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Fast-track ventilation strategy to cater for pandemic patient isolation surges

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S U M M A R Y

Background: The shortage of isolation facilities in hospitals was highlighted during the severe acute respiratory syndrome (SARS) pandemic in 2003. Yet, as the nature and scale of future pandemics cannot be adequately estimated, it is difficult to justify construction of sufficient isolation facilities. A fast-track and cost-effective ventilation strategy for the retrofitting of existing general wards could help hospitals deal with patient surges.
Aim: This article reviews the effectiveness of a fast-track, makeshift isolation approach employed during the SARS outbreak which involved installing simple window-mounted exhaust fans to create negative-pressure airflow in hospital general wards.
Methods: Computational fluid dynamics (CFD) was used to assess by simulation whether the approach adopted meets US Centers for Disease and Control and Prevention requirements for properly constructed isolation wards.
Findings: CFD simulation revealed that this makeshift approach could match the ventilation standards of isolation rooms. The approach was certainly effective as no secondary infections were reported in hospitals that used it during SARS.
Conclusions: When there is a shortfall in isolation facilities to accommodate a surge in patients, the proposed ventilation set-up could be quickly and widely implemented by existing general wards.

Introduction

Hospitals in many countries found it difficult to handle the large numbers of patients requiring isolation during the severe acute respiratory syndrome (SARS) outbreak in 2003.[1] General wards were not equipped with the necessary air-control environment to isolate such a widespread infection.[2,3] The nature and scale of future potential pandemics is always difficult to predict, as is the capacity of the required isolation rooms.[4] Isolation facilities are costly to build, consume more energy, disrupt smooth operations due to their segregated physical design and occupy valuable hospital space. Nevertheless pandemic outbreaks can reach magnitudes that exceed the maximum capacity of available isolation rooms.[5,6] The challenge for hospitals is to develop adequate surge capacity to isolate known patients or those likely to be infectious by the airborne route in case of an outbreak.

During the SARS outbreak a simple and cost-effective method for constructing isolation rooms was developed whereby makeshift facilities were created in general wards by

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Figure 1. Installation of a window-mounted exhaust fan in a hospital ward. (Reprinted by permission from Annals, Academy of Science Singapore: Dessmon YH Tai, SARS: How to Manage Future Outbreaks? *Annals, Academy of Medicine*, 2006; **35**: 368—373.)

installing two high-speed, window-mounted exhaust fans in the cubicles to create negative-pressure air flows.[7,8] A number of countries reported the success of makeshift isolation rooms in preventing cross-infection.[9,10]

Ventilation requirements for isolation rooms as specified by the US Centers for Disease and Control Prevention (CDC) are 'To introduce high air ventilation rates for better dilution efficiency' and 'To create pressure gradient to prevent air flowing from less clean to clean areas'.[11] This paper reports the use of computational fluid dynamics (CFD) to validate whether the makeshift set-up used during SARS could meet these requirements.

Methods

Makeshift isolation strategy

Various countries adopted makeshift arrangements to cater for the influx of patients requiring isolation during SARS.[12—18] The set-up employed in Hong Kong consisted of two window-mounted exhaust fans located high on either side of the external window, delivering more than 12 air changes per hour (Figures 1 and 2).[19] All windows in the general ward were closed and the ward door was opened. Airflow was directed from the cleaner ward corridor into the ward cubicle and then exhausted outside such that there was little chance of pathogen-laden air flowing into the corridor and other indoor hospital areas.[12—18]

Computational fluid dynamics (CFD) analysis

CFD analyses fluid-flow problems based on mathematical equations known as Navier—Stokes equations.[20] By solving these equations with defined boundary conditions it is possible to calculate air movement and predict temperatures and particulate migration in any indoor or outdoor environment.[21] These equations are partial differential equations that cannot easily be resolved through analytical means. The numerous iterations required to linearize these equations in CFD involve substantial computer time and memory but CFD has gained popularity as computer technologies have advanced. Results can be presented as three-dimensional colour illustrations covering many types of engineering fluid-flow problems and heat transfers.[21]

CFD has been used to investigate the ventilation performance of operating room contamination control strategies; to examine surgical suite ventilation systems and to identify

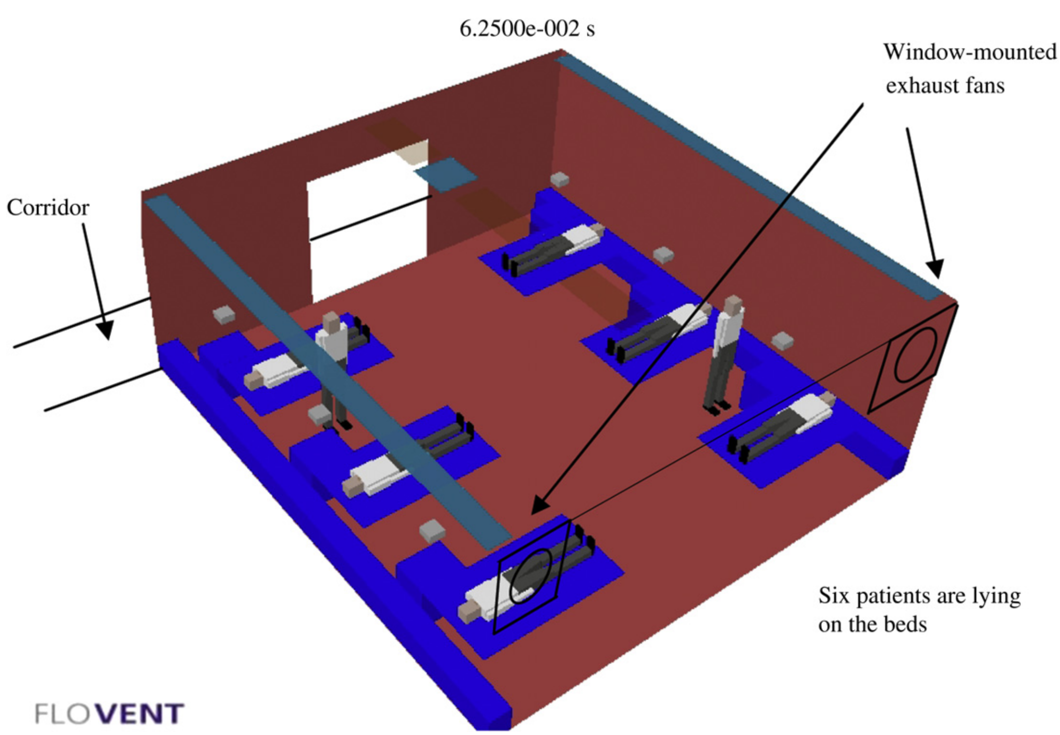

Figure 2. General ward with six patients, two healthcare workers and two window-mounted exhaust fans.