Engineering Solutions for **Infection Control**

Simulation assists in designing a hospital ward to reduce the airborne transmission of diseases such as tuberculosis and influenza.

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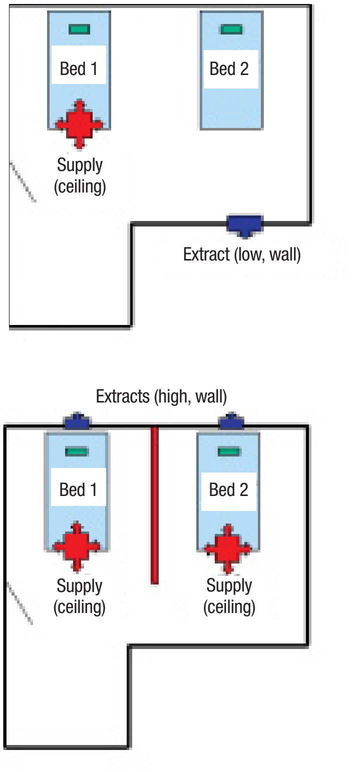
Hospital Nacional Dos de Mayo in Lima, Peru, was the site of a TB ward ventilation system redesign.

Hospital-acquired infection poses a major problem in healthcare facilities around the world. Although many infections are transmitted through hand-to-hand contact, airborne transmission also may play an important role; this is the primary mechanism for a number of infections, including tuberculosis (TB) and influenza. Airborne routes also have been implicated in the transmission of hospital-acquired infections such as methicillin-resistant *Staphylococcus aureus*, *Acinetobacter* spp and norovirus. Successful control of infection involves breaking the chain of transmission. To do so, it is necessary to understand both the mode of transmission as well as the nature of the pathogen and its behavior in the environment.

The role played by airborne transport of pathogens has been the driving force behind the research carried out by the Pathogen Control Engineering Group at the University of Leeds in the U.K. for the past 10 years. The multi-disciplinary team of engineers, mathematical modelers and microbiologists is based in the School of Civil Engineering, with strong links to clinicians at the Leeds Teaching Hospitals and to academics and scientists around the world. Originally set up to investigate ultraviolet (UV) air disinfection devices to combat TB, the group now focuses on understanding airborne transmission routes with a strong emphasis on the hospital environment. This knowledge is used to aid the development of new infection control technologies and to optimize engineering strategies to reduce the risk of disease.

The suitability of a ward ventilation system design was the subject of a recent study carried out using ANSYS CFX computational fluid dynamics (CFD) software [3]. The two-bed ward in Hospital Nacional Dos de Mayo, located in Lima, Peru, is one of a number of similar rooms housing patients with TB. Unusual to a hospital in this part of the world, the wards are mechanically ventilated. Any airborne transmission of TB within the hospital will be strongly influenced by the imposed ventilation flow. As part of a wider project researching TB transmission, led by Dr. Rod Escombe of Imperial College in London, U.K., the CFD study was carried out to examine whether changes to the ward layout and ventilation system could reduce the risk of cross-transmission between patients, staff and visitors in the hospital.

A simplified geometry represented the key features in the ward, including the basic furniture, the ventilation supply and extract vents. Isothermal airflow was modeled on an unstructured tetrahedral grid using a standard k–ε turbulence model. Supply air velocities were defined to ensure a room ventilation rate of 6 AC/h for all simulations, and a pressure of –10 Pa was imposed on the extracts to



Original room layout and ventilation system (top) and proposed new layout (bottom) showing the location of the partition between the two beds, the additional ventilation supply diffuser and the modified extract locations simulate the negative pressure that is maintained in the real facility. As the study focused on the risks of cross-infection, it was important to include a model to represent the release of infectious material from TB patients. To relate the CFD study to published outbreak data, a scalar infectious particle production variable was defined in terms of units of infectious dose, known as "quanta."

To represent a patient's production of TB bacteria, a small inlet condition was located close to the head of each bed. Scalars, representing the infectious particles produced by each patient, were introduced into the room at a constant rate of 14 quanta/hour in order to represent the typical production rate of a pulmonary TB patient.

The CFD study made it quick and easy to compare the impact of a number of proposed modifications to the ward. The original room layout with its single ceiling-mounted supply diffuser and wall-mounted extract resulted in significant mixing of TB contamination throughout the room, demonstrating the high risk of cross-infection between patients. The simple addition of a partition between the two beds yielded an immediate benefit, providing a physical barrier that limited the transfer of infection between the two areas. As a low-cost intervention, this could prove beneficial in resource-poor countries, although it may not be suitable for naturally ventilated environments. Combining the partition with a new ventilation system layout, comprising ceiling supply diffusers above the foot of each bed with wall-mounted extracts at the head of each bed, yielded the best results. Despite the ventilation rate remaining constant, the transfer of infectious material between the two beds was reduced by over 75 percent, representing a significantly reduced risk of cross-infection between patients. These findings were of immediate benefit to the architects redesigning the ward, who based the new ventilation system and ward layout directly on the study results. ■

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References

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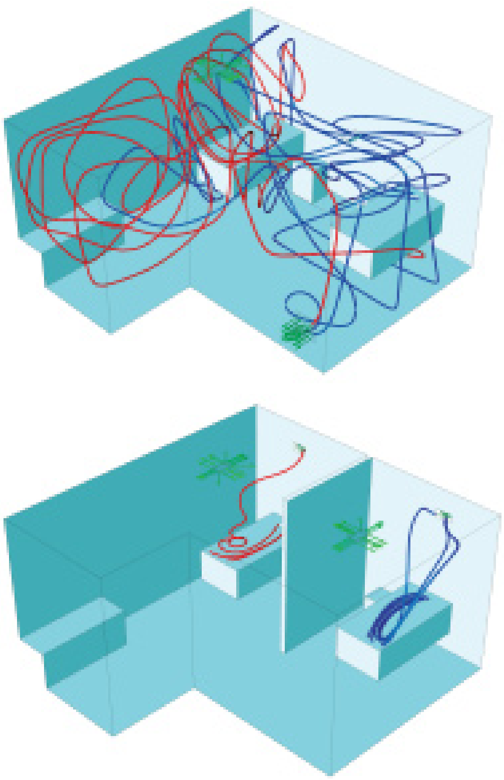
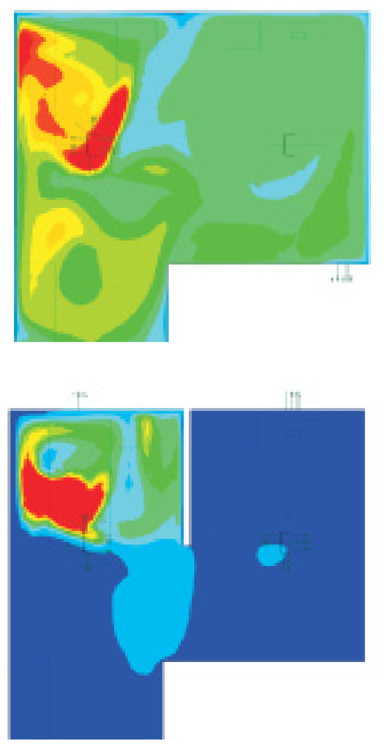


Streamlines originating from patients 1 (red) and 2 (blue) show how a partitioned room with modified ventilation system (bottom) more efficiently extracts contaminated air than the original room (top) does.



Contaminant concentration contours, at an elevation of 1.4 m above the floor originating from patient 1. The figure on the top has no partition, while the figure on the bottom uses a partition and ventilation systems local to each patient.