American Journal of Infection Control ■■ (2017) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

AJIC American Journal of Infection Control

Major Article

The influence of spatial configuration on the frequency of use of hand sanitizing stations in health care environments

Jun Rong Jeffrey Neo MS *, Rana Sagha-Zadeh PhD

Design and Environmental Analysis, Cornell University, Ithaca, NY

Key Words:
Hand hygiene
Space syntax
Health care-associated infection
Health care quality

Background: The lack of user-friendly, accessible, and visible hand sanitizing stations (HSSs) in health care environments are significant factors affecting low hand hygiene compliance rates among caregivers.
Objective: To determine whether the simulated parameters of visibility and global traffic flow score for an HSS can influence the frequency of use of that HSS.
Methods: Space syntax was used to measure virtual simulation of spatial layouts of 3 units to provide quantitative visibility and global traffic flow scores for each HSS. The frequency of use of HSSs was measured for 2 weeks in 3 units in a community hospital through electronic tracking with self-developed motion sensors. Behavioral observations were also conducted during the same period to validate hand hygiene data obtained through electronic tracking. Linear models were used to tests how much variance in use is accounted for when visibility and/or global traffic flow are included in the model.
Results: When the visibility score for an HSS increases (decrease), frequency of use of the HSS will increase (decrease) (F [5, 65] = 13.877; $P < .001$). When the global traffic flow score for an HSS increases (decrease), frequency of use of the HSS will increase (decrease) (F [5, 65] = 13.877; $P < .001$).
Conclusions: This study proposed and validated a novel approach of using space syntax simulations to predict and optimize hand hygiene behavior.

Health care-associated infections (HAIs) affect more than 1.7 million individuals annually,[1] and cost the US economy approximately $8.2 billion.[2] Although various factors contribute to HAIs, contact transmission via the hands of clinical staff is the key pathway.[3] Hand hygiene compliance (HHC) with alcohol-based handrub or soap and water is considered the top infection-prevention measure to reduce pathogen transmission in health care environments.[4] However, achieving high levels of HHC has been a challenge.[5] Some studies indicate that even small improvements in HHC can reduce HAI rates.[6]

The absence of user-friendly or intuitive facilities and resources,[7] or low accessibility and visibility of hand hygiene (HH) supplies are key barriers believed to account for low HHC, making it difficult for caregivers to follow HH procedures.[8] Several studies indicate that the frequency of HHC was increased by improving the accessibility and visibility of hand sanitizing stations (HSSs).[7] Further, infection prevention guidelines, including those by the Centers for Disease Control and Prevention and World Health Organization, recommend the allocation of HSSs in locations with high visibility and accessibility.[6,9] However, when it comes to spatial allocation of HSSs, there is currently no systematic method to guide the decision-making process.

Currently, deciding where to place HSSs in hospitals is mainly intuitive and experiential. In 2013, a study by Western Michigan University proposed a theoretical framework for a 2-stage method for the optimal placement of HSSs: determine optimal locations customized to clinical units' specific layouts and workflows and select optimal HSS locations.[10] However, to date, no automated systematic process exists to identify the workflow path to highlight optimal locations or evaluate the effectiveness of HSS placement to accommodate and adapt to constant shifts in staff workflow processes, supplies, and facility functions. The existing research has mainly utilized methods such as behavioral observations and workflow diagrams to decode the movement flow and identify the most accessible and visible locations and is lacking in quantitative or analytical approaches. The main objective of this study was to propose a foundation for developing a quantitative and automated approach to optimize the allocation and placement of HSSs

* Address correspondence to Jun Rong Jeffrey Neo, MS, Design and Environmental Analysis, Martha Van Rensselaer Hall 4235, Cornell University, Ithaca, NY 14850.
E-mail address: jn458@cornell.edu (J.R.J. Neo).
Supported by American Academy of Healthcare Interior Designers & Steelcase Fellowship Grant, Cornell University Human Ecology Alumni Association Student Grant, and Cornell University Department of Design and Environmental Analysis Thesis Grant.
Conflicts of interest: None to report.

0196-6553/
http://dx.doi.org/10.1016/j.ajic.2017.01.033

for application in health care facilities, with the goal of maximizing adherence to HHC by environmental system design. Also, this study examined the relationship between proposed simulated values of visibility and global traffic flow based on spatial configuration and the placement of HSSs in 3 inpatient units of a community hospital and the actual frequency of the use of HSSs. By testing each of the following hypotheses, we hoped to determine whether or not the parameters of the proposed computerized assessment characterizing the spatial structure of a hospital nursing unit (visibility and global traffic flow) will predict the use of HSSs.

Hypothesis 1: When both simulated parameters of visibility and global traffic flow score for a hand sanitizing station increase (decrease), the frequency of use of HSSs will increase (decrease).

Hypothesis 2: When the simulated parameter of visibility score for an HSS increases (decreases), the frequency of use of HSSs will increase (decrease).

Hypothesis 3: When the simulated parameter of global traffic flow score for an HSS increases (decreases), the frequency of use of HSSs will increase (decrease).

Findings from this study can help to determine whether simulated spatial parameters of a unit floor plan can predict human behavior and if so, can they be used as a strategic tool to improve HHC and reduce HAI?

METHOD

Study design

This prospective cross-sectional study conducted over 2 weeks was used to test the hypothesis that spatial design as measured by computer-simulated values can predict HHC among occupants in health care environments. Visibility (independent variable 1) and global traffic flow (independent variable 2) generated from virtual simulation of spatial layouts of 3 units in a community hospital were attribute variables measured with space syntax. An attribute variable is a variable that can be measured as a given characteristic of a floor layout, but not manipulated. The frequency of use of HSSs (dependent variable) for any occupants, including caregivers, families and visitors, and patients, were measured via electronic tracking. The 3 units (cardiac intensive care, medical-palliative care, and neonatology) were chosen by convenience sampling.

Participants

The study was conducted from April 11-24, 2016, in a community hospital located in upstate New York.

Data collection

Measurement of simulated spatial layouts using space syntax

The space syntax method was used to measure simulated characteristics of the spatial layouts—quantitative visibility and global traffic flow values—for each HSS of the 3 acute care units.[11] These values indicate the simulated possibility of seeing the targeted HHS or passing it by. The spatial movement network was developed by overlaying the current location of HSS with respect to the other clinical functions on the architectural floorplans. Visibility (independent variable 1) was measured by calculating the number of spaces immediately connecting a space of origin, and global traffic flow (independent variable 2) was measured by calculating the visual distance from all spaces to all others.[11] Figures 1 and 2 provide examples of visibility and global traffic flow calculations.

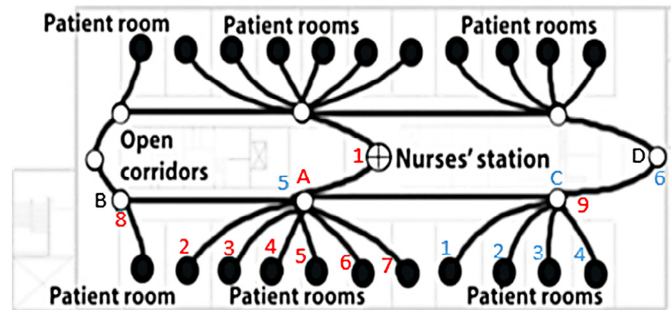

Fig 1. Visibility score of corridors. Corridor A score = 9 and corridor C score = 4.

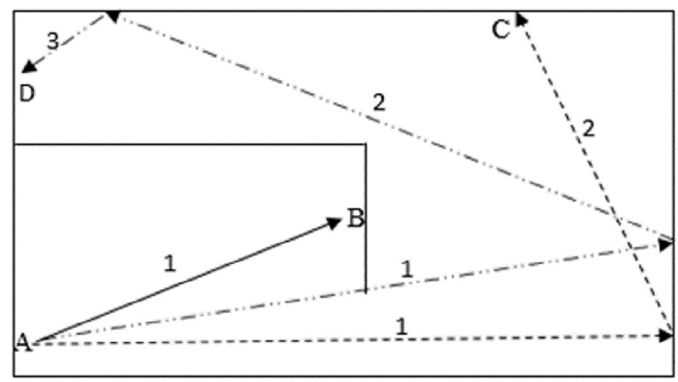

Fig 2. Determination of visual integration. Calculation of average traffic flow score from point A to points B (1), C (2), and D (3) = (1 + 2 + 3) / 3 = 2.

Electronic tracking of the frequency of use of HSSs

The frequency of use of HSSs (dependent variable) was measured from April 11-24, 2016, through electronic tracking with self-developed motion sensors. The motion sensors recorded data whenever a movement was detected as a user pushes the mechanical HSS to dispense soap or alcohol-based handrub. Due to the design of the motion sensors, only HH data from mechanical HSSs could be tracked. Seventy-one HSSs were chosen by convenience sample with 24 from cardiac intensive care, 23 from medical-palliative care, and 24 from neonatology. Sample rates were defined by the number of HSSs measured with electronic tracking / total number of available HSSs. The sampling rates were cardiac intensive care unit (23 / 44 [54.5%]), medical-palliative care unit (23 / 63 [36.5%]), and neonatology unit (24 / 68 [35.3%]). The criteria to select an HSS for convenience sampling were the HSS was located in a public space (eg, nurses workstation or outside a patient's room) and the HSS was of a mechanical design (instead of automated). The motion sensors were installed under the close supervision of permitted hospital staff from the Environmental Services Department. To control for variations in HH behaviors at different times of the day, electronic tracking that provided continuous and uninterrupted HH data over 2 weeks was used for this study. No anomaly trend (eg, outbreak of HAIs or flu season) was observed during the study duration.

Validation of electronic tracking via behavioral observations of the frequency of use of HHSs

Seventy-seven HSSs from the 7 units were sampled via behavioral observations; that is, observation of the frequency of use of HSSs among occupants. For each unit, the number of sampled HSSs were: cardiac intensive care unit (n = 25), medical-palliative care unit (n = 24), and neonatology unit (n = 28). Twenty hours of behavioral observations were conducted for each unit. To be sampled