Spread of Carbapenem-resistant *Enterobacteriaceae* in Intensive Care Unit and effective preventative strategies: Agent based model study

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BACKGROUND

- Carbaepenem-resistant *Enterbacteriaceae* (CRE) could propagate through contaminated hands of staff or environment, or the use of contaminated medical equipment and cause healthcare associated infections (HAIs).
- Critically ill patients in a compact space of intensive care unit (ICU) are at significantly high risk of CRE infection, which should be protected by effective infection control strategies. Agent based model (ABM) has been employed to examine the spread of infectious organisms and estimate the impact of intervention as it reflects behaviors of heterogeneous individuals.

OBJECTIVES

- To create an ABM reflecting the medical ICU to simulate the transmission of CRE.
- To identify effective preventative strategies to reduce CRE infection in the ICU.

METHODS

This study is conducted in a 2700-bed tertiary teaching hospital in Republic of Korea. Researchers had a meeting with the head staffs to get direct information and the blueprint of the medical ICU was obtained. Medical ICU consists of two units, and each unit holds fifteen beds. Five nurses work in each unit and six doctors and three technicians take rounds daily, contacting patients in the ICU. Healthcare workers (HCWs) are required to perform hand hygiene and wear disposable gowns and gloves before meeting a patient in ICU (pre-emptive contact precaution). We did a survey to collect data of the daily movement of HCWs and real hand hygiene rates of HCWs. An ABM was made using Python's Mesa library which simulates the situation in the ICU and the status of people carrying CRE. Probability of CRE transmission and isolation factor were calibrated by the real world data.

Figure 1. (A) Blueprint of ICU in Severance Hospital, (B) Simulated ICU in agent-based model

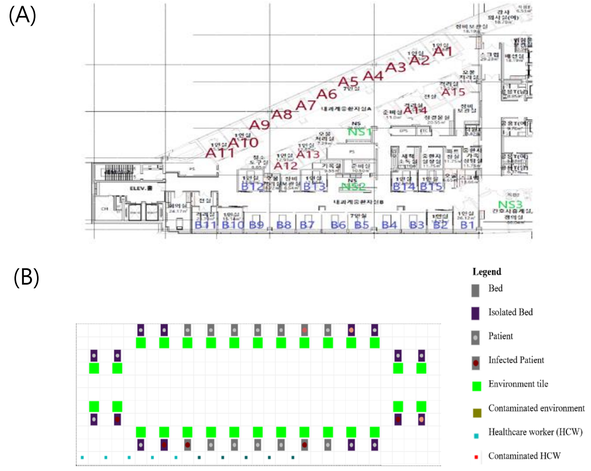
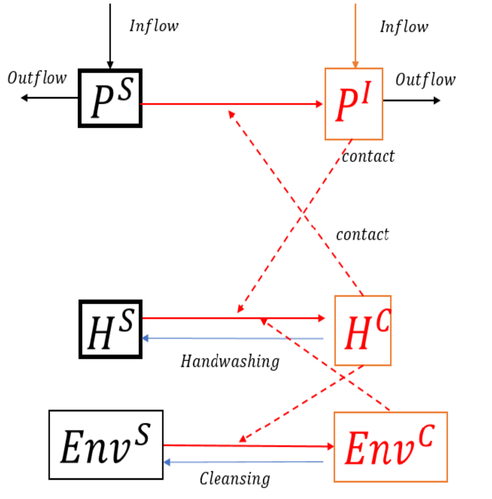


Figure 2. Dynamics between agents and environment



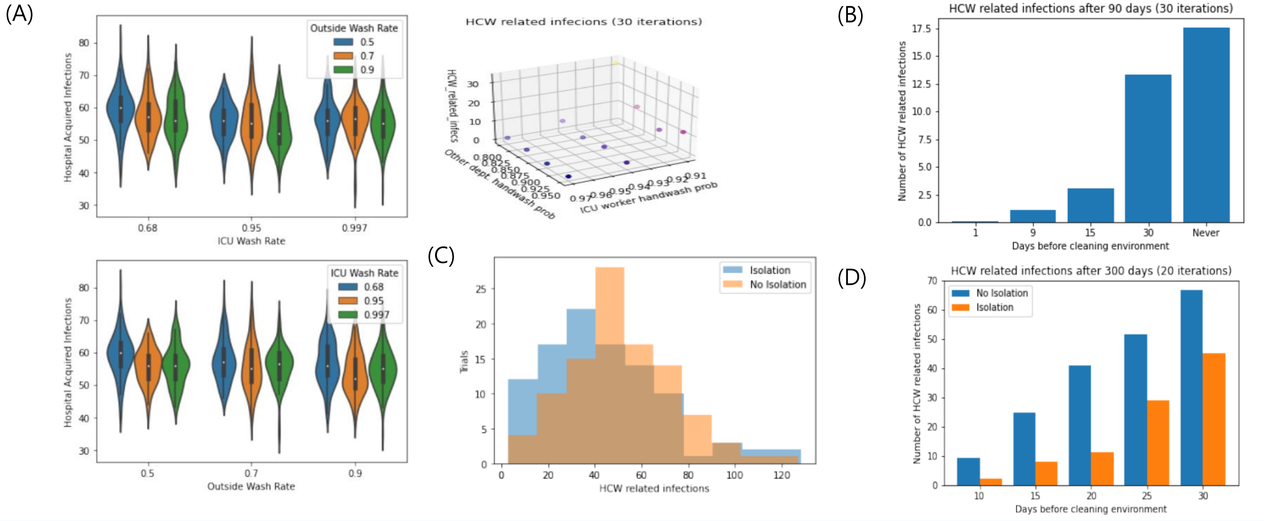
RESULTS

The dynamics among patients, HCWs and environment were constructed. Parameters were set up from the real data. At any given moment, there are about 2.5 patients infected with CRE, and transmission probability and isolation factors were calibrated according to this target. Interventions were enhanced environmental cleansing, hand hygiene rates of HCWs, and prompt isolation of infected patients through tests and actions. We found those interventions effectively reduced HAIs, and combining effects lead to better results.

Table 1. Parameters and variables in agent-based model

Parameter /Variable	Description	Value	Source
Num_HCW	Numbers of nurses/doctors/technicians	10/6/3	Meeting
Wash_ICU	Probability of ICU HCW hand washes	0.9	Survey
Wash_outside	Probability of technicians hand washes	0.9	Survey
Pr_sick	Probability of incoming patient having CRE	0.01	Data
Pr_admit	Probability of an empty bed accepts new patient	0.003	Data
Cleaning	Interval of environmental cleansing	40	Fixed
Separate_sick	Isolate sick patients	True	Fixed
Pr_transmit	Probability that CRE transmission occurs	0.0003	*Calibrated*
Iso_factor	Protective effect of CRE transmission in an isolated bed	0.75	*Calibrated*

Figure 3. Healthcare associated infections in study periods according to (A), HCWs hand hygiene, (B) interval of environmental cleansing, (C) isolation of infected patients, (D) combined of environmental cleansing and patient isolation



CONCLUSION

- Enhanced hand hygiene rates, frequent environmental cleansing, and prompt isolation of infected patients have drastic effects of reducing HAIs caused by CRE in this model. Bundle approaches should be considered to prevent the spread of CRE.