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Review

Evidence review of physical distancing and partition screens to reduce healthcare acquired SARS-CoV-2

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SUMMARY

We review the evidence base for two newly introduced Infection prevention and control strategies within UK hospitals. The new standard infection control precaution of 2 metres physical distancing and the use of partition screens as a means of source control of infection for SARS-CoV-2. Following review of Ovid-MEDLINE and governmental SAGE outputs there is limited evidence to support the use of 2 metres physical distancing and partition screens within healthcare.

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Introduction

The coronavirus pandemic has undoubtedly posed one of the greatest challenges to hospital infection prevention and control (IPC) teams in recent times. Surging hospital admissions combined with the novel nature of the pathogen required innovative IPC measures. This provided an opportunity to question traditional methodologies and investigate the efficacy of new mitigating measures. We have evaluated the evidence base for two new IPC measures that have been instigated within UK hospitals in an attempt to decrease hospital transmission of SARS-CoV-2. A new standard infection control precaution (SICP) of 2 metres physical distancing and the use of

partition screens in healthcare, as a means of source control when single room or isolation facilities are not available.

Methods

The results presented reflect the outputs of rapid reviews created using Ovid MEDLINE, capturing published SARS-COV-2 literature with combined appropriate key word searches, depending on the topic of interest. The full list of search terms, inclusive of dates are available in the [supplementary materials](#). In addition to peer reviewed articles, outputs from governmental SAGE (Scientific Advisory Group for Emergencies) meetings were reviewed for references and expert consensus, where appropriate this has been highlighted within the results and discussion section. For completion, searches were also

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supplemented with the use of internet search engines to identify further resources.

Results and discussion

Physical distancing

Given the intimate nature of direct care provision, there is an understanding that certain aspects of social distancing, for example working from home, are less applicable to the direct care environment. Therefore, the term physical distancing has been used in UK national IPC guidance [1]. The standard infection control precaution of physical distancing refers specifically to the actual measurable distance between two individuals while at work, within the health or other care environment. Physical distancing refers to the sole act of distancing oneself from others while at work, and does not incorporate additional measures, for example, video-conferencing or standard infection control precautions such as hand hygiene.

What physical distance should be maintained whilst working in a healthcare setting

As identified by SAGE, the highest risk of close-range transmission of SARS-CoV-2 is when someone is in face-to-face contact with an infected person while indoors [2]. A systematic search of Ovid MEDLINE from 1996 to September Week 5 2020 yielded 320 papers. Following title, abstract and full text review a single meta-analysis paper was included in this review. This meta-analysis of 29 unadjusted and 9 adjusted observational transmission studies, including SARS-CoV-2, SARS-CoV (severe acute respiratory syndrome coronavirus), and MERS (Middle East respiratory syndrome coronavirus) reported that a physical distance of more than 1 metre apart resulted in a large reduction in viral transmission when compared to direct contact, [adjusted Odds Ratio:0.18 (95% confidence interval 0.09 to 0.38) [3]. Furthermore, the risk of transmission decreased as distance beyond 1 metre increased, at 2 metres apart the risk of transmission of coronaviruses viruses was approximately half, than at 1-metre apart [3]. Although only 7 of the included studies in the meta-analysis investigated SARS-CoV-2, the association between physical distance and reduced transmission of viruses was observed irrespective of causative virus (SARS-CoV-2, SARS-CoV, MERS). WHO confirmed and probable case definitions were included within the studies used to create the meta-analysis, there was no effect modification by case definition identified with physical distance ($P_{\text{interaction}} = 0.41$) [3]. Within the meta-analysis the included studies investigated different physical distances (1.0, 1.8, and 2 metres) as the study intervention, the pooled results taken together by meta-regression, demonstrate the association between physical distance and risk of infection was stronger with increasing distance, a 2.02 change in relative risk per metre (1.08 to 3.76) was estimated [3].

This meta-analysis did not take into account the orientation of the individuals or the mechanism by which viral transmission may have occurred (direct contact, droplet, airborne) or the duration of the exposure. Furthermore, the distances examined were estimates by the authors, as many of the original studies included did not state precise distances. The dates of studies included in the meta-analysis was until May 3rd 2020.

However, a search of Ovid MEDLINE from 1996 to September Week 5 2020 (see [supplementary material](#)) did not yield any further evidence. Despite this, many of the papers included in the meta-analysis were completed in a healthcare setting and all were based in an indoor environment and therefore applicable to the health or other care setting.

The meta-analysis reported that increased distance from the source of infection reduces transmission, which would be in keeping with droplet spread infections. Acknowledging the above limitations, the results provide some evidence that a 2 metre distance reduces transmission risk compared to 1 metre.

Evidence of maintaining a 2 metre physical distance in regard to droplet/airborne transmission

In the literature, airborne infection refers to infection carried by small particles within the air, typically 5µm or less in diameter, these can also be referred to as droplet nuclei. Particles greater than 5–10µm in diameter are typically referred to as respiratory droplets. The term aerosol is used in some articles to refer specifically to droplet nuclei, while others will use it to describe a wide range of particle sizes. Within this document the term aerosol has been used as an overarching term to describe a wide range of particles of varying sizes. A systematic search of Ovid MEDLINE ([supplementary materials](#)) yielded 241 papers relating to droplet/airborne transmission and physical distance. Following title, abstract and full text review, eight papers were included in this review [4–11]. Their findings are summarised in [Table 1](#). None of the included papers were specific to SARS-CoV-2.

Liu *et al.* observed a substantial decrease in droplet nuclei exposure within 1–1.5metres distance of an infection source [8] using thermal manikin simulation. The author hypothesizes this to be a distance threshold, distinguishing two basic transmission processes, the short-range mode and the long range mode of airborne transmission. Within the short range mode, this included both conventional large droplet transmission and newly defined short range airborne transmission [8]. This is an important finding, given Kunkel *et al.* identified 90% of aerosols at 0.5 metres were <1µm in diameter using low (breathing) and high (coughing) flow rates, therefore a distance of 1–1.5 metres may significantly reduce exposure. Interestingly, Lindsley *et al.* demonstrated the impact of distance on exposure might be a function of time, where initially a physical distance of 1.83 metres decreased aerosol exposure but longer duration of exposure (>30mins) at a distance of 1.83 metres actually increased aerosol inhalation [7]. However, this was in a simulated environment without mixing airflow, which would be present in a ward/care environment, and likely reflects airflow dynamics. Although none of these studies specifically investigated SARS-CoV-2 virus and there are multiple limitations to be considered ([table 1](#)), they provide some evidence in addition to that of Chu *et al.* [3] that at a 2 metre physical distance, the risk of exposure decreases to an acceptable level, but is likely time dependant.

The use of partition screens for source control of infection

Source isolation of confirmed or suspected infected patients is a well-established infection control practice [12] and has been demonstrated to significantly decrease nosocomial spread of disease. Learning lessons from the original SARS1

Table 1
Summary of droplet/airborne transmission with respect to physical distance.

Author	Setting	Infectious agent	Sampling method	Distance (M)	Result	Limitations
Ai [4]	Simulation room with thermal manikins	Tracer gas technique	N/A	0.35, 1.0, 1.5	Time average exposure mostly decreases with an increase in separation distance, this effect was more prominent in steady state rather than short term events.	Tracer gas. Still Manikins, limited measurements, risk calculation relying on stable dosing flow rate, short term events limited to building up from background concentration.
Bischoff [5]	Human participants. Hospital ward and A&E	Influenza	Air sampling with rRT-PCR	0.30, 0.914, 1.829	Influenza virus was detected in 43% of known positive patient rooms. Exposure was mainly small particles. (diameter, <4.7 µm), with concentrations decreasing with increasing distance from the patient's head, -p value < 0.05, at 0.30 versus 1.8 metres.	All equipment removed from patients. Single time point. Assess exposure to virus rather than transmission. No asymptomatic individuals included.
Kunkel [6]	Simulation room	Bacteriophage T4	aerosol sampling, culture and qPCR	0.5, 3, 5, 7	Particle size distribution between 40-70µm. 49% of T4 DNA was extracted from 0.5µm sized particles at 0.5M and 90% from <1µm. No substantial size distribution of mass demonstrated at different locations but there was a decrease in magnitude of aerosols with increasing distance.	Surrogate organisms used. Not healthcare environment.
Lindsley [7]	Simulation air chamber	Influenza	Aerosol sampling, qPCR	0.46, 1.83	Increased distance from cough simulator to breathing simulator significantly reduced the amount of inhaled virus (P = 0.009). Analysis of longer exposure of 30mins duration, increased distance increased the overall particle inhalation	Two sizes of aerosol particles used. Uniform concentration of influenza within aerosols.
Liu [8]	simulation with thermal manikins	Tracer gas technique	Aerosol sampling. Computational fluid dynamics	0.5, 1.0, 1.5, 2.0, 3.0	Substantial increase in droplet nuclei exposure when within 1 –1.5M of infection source.	Exposure not transmission. The 1.5M threshold does not account for the cough scenario.
Savory [9]	cough test chamber using human participants	None	Particle image velocimetry	1.0	Following a cough air motion of 0.5m/s is identified at 1m away	Small sample size (12), single distance measured. Healthy volunteers without respiratory infection were studied. Particle size not studied.
Tang [10]	Human participants, simulated exposure manikins	Influenza	RT-PCR	0.1, 0.5	Failed to detect any influenza RNA landing on, or inhaled by, a life-like, human manikin target, after	Low PCR CT values in participants (visible droplets were present on the manikins after exposure). Experiment did not capture the entire exhaled breath/

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Table 1 (continued)

Author	Setting	Infectious agent	Sampling method	Distance (M)	Result	Limitations
Xie [11]	Mathematical modelling	None	N/A	0.5, 1.0, 1.5, 2.0, 2.5	<p>exposure to naturally influenza-infected volunteers.</p> <p>Particles between 60 and 100µm in size totally evaporate before falling 2M. Particles of the same size are carried more than 6 m away by exhaled air at a velocity of 50 m/s (sneezing), more than 2 m away at a velocity of 10 m/s (coughing) and less than 1 m away at a velocity of 1 m/s (breathing).</p>	<p>cough. Short exposure time and significant variability (10 seconds –15mins)</p> <p>Mathematical modelling based on multiple theoretical assumptions.</p>

outbreak, it was noted that full partitions (floor to ceiling, wall to wall) could be used to increase ante-room/side-room capacity within hospitals [13]. Seasonal influenza guidance from the CDC suggests the use of partitions as an engineering control [14]. Within international guidance on remobilisation of services and appropriate use of PPE during the SARS-CoV-2 pandemic, the use of transparent glass or plastic screens has been recommended by the CDC [15] and WHO [16] to prevent the spread of infection.

Screen composition and placement

Screens or partitions are typically composed of acrylic (plexiglass) or polycarbonate plastics, which offer greater malleability and impact resistance with less weight than glass [17]. The expectation is that the addition of a partition between bed spaces or out-patient waiting areas will reduce physical contact between individuals, reduce inhalation of infective aerosols and reduce deposition of infected aerosols on mucous membranes or high touch surfaces of adjacent individuals. Positioning is key to an effective partition, a clear requirement within industry is the dimensions of the partition should exceed the breathing zone of both users [17]. The breathing zone has been defined as a hemisphere of 30 cm extending forward in front of a patient's face and measured from a midpoint between the nose and mouth [18]. Openings in the partition should be kept to a minimum and not located within the breathing zone. Furthermore, industry practices suggest that surface mounted fixation of the partition is preferred to suspension, which could swing or waft air. While these recommendations appear logical, there seems to be a dearth of evidence supporting them.

The use of partition screens in simulated multi-bedded environments

Five papers examining the role of partitions within health-care have been included in this review [19–23], and are summarised in Table 2. Within a simulated ward environment, Noakes et al demonstrated that a physical barrier inserted between bed spaces could reduce the transmission of infection. This reduction of infection was based on the alteration of ventilation patterns and subsequent limitation of air mixing between different patient zones, thereby reducing cross contamination of airflow. The patient zone containing the outflow extractor (patient 1) demonstrated significant reduction in airflow into the adjacent patient (patient 2) zone, therefore reducing the risk of transmission of infection from patient 1 to patient 2. However, given the airflow extract remained fixed in patient zone 1, the risk of spreading infection from patient 2 to patient 1 remained similar, with and without the partition [19]. Within the same report, different scenarios were simulated encompassing modification of the ventilation system, comparison between these configurations demonstrated the impact of the bed space partition is secondary to the ventilation layout within the room [19]. King et al. used a univariate linear regression model to predict a halving of pathogen deposition per surface ($r = -0.32$, $p = 0.0254$) for patient 2 (using a partial partition, when the source of infection is patient 1) [20]. The reverse of this situation, where patient 2 is the source of infection shows no significant difference in bio-aerosol distribution with the addition of a partial partition [20]. Given the position of the air inlet remained static between experiments, it would seem the presence of the partition again

Table 2
Summary of partition use in multi-bedded bay environments.

Author	Setting	Partition	Infectious agent	Sampling method	Result
Noakes [19]	Two bedded bay	Full length vertical partition extending to the foot of bed	<i>Mycobacterium tuberculosis</i>	Computational fluid dynamics	Physical barrier inserted between bed spaces could reduce the transmission of infection, but this was dependant on the location of outflow extractor
King [20]	Two bedded bay	Plastic sheet hung between the patients bed spaces; gaps of 20 cm were left above and below the sheet (partial partition) and 80 cm at the end of the sheet from the wall	<i>Staphylococcus aureus</i>	Settle plates and computational fluid dynamics	Univariate linear regression model based on normalised deposition counts predicted a halving of pathogen deposition per surface ($r = -0.32$, $p = 0.0254$) for patient 2 (using a partial partition, when the source of infection is patient 1)
Ching [21]	Two and four bedded bay	fully extended, bed length (2.1 metre) and partial bed length (1.2 metre) curtains	Tracer gas	Computational fluid dynamics	In a two-bedded bay, without curtains, the concentration of bioaerosols on the adjacent bed was 11,503 cfu m ³ ; this reduced to 9865 cfu m ³ with partially extended curtains, and to 3782 cfu m ³ with fully extended curtains. For the four-bedded bay configuration, the results showed a similar trend for both partial and full extended curtains
Gilkeson [22]	Six bedded bay	Extended vertically from the floor to 2 feet below the ceiling and horizontally to beyond the foot of the bed	Tracer gas	Pulse injection technique	The cross ventilated partitioned ward led to a more heterogeneous tracer distribution compared with the open ward environment, but did demonstrate the ability of the partitions to effectively contain the source of infection
Nielsen [23]	Two bedded bay	Partial vertical textile partition, 10 cm opening above the floor, and 40 cm below the ceiling	Tracer gas	Calibrated multi-gas monitor and multipoint sampler	In a multitude of ventilation layouts, the partition was shown not to decrease cross infection between patients, and may increase infection exposure to simulated healthcare workers.

played a secondary role in bioaerosol deposition while room ventilation had the greatest effect. The authors hypothesise effectiveness of this partition is likely impeded by its curtain design allowing air flow above and below the partition, increasing possibility of cross contamination between patients.

In a six bedded bay, Gilkeson *et al.* demonstrated the ability of the partitions to effectively contain the source of infection [22]. However, the results did show that partitions can increase the risk of transmission of infection in oppositely partitioned patient zones [22]. Of note, when the source of infection is located close to an inlet window, within a partitioned bay, this can lead to increased exposure within the vicinity of the source and immediately downstream. In circumstances where the risk of airborne transmission is low, this risk is likely to be negligible. However, in the context SARS-CoV-2, the placement of partitions relative to suspected/infected patients within a bay requires careful consideration of ventilation. In contrast, Nielsen *et al.* showed partitions to be ineffective at reducing cross contamination between patients [23]. However, it is worth noting this simulation had a unique ventilation distribution layout, not typical of an average ward environment [23].

As highlighted, an important aspect in the use of partitions is ventilation and airflow. The WHO publication on 'natural ventilation for infection control in health-care settings' [24] stipulates that internal partitions must not restrict intended air flow paths. However, the above studies by King *et al.* and Noakes *et al.* would suggest changing the airflow is the exact mechanism by which partitions can reduce the transmission of infection; however, this needs to be taken in an individual patient/ventilation context. Morawska *et al.* has suggested that when partitions have been used to reduce SARS-CoV-2 transmission secondary measures may be needed to achieve requisite ventilation [25]. Furthermore, the addition of non-invasive equipment such as a partition into the clinical setting requires adjustment of the environmental cleaning/decontamination schedules and a risk assessment to ensure patient safety (emergency exits) is not compromised.

Conclusion

Maintaining physical distancing of 2 metres will minimise the risk of short-range transmission through droplets. There is limited evidence that a 2 metres distance is where the risk of droplet/short-range airborne transmission decreases to an acceptable level. However, the paucity of convincing reports of infection transmission beyond this distance suggest it is a pragmatically reasonable precaution. There is also limited evidence supporting the use of partitions for face-to-face interactions or between bed spaces. Studies investigating the use of partitions demonstrate that ventilation within a room plays an important role in how efficacious a partition will be. The main advantage to a partition would likely arise if the source of infection was next to the air extract, where the partition, in addition to the ventilation can further reduce infection spread. Partition decontamination is required and is a consideration for any engineering or environmental control. When considering the above interventions, it should be emphasised that an organisational approach to infection prevention is essential. This framework should encompass structures for organisational change to support clinical areas to

meet new requirements, and clear IPC leadership to ensure that multiple interventions are consistently implemented to reduce virus transmission.

Author statement

This is a working paper, and hence it represents research in progress. This paper represents the opinions of the authors, and is the product of professional research. It is not meant to represent the position or opinions of the author's affiliations or its staff members.

Credit author statement

MW, LR, JMI : Conceptualization, Methodology. CR : Data curation, Writing- Original draft preparation. MW LR, JIM: Supervision, Validation. CR JIM, LR, MW: Writing- Reviewing and Editing.

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Conflict of interest statement

No competing interests to declare.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.infpip.2021.100144>.

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