***Epidemiology and Infection***

**Probable transmission routes of the influenza virus in a nosocomial outbreak**

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**Supplementary Material**

**SI A. Parameter selection**

**Table S1.** Parameters for the multi-zone model.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Parameter** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** | **Zone 5** | **Zone 6** | **Data source** |
| **Volume (m3)** | 117.9 | 68.5 | 117.9 | 117.9 | 38.5 | 63.9 | [1] |
| **Supply airflow rate (L/s)** | 171 | 0 | 228 | 254 | 39 | 228 | [1] |
| **Exhaust airflow rate (L/s)** | 0 | 510 | 0 | 0 | 253 | 157 | [1] |
| **HEPA air purifier airflow rate (L/s)** | 346 | 0 | 450 | 363 | 0 | 0 | [1] |
| **Heat gain (kW)** | 2.310 | 0.900 | 2.310 | 2.158 | 0.506 | 0.840 | [1, 2] |

**Table S2.** Surface material types and areas.

|  |  |  |  |
| --- | --- | --- | --- |
| **Surface** | **Material type** | **Area*a* (cm2)** | **Data source** |
| Clothes | Porous surfaces | 10,000 | Assumed |
| Bed surface | 18,000 | Assumed |
| Curtains  | 1,000 | Assumed |
| Over-bed table | Non-porous surfaces | 4,800 | Assumed |
| Bedside table | 8,400 | Assumed |
| Cup | 250 | Assumed |
| Bed rail | 2,355 | Assumed |
| Water heater button | 3 | Assumed |
| Toilet door handle (outer) | Toilet surfaces | 47 | Assumed |
| Toilet door handle (inner) | 47 | Assumed |
| Toilet lid | 500 | Assumed |
| Toilet flush buttons | 3 | Assumed |
| Toilet taps | 3 | Assumed |
| Toilet sanitizer button | 3 | Assumed |
| Hand contact area | Skin | 40 | Estimated [3, 4] |
| Finger contact area | 3 | Estimated [5] |
| Non-mucosal regions of the head and neck | 1,300 | Assumed |
| Mucous membranes | Mucous membranes | 10 | Assumed [6] |

**a** Surface areas are effect areas that are commonly touched and not the actual areas.

**Table S3.** Transfer rates between surfaces of different materials.

|  |  |  |  |
| --- | --- | --- | --- |
| **Donor surface** | **Acceptor surface** | **Transfer rate** | **Data source** |
| Hand | Porous surface | 80% | [7] |
| Hand | Skin | 17% | [8] |
| Hand | Non-porous surface | 27% | [8] |
| Hand | Toilet surface | 36% | [8] |
| Hand | Mucous membranes | 34% | [9] |
| Porous surface | Hand | 3% | [10] |
| Skin | Hand | 17% | [8] |
| Non-porous surface | Hand | 29% | [8] |
| Toilet surface | Hand | 16% | [8] |
| Mucous membranes | Hand | 0% | Assumed |

**Table S4.** First-order inactivation rates at different sites.

|  |  |  |
| --- | --- | --- |
| **Site** | **Value** | **Data source** |
| In air | 0.36/h | [11, 12] |
| On porous surface | 1.78/h | [13] |
| On skin | 55/h | [12, 14] |
| On non-porous surface | 0.2/h | [15] |
| On toilet surface | 0.05/h | [16] |

**Table S5.** Virus sources at different sites of the index patient.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Sites** | **Value** | **Data source** |
| $$L\_{0}$$ | In initially expired droplets | 104–108 TCID50/mL***a*** |  [17] |
| $$L\_{s}$$ | On skin | 1.9 × 10−7$L\_{0}$ TCID50/cm2 | Estimated***b*** |
| $$L\_{p}$$ | On porous surfaces | 2.3 × 10−7$L\_{0}$ TCID50/cm2 | Estimated***b*** |
| $$L\_{np}$$ | On non-porous surfaces | 1.0 × 10−6$L\_{0}$ TCID50/cm2 | Estimated***b*** |

**a** The tissue-culture infectious dose (TCID50) is the quantity of virus required for a cytopathic effect in 50% of inoculated cultures [18].

**b** When the index patient coughed, the airborne droplets became suspended in the air and the other droplets were assumed to be uniformly deposited on a small area around him. The virus concentrations on different surfaces varied with the first-order inactivation rates of the surface materials and the largest diameter of the virus-containing droplets $d\_{g}$. Here, $d\_{g}$ was set to be 200 m.

**Table S6.** Dose–response parametersat different exposure sites.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Exposure site** | **Value** | **Data source** |
| $$α\_{m}$$ | Mucous membranes | 1.4 × 10−3/TCID50***a*** | Estimated [12] |
| $$α\_{r}$$ | Respiratory tract | 1.03/TCID50***a*** | Estimated [12] |

**a** Dose–response parameters were calculated using ID50 from Spicknall *et al.* [12] with the equation $α=ln2/ID\_{50}$[13].

**Table S7.** Behaviour frequencies

|  |  |  |  |
| --- | --- | --- | --- |
| **Behaviour** | **Executors** | **Frequency**  | **Data source** |
| Touching one’s own clothes | All agents | 3/h  | Assumed |
| Touching one’s own non-mucosal regions of head and neck | All agents | 13/h | Estimated [19] |
| Touching one’s own mucous membranes | Nurses and the health assistant | 9/h | Estimated [20] |
| Doctors | 5/h | Estimated [20] |
| Patients, visitors and cleaning staff | 16/h | Estimated [20] |
| Touching one’s own bed rails | Patients | 10/day | Assumed |
| Touching one’s own over-bed tables | Patients | 3/day | Assumed |
| Touching one’s own bed surfaces | Patients | 3/h | Assumed |
| Touching one’s own bedside table | Patients | 3/day | Assumed |
| Helping index patient fetch water | Health assistant | 2.5/day | [21] |
| Helping index patient with urination | Health assistant | 4–7/day | [22] |
| Helping index patient with defecation | Health assistant | 1/3–3/day | [23] |
| Fetching water | Normal patients | 2.5/day | [21] |
| Urination | Normal patients | 4–7/day | [22] |
| Defecation | Normal patients | 1/3–3/day | [23] |
| Visiting patients | Visitors | 1/day | Assumed |
| Medical examinations | Doctors | Beginning at 08:00 | Assumed |
| Routine rounds | Nurses | Beginning at 07:00, 11:00, 15:00, 19:00 and 23:00 ***a*** | Assumed |
| Cleaning cubicles | Cleaners | Beginning at 08:00 and 18:00 | Assumed |
| Cleaning toilets | Cleaners | After cleaning cubicles | Assumed |

**a** Nurses were assumed to take observations for every patient (such as pulse, temperature and blood pressure) every 4 h in the daytime, for a total of five times per day.

**Table S8.** Assumed sequences of touching surfaces with respect to behaviours.

|  |  |  |
| --- | --- | --- |
| **Behaviour** | **Executors** | **Assumed sequence of touching surfaces*a*** |
| Touching one’s own clothes | All agents | Clothes |
| Touching one’s own non-mucosal regions of head and neck | All agents | Non-mucosal regions of head and neck |
| Touching one’s own mucous membranes | All agents  | Mucous membranes |
| Touching one’s own bed rails | Patients | Bed rails |
| Touching one’s own over-bed tables | Patients | Over-bed tables |
| Touching one’s own bed surfaces | Patients | Bed surfaces |
| Touching one’s own bedside table | Patients | Bedside tables |
| Health assistant helping index patient fetch water | Index patient | Call bell |
| Health assistant | Cup → water heater button → water heater button → cup |
| Health assistant helping index patient with urination/defecation | Index patient | Call bell |
| Health assistant | Toilet door handle (outer) → toilet door handle (inner) → toilet lid → toilet lid → toilet flush button → toilet tap → toilet sanitizer button → toilet door handle (inner) → toilet door handle (outer) |
| Fetching water | Patients (not bed-bounded) | Bed surface → bed rails → cup → water heater button → water heater button → cup → bed rails → bed surface |
| Urination/defecation | Patients (not bed-bounded) | Bed surface → bed rails → toilet door handle (outer) → toilet door handle (inner) → toilet lid → toilet lid → toilet flush button → toilet tap → toilet sanitizer button → toilet door handle (inner) → toilet door handle (outer) → bed rails → bed surface |
| Visiting patients/medical examinations/routine rounds | Visitors/doctors/nurses | Curtains → bed rails → bed surfaces → clothes → patients’ hands → clothes → bed surfaces → bed rails → curtains  |
| Cleaning cubicles | Cleaners | Curtains → over-bed table***b*** → bedside table***b*** → curtains |
| Cleaning toilets | Cleaners | Toilet outside door handle → toilet inside door handle → toilet lid***b*** → toilet lid***b*** → toilet flush button***b*** → toilet inside door handle → toilet outside door handle |

**a** HCWs’ surface touching sequences were assumed on the basis of YouTube videos of student-focused training in health care from the Arizona Medical Training Institute (AZMTI) (<https://www.youtube.com/user/AZMTI>).

**b** Underlined text denotes surfaces cleaned by the cleaning staff.

**Table S9.** Other parameters.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Description** | **Value** | **Data source** |
| $$T$$ | Computational duration | 5 days, from 27 to 31 March 2008 | Assumed [1] |
| $$d\_{a}$$ | Largest diameter for airborne droplets | 10 m | [17, 24] |
| $$d\_{i}$$ | Largest diameter for inspirable droplets | 100 m | [17] |
| $$d\_{g}$$ | Largest diameter for virus-containing droplets | 200 m as the baseline value; 20–200 m for sensitivity analyses | Assumed [6] |
| $$p$$ | Pulmonary ventilation rate | 0.48$ m^{3}/h$ | [25] |
| $$f\_{c}$$ | Frequency of cough | 12/h | [17] |
| $$t\_{s}$$ | Temperature of supply airflow | 21.05°C | [1] |
| $$N\_{c}$$ | Number of droplets generated per incidence of cough | 2,000 | Estimated [26] |
| $$N\_{ip}$$ | Number of index patients | 1 | [1] |
| $$N\_{h}$$ | Number of health assistants | 1 | Assumed |
| $$N\_{np}$$ | Number of normal patients at one time point | 27 | Assumed [1] |
| $$N\_{v}$$ | Number of visitors | 0–3 for each patient | Assumed |
| $$N\_{d}$$ | Number of doctors | 3 | Assumed |
| $$N\_{n}$$ | Number of nurses | 3 | Assumed [27] |
| $$N\_{cs}$$ | Number of cleaning staff | 1 | Assumed |
| $$η\_{c}$$ | Surface cleaning efficiency | 80% | Assumed |
| $$P\_{w}$$ | Probability of nurses and doctors washing hands after contacting a patient | 67.3% | Estimated [28] |
| $$η\_{w}$$ | Hand-washing efficiency | 0.4 | Estimated [29] |

**SI B. Supplemental figure**



**Fig. S1** Division of the outbreak ward into six zones for multi-zone modelling. The corridor was divided into three zones.

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