SYNOPSIS

KEY POINT SUMMARY

OBJECTIVES

The objective of this research study was to examine whether the spread of airborne infectious diseases was supported by adequate evidence and whether this evidence provided requirements to lessen the spread of these diseases in different environments.

Role of ventilation in airborne transmission of infectious agents in the built environment - a multidisciplinary systematic review

Li, Y., Leung, G.M., Tang, J.W., Yang, X., Chao, C.Y., Lin, J.Z., Lu, J.W., Nielsen, P.V., Niu, J., Qian, H., Sleigh, A.C., Su, H.J., Sundell, J., Wong, T.W., Yuen, P.L., 2007 |
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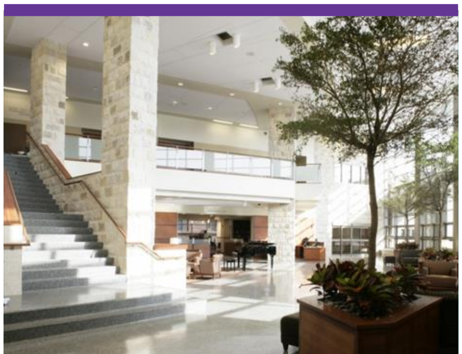
Key Concepts/Context

The early 2000s saw the surfacing of severe acute respiratory syndrome or SARS, the large-scale return of tuberculosis or TB, an influenza pandemic, and the intentional dispersion of diseases like anthrax – all of which are highly infectious airborne diseases. Authors noted that densely populated urban areas and offices, schools, other buildings, aircraft, and other mass transport vehicles (where people spent most of their time) were ideal for the transmission of SARS. This study reports on a literature review conducted to determine if ventilation rates and airflow patterns in different indoor environments affect the spread of airborne infectious diseases. The study concluded there was strong evidence showing the association between ventilation rates, airflow pattern, and the transmission of airborne diseases like measles, TB, chickenpox, anthrax, influenza, smallpox, and SARS. At the same time, the study also indicated a lack of adequate evidence and data to determine the minimum ventilation requirements in healthcare and non-healthcare facilities.

Methods

The methodology for the study involved a systematic literature review. A panel comprised of six experts in medicine and public health and eight in engineering was put together to identify the norms, keywords, and inclusion and exclusion criteria to shortlist articles (in English) from electronic databases. After the articles (published between 1960 and 2005) were shortlisted, their content was assessed based on available evidence for one of the following three conditions:



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- Direct connection between the outbreak of an airborne infection and an enclosed space without access to outdoor air
- Inverse association of airborne infection in host with ventilation rate per person
- Outbreak of an airborne infection in an enclosed space where air transport of an infectious droplet was further than the distance it normally would have travelled when transmitted by an infected individual

The articles were also assessed for the quality and rigor of research methodology and technique – scientifically robust, repeatable, and reliable being the sole criteria here.

Findings

The initial inclusion and exclusion criteria yielded 183 articles. A final 40 studies (45 papers) were reviewed in detail for this paper. The authors presented the findings of the review in three categories: an overall assessment, the role of the ventilation rates, and the role of airflow patterns:

Overall assessment: The panel found 18 studies to be non-conclusive, 12 partly conclusive, and 10 to be conclusive about ventilation rate and airflow in indoor environments as related to the spread of infectious diseases. On the basis of the evidence in these 40 studies, the authors determined that the literature indicated strong evidence regarding the association of ventilation and airflow (in indoor spaces) with the transmission of infectious diseases of measles, TB, chickenpox, influenza, smallpox, and SARS. The facilities studied included: pediatric offices, health clinics, hospitals, ships, aircraft, high-rise apartments, offices, nursing home, church, postal facility, jail, school, city (for animals), cage, and test chamber (the last two for lab animals). In most of the studies the first incidence of infection with one or more secondary cases arising from it were examined.

Studies considered partly conclusive were those with robust epidemiological evidence but incomplete data on ventilation or the possibility of other routes of disease transmission. The multidisciplinary research teams' studies were more comprehensive than studies carried out by research teams from single disciplines.

Role of ventilation rates: Of the 10 conclusive studies, five studied ventilation rates and their role in the transmission of airborne pathogens. Two of these involved case-control experimental studies of animals for human diseases. One study concluded that exhaust air from a TB ward infected animals in an exposed chamber, while the same air delivered to a control chamber (with ultraviolet-radiated air) did not infect animals. The second study found influenza in infected mice was transmitted to non-infected mice in the same cage – separated by double mesh wire screen. The study concluded (i) chance of mice acquiring airborne influenza was inversely related to the ventilation rate and (ii) high relative humidity was effective in a decreased rate of infection. A population-based study in a hospital found that health workers in non-isolation rooms were more susceptible to TB infection with ventilation rates being less than two air changes an hour. A study of the spread of pneumococcal disease in a jail found that cellblocks with crowding and poor ventilation had the highest rates of the disease. A study on the outbreak of influenza in an aircraft attributed it to the absence of outdoor air inside the enclosed space.

Of the partly conclusive studies, five reported on the impact of ventilation rates. One study reported on detection of rhinovirus in the air filters in three office buildings and incidences of workers acquiring cold illnesses.

Role of airflow patterns: Among the 10 studies considered conclusive there were five that reported an association between airflow patterns and spread of pathogens. These five studies showed that an airborne transmission route or means contributed to infections in secondary patients who were located at a distance from the index patient – in hospitals and pediatric offices. Using smoke to visually represent the flow of air, one study demonstrated how heat from radiators in the index patient's room on the ground floor moved the air upwards through stairwells and semi-open windows to infect patients in three upper floors with smallpox. In later years, three other studies used tracer gas techniques and direct aerosol dispersion measurements to examine the spread of measles in a pediatric office, and chicken pox, TB, and SARS in three different hospitals. In all of these studies the transmission of the pathogen appeared to be connected to the design of the facility – smallpox being transmitted upwards because of the heat emitted from the radiator in the index patient's room; in the case of measles in the pediatric office and TB and chicken pox in hospitals – these rooms all were in positive pressure, causing the pathogen to travel into hallways and other rooms. In the case of SARS – an inoperative return air outlet in the index patient's cubicle enabled the spread into other cubicles in the same ward.

There were eight studies in the partly conclusive papers that delved into the probable impact of the direction of airflow on the transmission of SARS. The research panel, however, considered the hypotheses in these studies as partly conclusive, owing to their descriptive nature.

Limitations

The authors identified limitations of the study in connection with the determination of a study being conclusive – in whole, in part, or not. The first was that the decision of a study being considered conclusive, partly conclusive, or not conclusive was the result of compromise among the experts of varying backgrounds on the panel. Age of the study and technology varied over the years – the standard for links between index and secondary cases in the 1960s and 1970s were different from those in the 1990s and 2000s. Therefore, whether a study was conclusive also depended on the familiarity of individual panel members with the methodology prevalent during the time of the study. Lastly, when the panel was indecisive about a study's conclusiveness, the decision of the chairperson in the matter was final.

Design Implications

This literature review strongly alludes to evidence demonstrating the connection between building ventilation and airflow directions with the transmission of airborne infectious diseases like measles, TB, chickenpox, smallpox, anthrax, influenza, and SARS. However, it does not provide adequate information on ventilation requirements in either healthcare or non-healthcare facilities in connection with transmission of these or other airborne diseases. Some implications for design inferred from this literature review and its subsequent discussion section are:

- An efficient airflow pattern should be designed in buildings that could be potential sources for infections and contagious diseases.

Evidence supports the designing of negatively pressurized isolation rooms in hospitals for patients with the above diseases.