excrements carrying the pathogen also transfer the disease to others. Later on it became clear a specific types of microbes latently established in the community or in animal reservoirs are responsible for each infectious disease. Sometimes they flare-up, transmitting from one host to another, resulting in an epidemic. When the community acquires herd immunity, the disease wane and move to another location, or reappear at the same place later. Rarely a microorganism, naturally associated with an animal, jumps to a human and after genetic alterations develops into a contagious illness. Most of the existing infectious diseases are believed to have originated by the above evolutionary process. The genetic material of the coronavirus (SARS-CoV-2) resemble those of viruses present in some species of bats, but definitive evidence is not available to determine how it passed to humans.

Depending on the nature of the infectious agent and symptoms caused by its invasion to the human body, diseases spread via one or several of different modes. Notably; direct or indirect exposure to body fluids, food or water contaminated with excretions of the sick, pathogen released to air or mediation of another living organism (vector).

Pathogens evolve to optimize the mode of transmission to proliferate and survive, but not to exterminate the host. Propensity of evolution via genetic changes is higher in the case of viruses, notably those based on RNA. More the virus replicate by infecting a larger population, chances of popping up variants increase proportionately.

**Respiratory transmission of**
**infectious diseases**

One of the most effectual modes of disseminating an infection is releasing the pathogen into the air in coughing, sneezing, talking or exhalation. Here, germs enter into the bodies of other people during inhalation, deposition on lips, nostrils, eyes or skin. Those deposited on surrounding objects sometimes contaminate hands and may subsequently enter the mouth. Apart from COVID-19, quite a number of most contagious viral and bacterial diseases spread by the airborne route. These include viral diseases; common cold, influenza, measles, mumps, chicken pox, viral meningitis and bacterial diseases; tuberculosis, diphtheria, whooping cough and anthrax. Lungs and the respiratory tract are more susceptible to intrusion by germs compared to the gastrointestinal tract, because the acidity of the latter resist foreign organisms.

Airborne diseases are hardest to control, because of the high probability of transmission through an all-pervading invisible medium and prohibitive difficulty of sterilizing large volumes of air.

The direct respiratory transmission of a pathogen proceeds via two aerodynamical mechanisms; droplet transmission and aerosol transmission, the latter is also referred to as airborne transmission.

**Droplet Transmission**

When an infected person cough, sneeze, speak or exhale deeply, ejected fluid droplets disperse into air. These droplets constituted largely of water, enclose mucus and the pathogen. With the initial velocity imparted, droplets propel forward and begin to fall owing to gravity, following a curved trajectory.

At school, we learn that all falling objects; irrespective of mass and size, moves with continuously increasing speed at a constant acceleration of approximately 10 meters per second. This is in absence of air resistance, negligible compared to gravitational force for heavy objects. Situation differs in the case of small particles, where air resistance is comparatively important. As shown by Irish physicist George Stokes, falling spherical particles encounter a breaking force proportional to the velocity. Consequently they accelerate for very short time and thereafter fall down with a uniform speed proportional to the square of the radius. Thus larger droplets, those greater than 5-10 micrometers (1micrometer = 1/1000 of a millimeter) fall rapidly and reach the ground after propelling a short distance of about 1-2 meters. Only those persons within this range get exposed to larger droplets. Smaller droplets fall further or remain airborne and floats around.

Particles floating in air without settling down to the ground are known as aerosols.

Water in respiratory droplets evaporate, converting sizable ones to smaller entities; more likely to be transported as aerosols. Sometimes water evaporates completely producing nuclei carrying the pathogen. Nuclei being lighter remain afloat longer. Evaporation depends on relative humidity and ambient temperature.

The genius scientist and engineer William F. Wells working in Baltimore hospital, United States, in 1934 was the first to analyze theoretically the respiratory transmission of infections, distinguishing droplet and aerosol modes.

**Aerosol Transmission**

Smaller droplets (less than 5-10 micrometers and sometimes even larger), those reduced to similar sizes by evaporation of the water content and droplet nuclei resulting from drying-up of droplets remain suspended in air without falling to the ground. They can be carried long distances exceeding 10 meters by air currents or accumulate in poorly ventilated spaces. Evaporation to dryness could inactivate pathogen and many viruses and bacteria seem to have evolved strategies to circumvent this problem – possibly the residue mucus help to preserve them live.

To prove the aerosol hypothesis, William Wells vented air from a tuberculosis ward in Baltimore hospital to a compartment where Guinea pigs were nourished. He observed about 3 percent of the animals contracted tuberculosis. Examination of the lesions in lungs revealed they have originated by deposition very few bacilli each time; further supporting the aerosol hypothesis. Aerosols being minute, each carry very few microbes. In another experiment Wells irradiated air from the tuberculosis ward with ultraviolet light before venting to the Guinea pig cage. Here none of the pigs developed the disease, confirming germs originated from the ward.

Today we describe tuberculosis as an archetypal example of a respiratory disease communicated by aerosols. Measles and chickenpox also spread predominantly via aerosol route.

Despite the seminal work of W.G. Wells, medical texts continued to emphasize most respiratory infections including common cold and influenza transmits via droplet mechanism. For this reason the COVID-19 virus was assumed to transmit primarily via droplets and preventive measures were recommended accordingly.

Although scientists continued to insist COVID-19 virus could communicate via aerosols; World Health Organization (WHO) and Center for Disease Control and Prevention (CDC), United States and several other leading health care authorities did not acknowledge airborne transmission. About a month ago, all these organizations revised their websites making statements to the effect that COVID-19 could also be transmitted by aerosols.

At shorter distances (2-3 meters), both droplets and aerosols pass on coronavirus. Whereas at longer distances (especially unventilated situations) aerosols play a predominant role.

There exist reasons to suspect aerosol communicated illness is more virulent. In droplet mechanism, the virus lands on the nasal region of the respiratory passage gradually proliferating downwards in the respiratory tract. Whereas aerosols can reach the lungs directly, causing acute respiratory complications instantly. Possibly when virus is first introduced into the upper respiratory tract by droplets, the local infection there induce some immunity before it reaches the lungs – suggesting aerosol communicated infection is more virulent.

**COVID Transmission modes and control measures**

Decisions regarding what measures to be adopted in controlling an infectious disease necessitates gaining an understanding of the nature of the causative agent and how it is transmitted. For diseases known to have existed for long periods of time, requisite information is readily available permitting immediate intervention. When COVID-19 surfaced it was a new disease not known to have existed previously. Modern science was quick to ascertain the genotype (complete genetic information of an organism) and phenotype of the virus (actually observed characteristics of an organism) and pathology of the disease – information essential design vaccines and curative medicines.

Finding how the virus spreads poses more challenges, especially when there are more than one possible modes of transmission. Here it is important to determine the relative weightage of each mode. In absence of detailed information regarding modes of transmission, droplet mechanism was assumed; because common viral respiratory diseases are considered to pass via this avenue. Accordingly, preventive measures recommended were; social distancing, limiting mobility, wearing masks and sanitization of the hand as well as surfaces likely to be contaminated by the deposit of droplets.

Even in situations where aerosol transmission turns out be more likely, it is imperative, the measures recommended for the droplet mode are strictly followed. However, additional safeguards needs to be imposed when aerosols poses a threat. Aerosols travel longer distance from the source and could diffuse throughout a closed space or carried further by air currents. Masks one wears has to be the type that filters aerosols and tight fitting to avoid aspiration of air from the gaps during inhalation. The risk of aerosol transmitted infection is vastly higher in poorly ventilated indoor environments.

In outdoors situations aerosol transmission is minimal provided social distancing (about 2-3 meters) is strictly maintained while wearing masks, as aerosols diffuse fast. However open markets cannot be considered as outdoor owing to poor circulation. Here additional precautions are necessary to avoid overcrowding.

**Superspreading of COVID-19**

In many instances a good number of people gathered in markets, shops, malls and auditoriums or enclosed workplaces have contracted COVID-19, presumed to be infected by one identified carrier. All individuals who contracted the infection were most unlikely to have encountered the carrier at 1-2 meter distance. Obvious conclusion would be, the virus had been in air and many have breathed it. Experiments indicate virus could survive in aerosols several hours. Poor ventilation, improper air-conditioning and air recycling accumulate aerosols. An infected individual identified to have created a big cluster is sometimes referred to as a superspreader. However, it does not necessarily imply the subject shreds more of the virus. Often the cause of extensive spread had been the nature of an event or the environment where people gathered and participated. In a large congregate, one carrier moving around could contaminate breathing air with germs harbored aerosols to lethal proportions, if the ventilation is inadequate. Imagine the extent of transmission in such situations, when there are several carriers!

A peculiarity of the COVID-19 pandemic: over-dispersion of the basic reproduction number

The present pandemic is peculiar in terms of a concept in mathematical epidemiology referred to as over-dispersion of the basic reproduction number. Basic reproduction number (R0) refers to the average of number of new cases generated by one carrier of the pathogen. For COVID 19 value of R0 is generally a number around 2. It is an average, if we take R0 as 2; it does not mean every infected person reproduce 2 others. The value of R0 could fluctuate randomly or follow an identifiable non-random pattern to yield an average of 2. Statistics of corona virus cases points to the latter.

A larger percentage of infected persons may not pass the disease to anyone, but if each in a smaller percentage of carriers, under special circumstances; infect numbers very much greater than 2, you still would obtain an average of 2. This is exactly the pattern observed in COVID-19 – about 75 percent of the infected persons do not pass disease to others! The flu of 1918 which caused a major calamity also had a basic reproduction number of about 2. Here, contrastingly; 40 percent did not cause secondary infections. Mathematicians measure this difference in terms of another parameter known as the over-dispersion factor denoted by K. The value of K for COVID-19 and the 1918 flu are 0.1 and 1 respectively. A small value of K implies a large percentage of infected persons rarely pass the disease to others, while a small percentage aggressively and sporadically fuel the epidemic.

In Sri Lanka and elsewhere the COVID-19 epidemic progressed mainly as clusters appearing spatially and temporally. The low over-dispersion factor of the present pandemic testifies cluster effect.

If causes are understood and actions taken to alleviate them, low over-dispersion can be advantageously exploited to mitigate the pandemic. A small value for K, means; rare situations congregating people, trigger the pandemic. If they are identified and eliminated, pandemic will dwindle and disappear allowing time for vaccinations secure long term safety and suppress breeding of variants.

The over-dispersion of basic reproduction number of the present pandemic imply that in respiratory transmission of the coronavirus ; it does not significantly distribute via random association of infected and susceptible individuals, but largely by a small set of noticeable social situations and therefore in principle, suppressible by community efforts to follow preventive measures. The pandemic may be suppressed by curtailing events and situations leading to breeding of clusters without restricting routine and other activities essential to drive the economy.

Many epidemiologists believe one of the main causes of low value of K is a direct consequence aerosol transmission under circumstances favorable to their accumulation – especially events and situation that congregate people.

Low dispersion of the basic reproduction number is also advantageous to the virus to resist the pressure of herd immunity. Even if a large fraction of a population is vaccinated, a local situation favorable for super-spreading could create a cluster.

Flu pandemic of 1918 fizzled out completely in 2.5 to 3 years, presumably because of the much higher value of K and rapid acquisition of herd immunity by exposure to the pathogen. Apart from distinctions in the viruses and their pathologies; a noteworthy difference of 1918 pandemic and COVID-19 are: smaller population densities, less human mobility and rarity of super spreading situations and events in the former.

Since the emergence of the COVID-19 epidemic in China, world learned so much about the disease. Yet, there are unknowns; especially finer details of how it propagates and how to cure it. The complex phenomenon of COVID-19 spreading cannot be understood entirely in terms of two numbers R0 and K – although these quantities have provided valuable insights.

We know for certain corona virus can be suppressed by control measures and vaccination. It is the duty of every citizen, community and nation to strictly abide by rules of prevention until vaccines are rolled out and appropriately thereafter.