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The Effect of Alcohol Dispenser Visibility on Hand Hygiene Compliance in Intensive Care Units

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B.A., University of Chicago, 2015

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An abstract of

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Abstract

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By Holly Kassner

Our study analyzed whether intensive care units (ICUs) rooms with hand hygiene (HH) dispensers with higher visibility on entry and exit will have higher levels of HH compliance than those with lower visibility. Additionally we tested whether individual feedback or immediate voice feedback systems would increase HH compliance relative to HH dispenser visibility. The study population was comprised of healthcare workers (HCWs) (n=276) working in hospital ICUs (n=5) between October and December 2017 with a total of 68 individual rooms and 204,085 observations. HH was measured using Bluetooth sensors on dispensers and HCW badges and worked on proximity for entry and exit. The rooms were ranked based on the visibility of their dispensers on room entry and exit and then grouped into high, medium, and low ranks at near-tertiles. The overall compliance level without interventions was 39.17%, with low visibility ranked rooms at 35.55%, medium visibility ranked rooms at 45.04%, and high visibility ranked rooms at 32.34%. After controlling for shift, HCW type, isolation precautions, and intervention interaction using multivariate analysis, rooms with low scores of visibility were more likely to have lower odds of compliance (adjusted odds ratio OR 0.81, 95% CI (0.79, 0.83)) than rooms with high visibility (aOR 0.72, 95% CI (0.70, 0.74)). The referent group of medium ranked rooms was still the highest of the three tiers of ranks in comparison. HCWs had 1.41 (95% CI (1.39, 1.44)) times higher adjusted odds of performing HH after receiving immediate voice feedback and 1.19 (95% CI (1.17, 1.21)) higher adjusted odds with individual feedback compared with no intervention. Interaction odds ratios between the different interventions and room visibility indicated that rooms with high visibility benefited more from individual feedback (aOR 1.44 95% CI (1.39, 1.49)) than rooms with low visibility (aOR 1.19 95% CI (1.16, 1.23)), whereas there was no difference in effect by voice feedback. Our findings suggest that interventions such as individualized records of compliance and immediate voice feedback increase the level of HH compliance in ICU units even if visibility levels of the dispensers remain poor.

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Background

Healthcare-associated infections (HAIs) are a major source of morbidity, mortality, and hospital expenses, with an estimated 721,800 infections per year in acute care hospitals in the United States and as many as 1 in 25 inpatients acquiring an HAI during their stay (1). HAIs are preventable with proper implementation of infection control techniques such as basic hand hygiene (HH) and wearing appropriate personal protective equipment (PPE). However, despite the evidence for HH's efficacy in preventing infections, basic compliance for healthcare workers (HCWs) is very low, averaging around 40% in many hospitals (2). A recent systematic review reported many efforts to increase HH compliance using various feedback techniques with varying degrees of success, and only moderate improvements to long-term compliance levels (3).

One method of studying human behavior and interactions with objects is spatial syntax. Spatial syntax has been used in healthcare settings to plan wards with ideal patient visibility to nurses while considering patient privacy in order to promote better care and increase patient satisfaction (4). Placing alcohol dispensers in specific locations in and around each hospital room using spatial syntax as a guide may make it easier for HCWs to remember to perform HH, due to the dispensers being in their line of sight when entering and exiting the room. Additionally, certain location characteristics may make it more convenient to perform HH due to the workflow route the HCW would take to care for the patient, increasing not only room entry and exit compliance, but potentially compliance to the World Health Organization's (WHO) Five Moments of HH: "before touching a patient, before clean/aseptic procedures, after body fluid exposure/risk, after touching a patient, and after touching patient surroundings" (5).

Several studies have researched spatial syntax in hospital environments and the effects on HH of sink or dispenser placement in hospitals (6). Since visibility of the dispensers may be important in higher HH compliance levels, one study used visual cues with flashing lights to focus attention on the dispensers at a hospital entrance (7). Another study focused on the usability of the dispensers by issuing an agreed upon usability score that included visibility to each dispenser to compare their use (8). However, studies are often limited by their methods of data collection as a result of small numbers of observations, of monitors who may be limited in their accuracy by Hawthorne effect among participants or observational bias where compliance may be increased due to the observation, or of being limited to hospital entrances or corridors rather than inside patient rooms (9).

Studies have also addressed HH compliance levels in regards to the time of day or fatigue through work shifts, which showed a decrease in HH compliance nearing the end of shifts and during the night shift (10). Other non-HH-related studies have shown that decision fatigue can impact antibiotic prescriptions in hospitals by doctors over the course of the workday, increasing the number of prescriptions filled during later hours of their shifts (11). Studying the effect of clear visibility and location of the HH dispensers may show differing compliance levels over a workday.

Personal protective equipment (PPE) such as disposable gloves, gowns, and masks, is very important in preventing the spread of HAIs in hospitals. Full HH compliance for isolation precautions requires HH performed before the donning of disposable gloves and after their doffing in addition to wearing disposable gowns for contact precautions and masks or N-95 respirators for droplet and airborne precautions.

For *Clostrium difficile* contact precautions, alcohol-based HH is performed before donning gloves on room entry, and soap and water HH performed after patient contact on exit. However, isolation precautions are often associated with lower levels of HH compliance due to misconceptions about the steps required for full HH and PPE compliance or inconvenience caused by the steps involved (12). To increase this compliance, one study has shown that more visibly placed sinks in a surgical transplant unit were associated with a higher compliance for *Clostrium difficile* contact precautions (13).

Differences in HH compliance by types of HCWs have also been studied in the literature. One study has shown a marked difference between the average HH compliance between nurses and physicians in that nurses were 1.5 times more likely than physicians to be compliant (14). Another study also showed a similar result for nurses' higher levels of HH compliance compared to physicians and other allied health professionals (15).

The Prevention Epicenter of Atlanta and Consortium Hospitals (PEACH) HH Study (16) used Bluetooth technology to electronically monitor participating HCW HH compliance on entry and exit to patient rooms. The study used different types of interventions to determine which is the most useful for increasing HH compliance in HCWs. The interventions included individual feedback where the individual HCW privately received their HH compliance level at the end of each week. Immediate voice feedback is where an individual is notified by the Bluetooth system's speakers on the dispenser with a voice recording of "please perform hand hygiene" when they do not perform HH after 5 seconds of entering or exiting a room. To address the gaps in the

literature, I used data from the PEACH study for a secondary analysis of HH compliance by room dispenser visibility. The methods from this large study limit potential observation bias, standardize the collection and measurement of data, and provide a vast amount of observations for each room, enabling higher precision. In addition, analyzing the visibility ranking system in addition to HH individual or voice interventions will provide information about the differences in usefulness of each intervention.

Methods

Hypothesis and Study Questions: We believe that HH dispensers with higher visibility will be used more frequently than those with lower visibility. The overall compliance level for a room with more visible dispensers will be higher than a room with less visible dispensers where compliance is defined as whether or not a HCW used the dispenser for HH (dichotomous). Additionally we believe that the voice feedback phase of the study will increase the level of compliance for rooms and healthcare workers and that low dispenser visibility (with predicted low compliance) can be overcome by this voice feedback system.

Study Population: The data is from the PEACH HH study performed at Emory University Hospital Midtown between October 1st, 2017 and December 31st 2017, incorporating 5 ICUs, 68 rooms, and 276 healthcare worker participants. HCW type was grouped into nurses, physicians, nurse techs, therapy (physical therapy and respiratory), administrators, unit administrators, and other (X-ray technicians, pharmacists, phlebotomists).

Data Collection: The data collected on HH compliance by HCWs is taken from the Prevention Epicenter of Atlanta and Consortium Hospitals (PEACH) HH Study that uses Bluetooth technology to electronically monitor participating HCW HH compliance on entry and exit to patient rooms. Bluetooth sensors were attached to HH alcohol dispensers and participating HCW's badges. When a HCW came into close proximity with a dispenser and used it, a HH observation was recorded as compliant. If a HCW passed a proximity threshold without activating the sensor on the dispenser, the HH observation was recorded as noncompliant.

The data in this study is a subset of the data from several phases of this larger study that investigated methods of feedback on HH compliance. This study and the survey for the visibility ranking system were approved by the Emory IRB board (Protocols IRB00086420 and IRB00099962). All participants consented to be included in the study with de-identified information.

The first phase of the study starting in October 2017 was the control phase where all units received no feedback but HH compliance was monitored. The next phase had half the units receive individual feedback and the others received real-time voice feedback. After a washout period where the voice feedback and individual feedback were ended and no observations were recorded, the units switched interventions (e.g. voice feedback to individual feedback or individual feedback to voice feedback) and HH compliance was monitored again.

Visibility Ranking System: To create the alcohol dispenser visibility ranking system we first administered a short survey using photos of patient rooms and the location of the HH dispenser in order to obtain consensus on what elements of location and usability (i.e. visibility, accessibility, and workflow path) were most important to HCWs. We used sampled a pool of individual HCWs employed by Emory Healthcare and students affiliated with Emory University and Emory Healthcare to complete the ranking survey (Appendix A), some of whom have been previously engaged with hospital HH activities including the PEACH study (n=18/49, 36.7% participation). For analysis we used Delphi consensus with an *a priori* consensus and exclusion criteria of 80% to identify the most important attribute. The element of "visibility" was the most agreed upon element of the survey with a standard deviation of 1.48, followed by accessibility (1.51), and workflow

path (1.71) and therefore was chosen to be the key element for the ranking system. Additionally, since the workflow path for nurses may differ from that of doctors or other HCWs, a standardized element of "workflow path" would not have been possible.

A group of 4 members of the HH team independently ranked the visibility of the dispensers both on room entry and room exit on a 5-point scale with 5 being best visibility and 1 being not visible. Using the %MAGREE SAS macro (30), we calculated the kappa coefficient for inter-rater reliability of the ranks as $\kappa = 0.715$ ($p<0.0001$), which corresponds to substantial agreement between our raters. We took the average of the scores on the 5-point scale to assign the ranks of visibility for each room. The ranking scores of visibility were divided into three groups (low, medium, and high visibility) with cut points for these groups chosen near the tertiles to allow for a balance in each category due to 14 units having the score 3.625. Low rank had scores that were between 1.175 and 2.875. Medium rank had scores between 3 and 3.625. High rank had scores between 3.75 and 4.75.

Descriptive analysis: We calculated HH compliance by dispenser visibility rank, by unit, HCW type, work shift, room isolation status, and intervention (individual feedback, voice feedback, none). HCW type was grouped into nurses, physicians, nurse techs, therapy (physical therapy and respiratory), administrators, unit administrators, and other (X-ray technicians, pharmacists, phlebotomists). Work shift was defined as the day shift (7am to 7pm) and the night shift (7pm to 7am). Isolation status was defined by "none," "*Clostrium difficile* precautions" (disposable gloves and gowns, and HH performed with alcohol rub on entry, soap and water on exit), and "isolation precautions" (disposable gloves, gowns and/or masks, and HH using alcohol rub before donning and after doffing).

Isolation status for the room was collected based on individual patient precaution needs programmed from the electronic clinical surveillance system TheraDoc and updated daily, which is how it was captured for analysis (#34).

Analysis: All analyses were conducted in SAS 9.4 (SAS Institute Inc, Cary, NC.). Logistic regression was performed to compare the association of HH compliance with room dispenser visibility ranking. We controlled for shift (day shift and night shift), type of HCW, and room isolation status. The phases used for this analysis were the control phase, where there were no interventions, and both intervention phases of the study, where there was either individual feedback or voice feedback, to determine whether the feedback interventions could overcome a low ranking for the room HH dispenser visibility. The Breslow Day test was performed to test for interaction between dispenser visibility rank and intervention type in addition to assessing differences in unadjusted frequencies between the types of interventions.

Results

The scores of the ranking system ranged from 1.175 to 4.75 with the mean score of 3.205 and the mode score 3.25. Unit 71 ICU had the most variation in scores (range 3.575, standard deviation 1.028) and Unit PICU had the least variation in scores and most standardized room layouts (range 0.375, standard deviation 0.117). The full distribution of the scores is shown in Table 1 as well as a map of the unit rooms and their individual scores in the Appendix B. The distribution of room visibility ranks by unit was quite wide as shown in Figures 2-6. Unit 11 ICU and PICU had extremely tight distribution of values while Units 31 ICU, 41 ICU, and notably 71 ICU had wide distributions due to less standardized layouts of the older units. Unit 11 ICU had ranks mostly in the medium range and PICU had ranks in the low range while 31 ICU and 41 ICU straddled multiple ranges including high visibility. There was no obvious relation between mean compliance and room visibility rank, as shown in Figure 1. Correlation between room visibility rank and mean HH compliance was not statistically significant ($\rho = .01$, $p=0.9795$).

There were 203,985 total observations. Nurses made up the majority of the observations (37,116 observations 78.73%) and almost half the observations were from Unit 71 ICU (22,558 observations, 47.85%), partly due to being a larger ICU with 20 rooms rather than the standard 12. The overall average level of compliance was 53.33% (Table 1). On average across all intervention phases, HH compliance for low visibility ranked rooms was 52.46%, for medium visibility ranked rooms was 55.94%, and for high visibility ranked rooms it was 49.84% (Table 2). Nurses had an average HH compliance of 53.76%, physicians had 54.39%, nurse techs had 49.24%, unit administrators had 34.23%, administrators had 54.71%, therapists had 52.56%, and other HCWs had

65.12%. As shown in Table 2, Unit 31 ICU had the highest level of compliance at 62.03% and Unit 41 ICU had the lowest at 45.16%. The AM work shift (7am to 7pm) had higher levels of compliance (53.87%) than the PM work shift (7pm to 7am) (51.98%). Isolation precautions were related to higher levels of compliance with an average of 57.42% compliance compared to 53.74% compliance when no specific precautions were in place, while *Clostrium difficile* precautions only had 32.27% compliance. Compliance with no interventions was 39.17%, compliance with immediate voice feedback was 61.26%, and compliance with individual feedback was 53.8%.

As shown in Table 3, HH compliance varied between both room visibility rank and by intervention. With no interventions, low visibility ranked rooms had 35.55% compliance, medium visibility rooms had 45.04% compliance, and high visibility rooms had 32.34% compliance. With individual feedback, low visibility ranked rooms had 51.82% compliance, medium visibility rooms had 54.24% compliance, and high visibility rooms had 56.45% compliance. With immediate voice feedback, low visibility ranked rooms had 62.48% compliance, medium visibility rooms had 64.73% compliance, and high visibility rooms had 54.11% compliance.

Interaction was assessed between the visibility of the dispensers and the intervention and the impact of each intervention type was found to differ by room visibility rank category (Breslow-Day $p<0.0001$).

For logistic regression, we chose the medium visibility rank as the reference group (Table 4). The unadjusted OR for low visibility rooms was (0.94 95% CI (0.93, 0.95)) and the unadjusted OR for high visibility rooms was (0.89 95% CI (0.88, 0.89)). Room precautions for *Clostrium difficile* showed a large decrease in HH compliance

(unadjusted OR 0.60, 95% CI (0.58, 0.62)) while other isolation precautions had a small, but statistically significant increase in HH compliance across all ranks of units (unadjusted OR 1.07, 95% CI (1.05, 1.08)). With nurses as a reference group, unit administrators were less likely to be HH compliant followed by nurse techs and therapists, while physicians and administrators did not differ significantly from nurses. Additionally, the day shift time frame was associated with statistically significant higher levels of HH compliance than the night shift with an unadjusted OR of 1.04 (95% CI (1.03, 1.05)).

After adjusting for type of HCW, shift, room precautions, and intervention types, the main effects indicated that rooms with low scores of visibility were more likely to have lower levels of compliance than medium rank rooms (adjusted odds ratio (aOR) 0.81, 95% CI (0.79, 0.83)). High visibility rooms also had lower compliance than medium compliance rooms (aOR 0.72, 95% CI (0.70, 0.74)). As shown in Table 4, the referent group of medium visibility ranked rooms was still the highest of the three tiers of ranks in terms of compliance even after adjustment for other covariates and interaction.

Both types of interventions—individual feedback and immediate voice feedback— were associated with significant increased main effects of HH compliance. After adjusting for all factors, HCWs had 1.41 (95% CI (1.39, 1.44)) times higher odds of performing HH after receiving immediate voice feedback and 1.19 (95% CI (1.17, 1.21)) higher odds with individual feedback compared with no intervention.

Significant interaction was observed between the interventions by room visibility rank. In rooms with low visibility of the dispensers, the interventions worked equally

well as in medium visibility rooms (both aOR 1.19 95% CI (1.16, 1.23)). In rooms with high visibility of the dispensers, individual feedback was associated with higher levels of HH compliance (aOR 1.44 95% CI (1.39, 1.49) for individual feedback and 1.16 95% CI (1.12, 1.20) for voice feedback).

Discussion

Surprisingly at first, there was no dose-response relationship between visibility and HH compliance. Medium rank visibility scores were associated with the highest HH compliance, followed by low visibility ranks and then high visibility rank rooms. More variability in HH compliance was found with HCW type, shift, room precautions, and interventions than dispenser visibility. One explanation is that visibility may not impact HH compliance as much as having a standard location for the dispensers in each room of the units; many of the rooms with low visibility scores were in units with a very standardized layout for each room while many rooms with high visibility scores were in units with a highly variable layout and a wide distribution of individual room scores.

The other hypothesis question pertained to whether the interventions were able to overcome poor visibility ranks in the ICUs. There was variability in the effect of the interventions by room visibility rank. In rooms with low visibility, the interventions worked equally well to increase HH compliance. However in rooms with high visibility, individual feedback was associated with higher levels of HH compliance by a greater degree although immediate voice feedback remained helpful. Both interventions significantly increased HH compliance, but differed for the most effective levels by room visibility.

The non-standardized room layouts may be the root of the surprising difference between low and high visibility-ranked rooms compared to the medium visibility rooms. When tending to multiple patients in different rooms, a HCW's focus may not always be on performing HH consistently, especially if the staff to patient ratio is too low. When each room that is entered has a different layout and location of an HH dispenser, it could

be difficult to remember its location in each individual room when the layouts are extremely different. However, if the dispensers are always in the same general location (e.g. to the right of the door on entry), then a habit may be formed to automatically head towards the right upon entering the room to use the dispenser. In units where this is already standard, the knowledge of one's own compliance level and goal with the method of individual feedback may be enough for a HCW to remember to use the dispensers since they are not searching them out in every room they enter.

Our study had similar results to prior studies on HH compliance by work shift, with the night shift having lower levels of overall compliance compared to the day shift (10, 11). While HH compliance for physicians in our study did not differ significantly from nurses, unlike other studies where nurses had higher levels, nurses did have higher levels of HH compliance in our study than nurse techs and therapy workers (11). The lower levels of HH compliance with *Clostridium difficile* may be due to confusion about the appropriate methods of PPE and HH in this specialized case or the inconvenience of having to seek out different areas for HH within a familiar room; more importantly, under C. difficile precautions, HH using alcohol rub is expected only upon entry, therefore non-compliance via Bluetooth on exit might be acceptable. Higher HH compliance using alcohol dispensers was observed with general isolation precautions, indicating that awareness of patient infectious status does affect HH behavior

The average HH compliance increased from 39.17% under no intervention to 57.50% averaged between individual and immediate voice feedback interventions. The change is significant and shows that these individual feedback and real time voice interventions do impact compliance levels and can help poor dispenser placement.

Additionally, fostering a unit culture where HH is seen as important to HCWs, administrative staff, and to patients may lead HCWs to correct their coworkers and help increase HH compliance further. A recent study has shown that empowering HCWs to coach each other with both positive and negative feedback can increase HH compliance in a unit over time (17). Therefore, with these interventions and changes to unit and workplace culture, overall HH compliance may be able to be increased in ICUs.

Strengths and Limitations

Strengths: Since HH compliance was recorded via a Bluetooth badge system, this study has many advantages in data collection. There are several hundred thousand observations over a 3-month period, resulting in more accuracy and precision than prior studies that relied on human observation and were more limited in time and resources. The Bluetooth system can also capture observations during the night shift, which would be difficult to study covertly due to the lower numbers of staff during the night shift.

Additionally, because the system is electronic and incorporated a washout phase between interventions, as well as a crossover design such that all units received both interventions, this study benefits from the lack of Hawthorne effect and unit-based control by intervention. While the HCWs are aware that their badge records their compliance since they have volunteered for the study itself, it is less likely that HCWs will have their original baseline level of compliance altered from the Hawthorne effect. This study benefits from the system of data collection since human monitors would be limited in their ability to collect this amount of accurate data due to Hawthorne effect, limited resources, and the detail of each observation.

Limitations: While there are many strengths to this study, its limitations include the layout of the units not being decided upon by the study and the inability to differentiate entry and exit of each HH observation. Since several of the units had a standardized layout of each room with all or most of the room scores being in the same ranking category, the workplace and HH culture of each unit may confound the results of the visibility due to some collinearity. In some ICUs, the average level of HH compliance may be higher due to a culture of simple correction and reminders by peers already in

place that is not related to dispenser placement. The analysis does not account for clustering of HH observations based on individual HCWs, who may have similar levels of HH compliance regardless of room or by ICU. However, because the study sought to determine if the dispenser visibility in the rooms themselves could be used to increase HH compliance regardless of individuals' compliance levels the results reflect the hypotheses of interest. Adjusting for the effect of individual HCWs would be expected to reduce the variability around odds ratio without changing the measures of effect.

Additionally the room ranking system itself and the tertile cutpoints were not validated by other sources or methods. However, after testing for correlation between the room visibility rank values and compliance on a continuous scale, there was no clear pattern that would suggest better performance by using different cutpoints.

Future Directions

In conclusion, our findings suggest that interventions such as personalized records of HH compliance as well as immediate voice feedback reminders via Bluetooth increased HH compliance in ICU units, and were more strongly associated with increases in HH than room visibility rank of HH dispensers. Additionally, the effect of type of intervention differed depending on the current visibility of the location of the HH dispensers in the room. Standardizations of ICU unit layouts when building new units, such that all rooms have similar floor plans and locations of HH dispensers and sinks, may be useful to increase HH compliance by making an automatic entry and exit routine possible. When not feasible or when updating an existing hospital layout, providing clear pathways and voice feedback interventions may also help overcome barriers to higher

HH compliance. Future studies should utilize sensors and other methods that differentiate between entry and exit in order to understand HCW's behavior in these moments and where best to place dispensers for the easiest access to encourage and improve hand hygiene.

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Tables

Table 1. Total Number of Rooms of Each Room Visibility Rank, Mean Level of Compliance, and Total Hand Hygiene (HH) Compliance and Total Observations per Room Visibility Rank for All Phases of Study by Healthcare Workers at Emory University Hospital Midtown in 5 Intensive Care Units (ICU) in Atlanta, Georgia, United States, 2017

Table 1. Total Number of Rooms of Each Room Visibility Rank, Mean Level of Compliance, and Total Hand Hygiene (HH) Compliance and Total Observations per Room Visibility Rank for All Phases of Study by Healthcare Workers at Emory University Hospital Midtown in 5 Intensive Care Units (ICU) in Atlanta, Georgia, United States, 2017

	Score	# of Rooms	Mean Compliance	Observations	Total Compliance
Low Visibility Rank	1.175	1	54.04%	3,919	55.94%
	2	1	40.22%	3,456	
	2.125	3	56.90%	10,791	
	2.215	1	50.27%	3,692	
	2.25	1	41.47%	2,976	
	2.375	8	53.39%	25,362	
	2.5	4	50.52%	14,681	
	2.625	1	68.49%	2,967	
	2.875	1	50.33%	4,053	
Medium Visibility Rank	3	3	61.30%	8,352	45.04%
	3.125	6	58.08%	19,634	
	3.25	2	54.45%	5,603	
	3.375	3	59.18%	8,963	
	3.5	4	50.88%	10,043	
	3.625	14	54.23%	33,148	
High Visibility Rank	3.75	2	43.71%	3,926	32.34%
	3.875	2	52.71%	4,295	
	4.125	2	55.34%	3,795	
	4.25	1	59.91%	2,896	
	4.375	3	52.82%	10,077	
	4.5	3	47.16%	9,947	
	4.75	2	46.18%	11,409	

Table 2. Level of Hand Hygiene (HH) Compliance and Total Number of Observations by Room Score Level, Healthcare Worker (HCW) Status, Unit, Shift, Isolation Status, and Feedback Intervention by Healthcare Workers of Emory University Hospital Midtown in 5 Intensive Care Units (ICU) in Atlanta, Georgia, United States, 2017

Table 2. Level of Hand Hygiene (HH) Compliance and Total Number of Observations by Room Score Level, Healthcare Worker (HCW) Status, Unit, Shift, Isolation Status, and Feedback Intervention by Healthcare Workers of Emory University Hospital Midtown in 5 Intensive Care Units (ICU) in Atlanta, Georgia, United States, 2017

		Compliance (%)	Total Observations
Room Visibility Rank			
	Low	52.46%	71,997
	Medium	55.94%	85,743
	High	49.84%	46,345
HCW Status			
	Nurse	53.76%	162,356
	Physician	54.39%	11,366
	Nurse Tech	49.24%	14,195
	Unit Administration	34.23%	1,966
	Administration	54.71%	945
	Therapy	52.56%	11,019
	Other	65.12%	2,136
ICU			
	11 ICU	53.93%	25,772
	PICU	52.85%	38,506
	31 ICU	62.03%	44,638
	41 ICU	45.16%	27,957
	71 ICU	50.97%	67,212
Work Shift			
	PM[a]	51.98%	58,768
	AM[b]	53.87%	145,317
Room Status			
	No Precautions	53.74%	180,806
	Clostridium dificile [c]	32.27%	6,758
	Isolation[d]	57.42%	16,521
Intervention			
	None	39.17%	46,548
	Individual Feedback	61.26%	78,281
	Voice Feedback	53.80%	79,256

a 7pm-7am
b 7am-7pm
c alcohol-based HH is performed before donning gloves on room entry, and soap and water HH performed after patient contact on exit
d HH performed before the donning of disposable gloves and after their doffing in addition to wearing disposable gowns for contact precautions and masks or N-95 respirators for droplet and airborne precautions

Table 3. Level of Hand Hygiene (HH) Compliance by Room Visibility Rank and Intervention

Table 3. Level of Hand Hygiene (HH) Compliance by Room Visibility Rank and Intervention			
	Compliance (%) No Intervention	**Compliance (%) Voice Feedback**	**Compliance (%) Individual Feedback**
Room Visibility Rank			
Low	35.55%	62.48%	51.82%
Medium	45.04%	64.73%	54.24%
High	32.34%	54.11%	56.45%

Table 4. Estimated Unadjusted Odds Ratio (OR) and Adjusted Odds Ratio (aOR) for the Association Between Room Visibility Rank of Hand Hygiene (HH) Dispensers on HH Compliance for Healthcare Worker Status (HCW), Feedback Intervention, Isolation Precautions, and Shift by Healthcare Workers of Emory University Hospital Midtown in 5 Intensive Care Units (ICU) in Atlanta, Georgia, United States, 2017

Table 4. Estimated Unadjusted Odds Ratio (OR) and Adjusted Odds Ratio (aOR) for the Association Between Room Visibility Rank of Hand Hygiene (HH) Dispensers on HH Compliance for Healthcare Worker Status (HCW), Feedback Intervention, Isolation Precautions, and Shift by Healthcare Workers of Emory University Hospital Midtown in 5 Intensive Care Units (ICU) in Atlanta, Georgia, United States, 2017

		OR	95% CI[a]	aOR	95% CI
Room Visibility Rank					
	Low	0.98	(0.98, 0.99)	0.81	(0.79, 0.83)
	Medium	1.00	Referent	1.00	Referent
	High	0.95	(0.94, 0.97)	0.72	(0.70, 0.74)
HCW Status					
	Nurse	1.00	Referent	1.00	Referent
	Physician	1.01	(0.99, 1.03)	1.01	(1.00, 1.03)
	Nurse Tech	0.92	(0.90, 0.93)	0.90	(0.88, 0.91)
	Unit Administration	0.64	(0.60, 0.68)	0.63	(0.59, 0.67)
	Administration	1.02	(0.96, 1.08)	1.01	(0.96, 1.07)
	Therapy	0.98	(0.96, 1.00)	0.96	(0.94. 0.97)
	Other	1.16	(1.12, 1.20)	1.07	(1.04, 1.11)
Work Shift					
	PM [b]	1.00	Referent	1.00	Referent
	AM [c]	1.04	(1.03, 1.05)	1.05	(1.04, 1.06)
Room Status					
	No Precautions	1.00	Referent	1.00	Referent
	Clostridium dificile [d]	0.60	(0.58, 0.62)	0.66	(0.63, 0.68)
	Isolation[e]	1.07	(1.05, 1.08)	1.03	(1.02, 1.05)
Intervention					
	None	1.00	Referent	1.00	Referent
	Individual Feedback	1.22	(1.20, 1.23)	1.19	(1.17, 1.21)
	Voice Feedback	1.10	(1.10, 1.11)	1.41	(1.39, 1.44)
Interaction					
	Low Rank * Individual			1.19	(1.16, 1.23)
	Low Rank * Voice			1.19	(1.16, 1.23)
	High Rank * Individual			1.44	(1.39, 1.49)
	High Rank * Voice			1.16	(1.12, 1.20)

a 95% Confidence Interval
b 7pm-7am
c 7am-7pm
d alcohol-based HH is performed before donning gloves on room entry, and soap and water HH performed after patient contact on exit
e HH performed before the donning of disposable gloves and after their doffing in addition to wearing disposable gowns for contact precautions and masks or N-95 respirators for droplet and airborne precautions

Figures

Figure 1. Graph of Mean HH Compliance by Room Visibility Rank

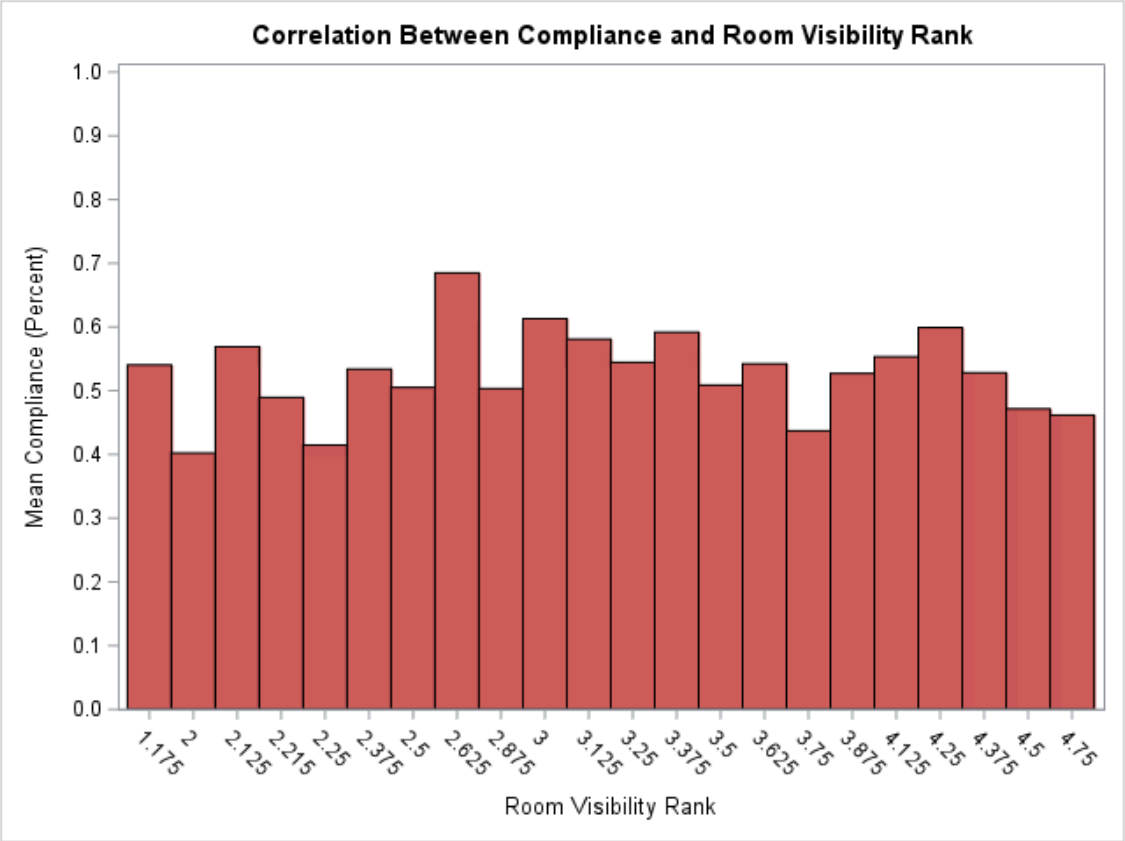


Figure 2. Variability of Room Visibility Rank Scores for Unit 11 ICU With 12 Rooms.

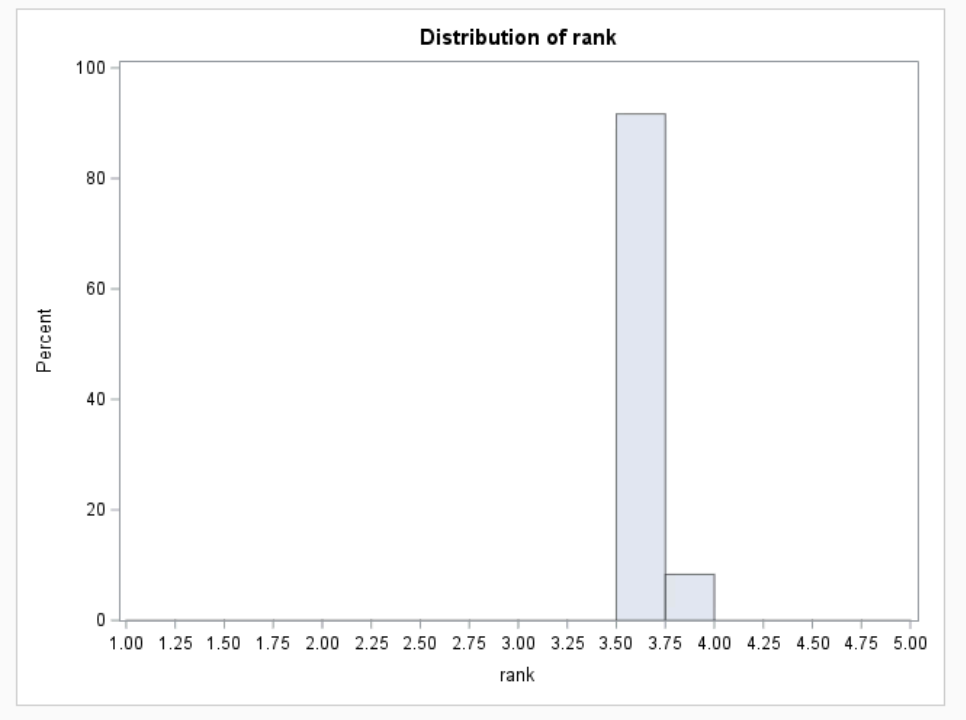


Figure 3. Variability of Room Visibility Rank Scores for Unit PICU With 12 Rooms.

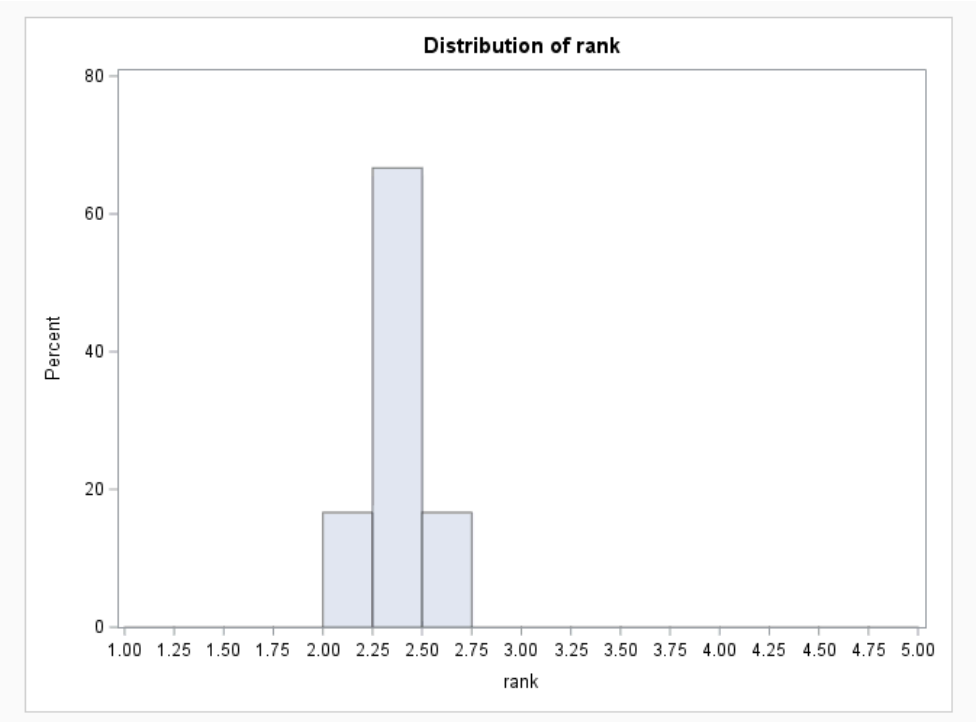


Figure 4. Variability of Room Visibility Rank Scores for Unit 31 ICU With 12 Rooms.

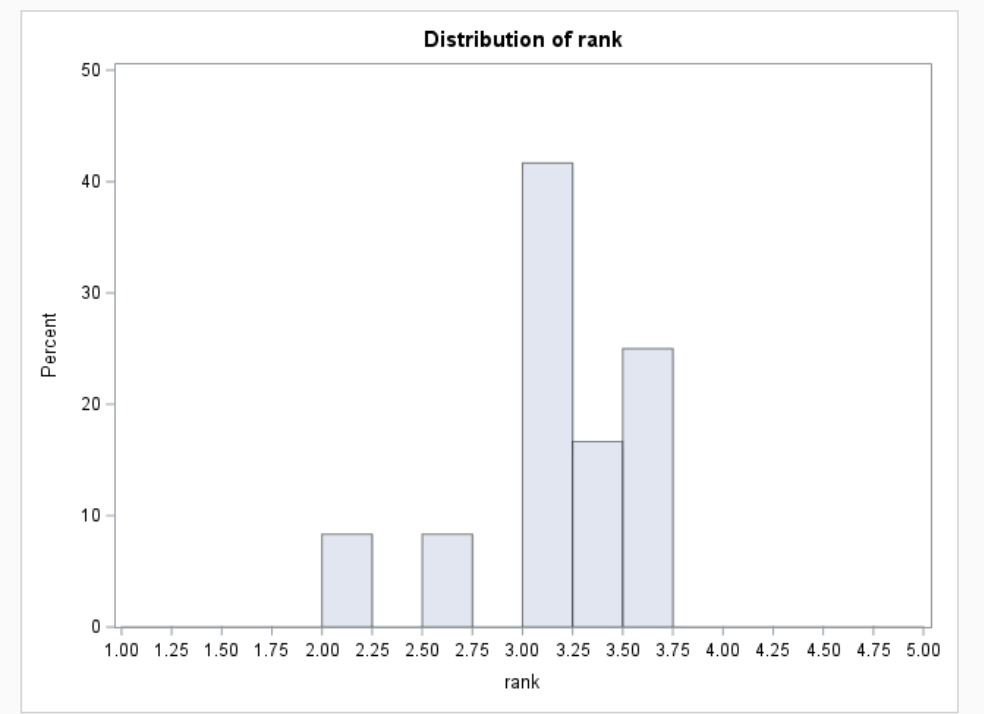


Figure 5. Variability of Room Visibility Rank Scores for Unit 41 ICU With 12 Rooms.

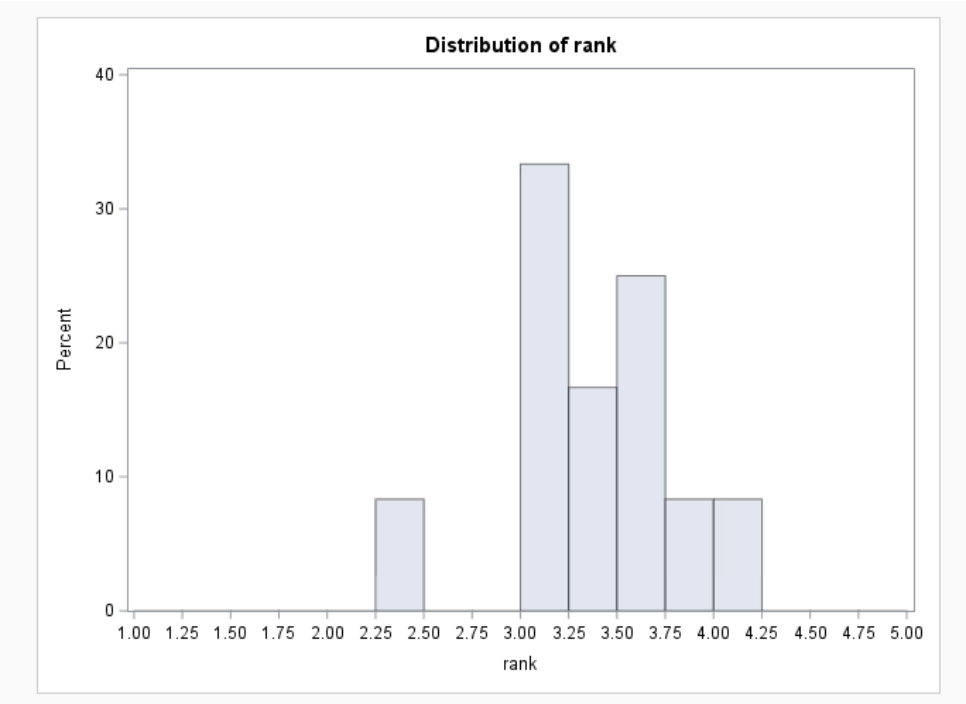
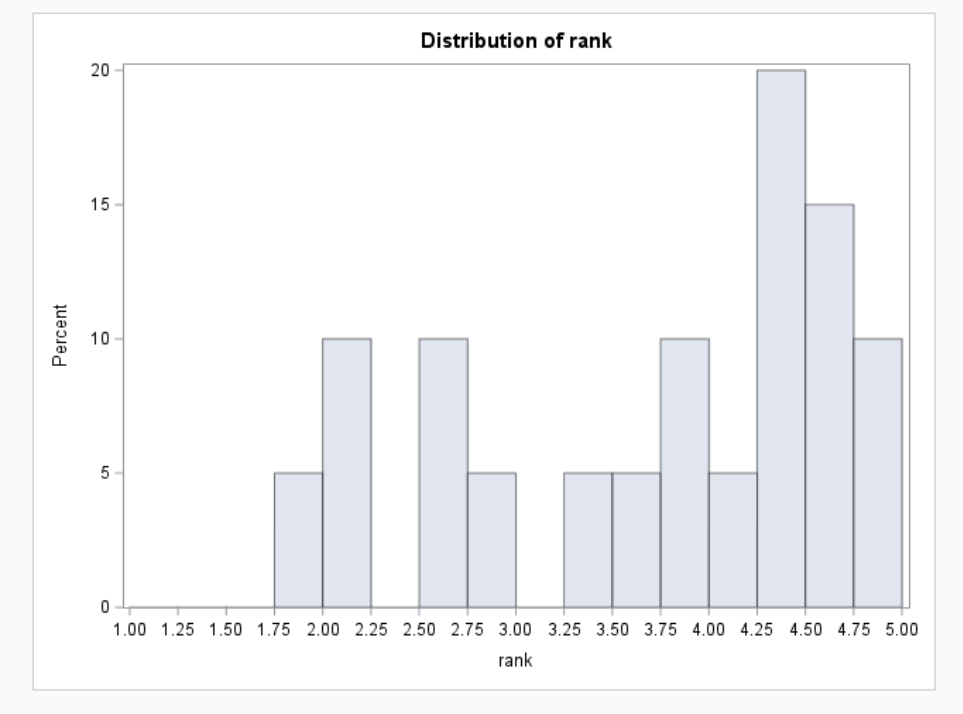
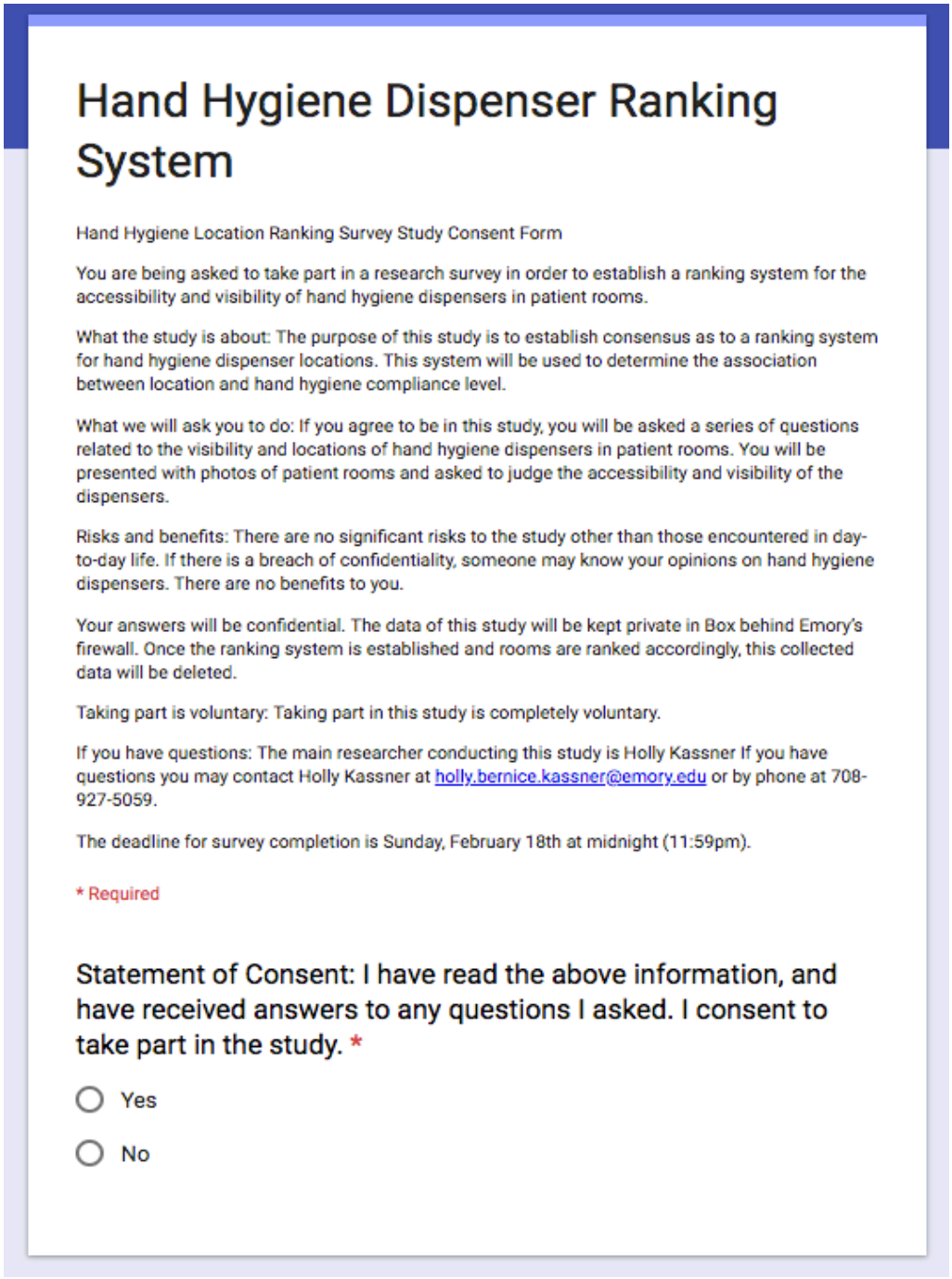


Figure 6. Variability of Room Visibility Rank Scores for Unit 71 ICU With 20 Rooms.



Appendices

Appendix A. Survey on HH Dispenser Visibility and Other Attributes Distributed to HCWs



Hand Hygiene Dispenser Ranking System

Hand Hygiene Location Ranking Survey Study Consent Form

You are being asked to take part in a research survey in order to establish a ranking system for the accessibility and visibility of hand hygiene dispensers in patient rooms.

What the study is about: The purpose of this study is to establish consensus as to a ranking system for hand hygiene dispenser locations. This system will be used to determine the association between location and hand hygiene compliance level.

What we will ask you to do: If you agree to be in this study, you will be asked a series of questions related to the visibility and locations of hand hygiene dispensers in patient rooms. You will be presented with photos of patient rooms and asked to judge the accessibility and visibility of the dispensers.

Risks and benefits: There are no significant risks to the study other than those encountered in day-to-day life. If there is a breach of confidentiality, someone may know your opinions on hand hygiene dispensers. There are no benefits to you.

Your answers will be confidential. The data of this study will be kept private in Box behind Emory's firewall. Once the ranking system is established and rooms are ranked accordingly, this collected data will be deleted.

Taking part is voluntary: Taking part in this study is completely voluntary.

If you have questions: The main researcher conducting this study is Holly Kassner If you have questions you may contact Holly Kassner at holly.bernice.kassner@emory.edu or by phone at 708-927-5059.

The deadline for survey completion is Sunday, February 18th at midnight (11:59pm).

* Required

Statement of Consent: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study. *

- ○ Yes
- ○ No

Ranking Survey

This survey seeks to rank the usability of hand hygiene foam dispensers.

Please rate the location of the dispensers in the following images according to these attributes for both room entry and room exit. All rooms are from Emory University Midtown Hospital participating in the PEACH hand hygiene study.

- Visibility - The hand sanitizer dispenser is considered visible if it is within view of the user when entering or exiting the room
- Accessibility - The hand sanitizer dispenser is considered accessible if there are no complete or partial physical obstructions
- Workflow path - The hand sanitizer dispenser is considered within the workflow path if it is placed along the shortest path to the point of care

If the dispenser is not visible in the pictures, then please mark the visibility as 0.

There is a 4 point scale used (None, Low, Medium, and High) for ranking each attribute of the dispenser.

In some examples there are moveable objects such as IV poles near the HH dispenser. Please ignore these objects in your responses since they may not always be in the same location.

What type of provider are you? *

- ○ Nurse
- ○ Doctor
- ○ Student
- ○ Nurse Tech
- ○ Other

Age *

- ○ Under 30
- ○ 30-39
- ○ 40-49
- ○ 50-59
- ○ 60 and above

Do you primarily work in an ICU or ward? *

- ICU
- Ward
- Evenly in both

1 IN. Please rate this dispenser

	None	Low	Medium	High
Visibility				
Accessibility				
Workflow Path				

2 IN. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

3 IN. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

4 IN. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

1 OUT. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

2 OUT. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

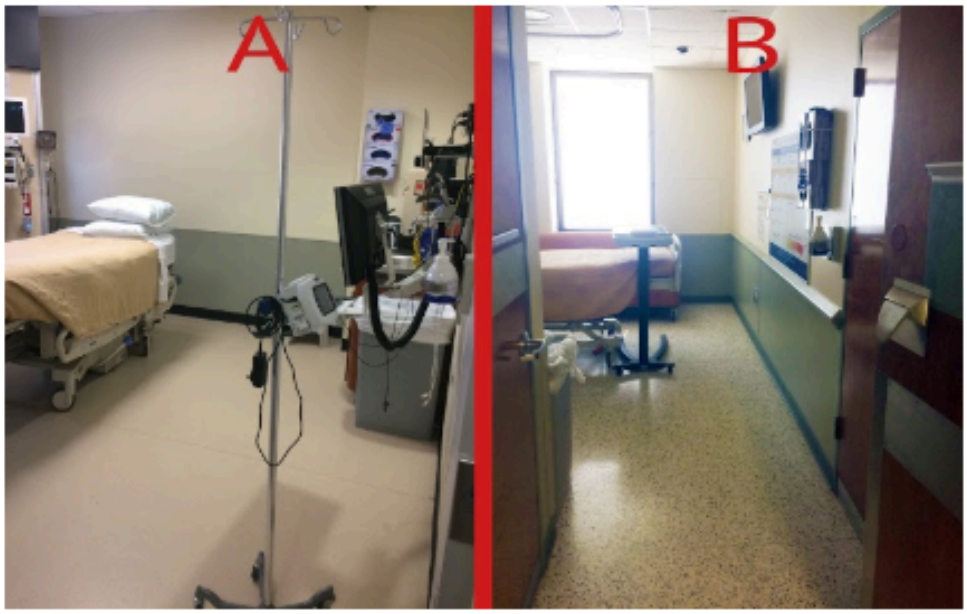
3 OUT. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

4 OUT. Please rate this dispenser

	None	Low	Medium	High
Visibility	○	○	○	○
Accessibility	○	○	○	○
Workflow Path	○	○	○	○

1. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?



- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

2. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?

- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

3. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?

- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

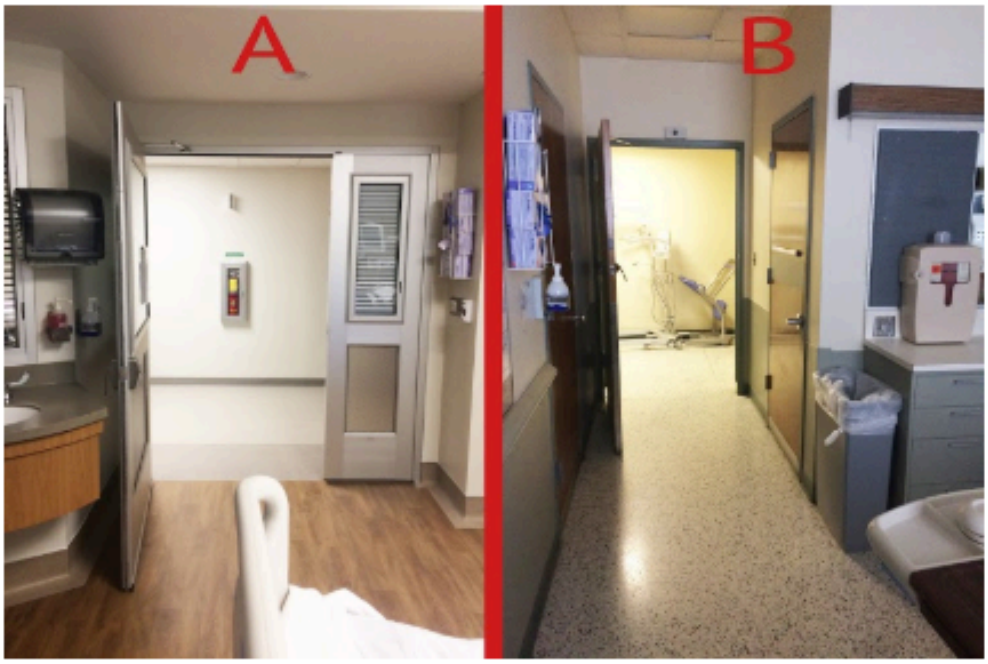
4. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?

- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

1. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?

- ○ A would be easier for me to use
- ○ B would be easier to use
- ○ Equally easy to use

2. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?



- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

3. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?

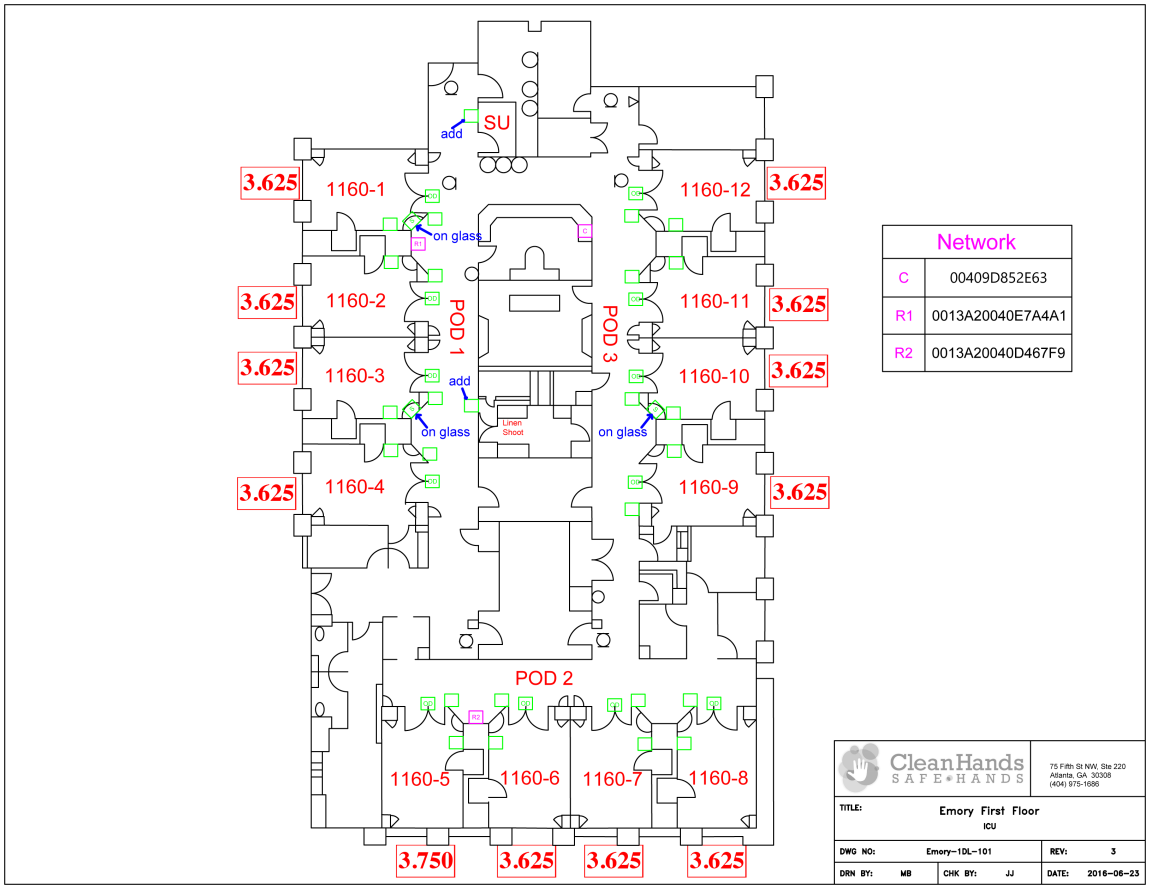
- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

4. Based on visibility/accessibility/location, which dispenser do you think is more likely to be used?

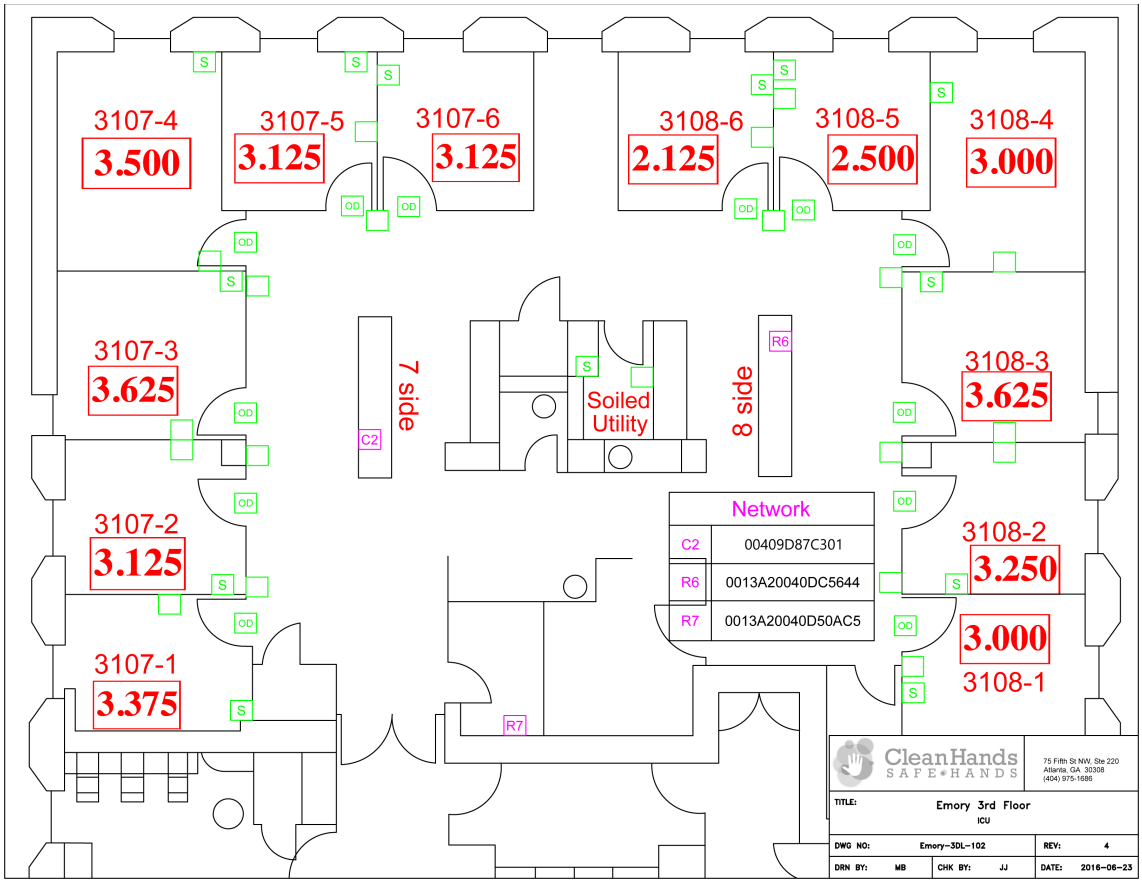
- ○ A would be easier to use
- ○ B would be easier to use
- ○ Equally easy to use

Appendix B. Maps of Units with the locations of HH dispensers and the ranks of individual rooms.

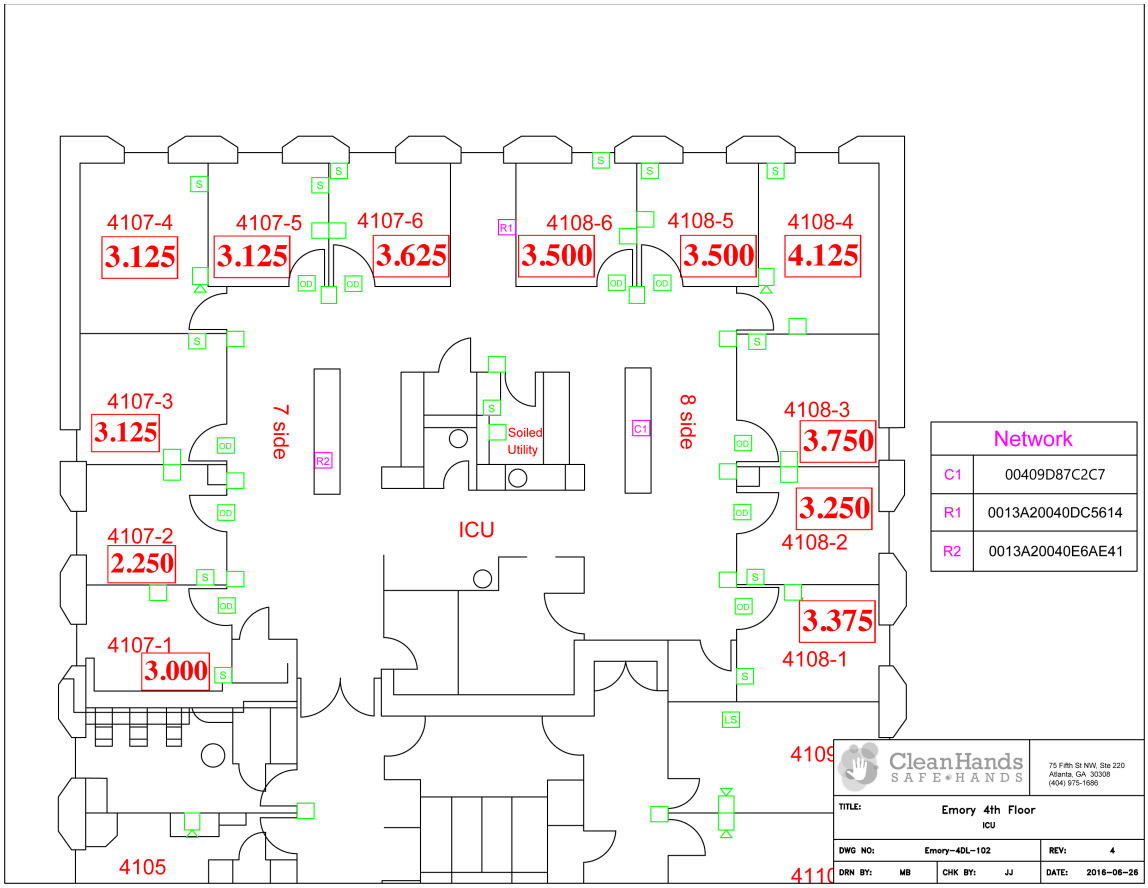
Map of Unit 11 ICU



Map of Unit 31 ICU



Map of Unit 41 ICU



Map of Unit 71 ICU