SYNOPSIS

KEY POINT SUMMARY

OBJECTIVES

The objective of this study was to develop a mathematical model to quantify the contamination of healthcare workers' hands from surfaces in different patient rooms.

Modeling environmental contamination in hospital single- and four-bed rooms

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Key Concepts/Context

Healthcare workers (HCWs) coming in contact with contaminated surfaces in patient rooms can potentially transmit pathogens from one patient to another. However, the authors contend, there is little evidence in literature to indicate the association between contact with contaminated surfaces, transmission of pathogens, and patient room design. The authors use observational study and computational fluid dynamics (CFD) simulations of bioaerosol deposition to develop a mathematical model to enable a quantitative comparison of patient room design in connection with hand contamination of HCWs. They found that the level of contamination depended on the type of care being provided, the number of contacts with the surface, and distribution of surface pathogens. They conclude that single-room designs are more effective in reducing the risk of infection.

Methods

This study involved a multidisciplinary approach. CFD simulations were used to display the patterns of spatial deposition of bioaerosals originating from an infected patient. The simulations were done for single- and four-bedded rooms in a hospital. There were eight scenarios simulated – different combinations of room type, air change rate (ACH), and infectious patient. The two room types had a ceiling-mounted supply diffuser for mechanical ventilations and a wall-mounted grille for removal of air. Patients were represented by simplified blocks. Bioaerosol release was simulated from a point 10cm above the patient's head. The CFD simulations were conducted in a high-performance facility at the University of Leeds using the software Fluent v.13.

This was preceded by an observational study of healthcare workers (HCWs) in a single-bedded room as they provided care. The care episodes were categorized into six areas, and the surfaces that the HCW touched during each episode was

DESIGN IMPLICATIONS

This study supports the design of single-patient rooms as they were seen to be more effective in reducing transmission of pathogens as compared to multi-bed rooms, where pathogens were transmitted by air to every patient bed. In the case of wards or multi-bed rooms, designers may pay particular attention to the location of patient beds in relation to air vents. Patient beds closest to the outlet vent were seen to be more contaminated than those away from the outlet vents.

identified. The sequence and frequency of each hand-to-surface contact was recorded along with performance and type of hand hygiene. Five surfaces were identified from the observations and the CFD simulation examined the deposits of aerosols on these surfaces: equipment, patient, hygiene areas, near-bed surfaces, and far-bed surfaces. It was assumed that the care was similar in both room types.

Based on the observational study and CFD simulation data, the authors developed a mathematical model, the pathogen accretion model (PAM), to quantitatively compare patient room design in connection with hand contamination of HCWs.

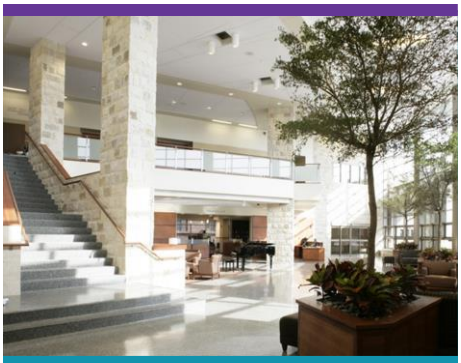
Findings

Bioaerosol deposition:

- In the case of the single-bedded room, deposits of the aerosol were seen to concentrate in the equipment areas, irrespective of the ACH.
- In the case of the four-bedded room, the concentration of the deposits was at the source and near the bed. When the source was:
    - Patient 1, some particles are deposited on every patient
    - Patient 2, the patient opposite (patient 1) got some deposits, while very few particles were deposited on the patients closer to the outlet vent
    - Patient 3, the opposite patient, (patient 4) got some deposits of the aerosol, but there are negligible deposits on patients 1 and 2
    - Patient 4, (closest to the outlet vent) there were negligible deposits on the other patients
- Ventilation rate of 6ACH exhibited a slight improvement over 4ACH with regard to deposition and spatial variation in deposits.
- Both ventilation rates and location of diffusers were relevant to the deposition and removal of airborne microorganisms.

Observational study findings:

- The probability of having contact with different surfaces ($p=0.04$) and performing hand hygiene
- ($p=0.02$) depended on the type of care provided.
- There was a statistically significant difference between the total number of times a HCW came in contact with a surface and the number of times hand hygiene was performed.



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- There were statistically significant differences in the choice of hand hygiene used.

Pathogen accretion model (PAM):

Application of this model to the eight scenarios showed:

- The positioning of an infected patient in connection with the ventilation air inlet and outlet had the most impact on deposition of particles.
- When a patient (whose neighbor was an infected patient) was located near the supply inlet, the risk of contamination was the lowest.
- When there was no obstruction between an infected patient (in a four-bedded room) and the outlet, the risk of surface contamination was the highest.

Limitations

The authors identify the following as possible limitations to the study:

- The CFD simulations did not take into consideration the movement of people.
- The CFD simulations assumed airflow to be steady.
- The size of particles in reality varied in size and were smaller and larger than the size assumed for this simulation.
- The PAM does not take into consideration temperature, humidity, and surface properties, which influence the concentration of microbes on a surface.

Other limitations of the study were regarding the observational study:

- The sample size of the participants was not mentioned.
- The duration of the observation was not mentioned.
- The number of patient rooms observed was not mentioned.

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