American Journal of Infection Control 42 (2014) 602-7

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Estimation of hand hygiene opportunities on an adult medical ward using 24-hour camera surveillance: Validation of the HOW2 Benchmark Study

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Key Words:
Handwashing
Monitoring
WHO Five Moments
Compliance

Background: We previously published a formula to estimate the number of hand hygiene opportunities (HHOs) per patient-day using the World Health Organization's "Five Moments for Hand Hygiene" methodology (HOW2 Benchmark Study). HHOs can be used as a denominator for calculating hand hygiene compliance rates when product utilization data are available. This study validates the previously derived HHO estimate using 24-hour video surveillance of health care worker hand hygiene activity.

Methods: The validation study utilized 24-hour video surveillance recordings of 26 patients' hospital stays to measure the actual number of HHOs per patient-day on a medicine ward in a large teaching hospital. Statistical methods were used to compare these results to those obtained by episodic observation of patient activity in the original derivation study.

Results: Total hours of data collection were 81.3 and 1,510.8, resulting in 1,740 and 4,522 HHOs in the derivation and validation studies, respectively. Comparisons of the mean and median HHOs per 24-hour period did not differ significantly. HHOs were 71.6 (95% confidence interval: 64.9-78.3) and 73.9 (95% confidence interval: 69.1-84.1), respectively.

Conclusion: This study validates the HOW2 Benchmark Study and confirms that expected numbers of HHOs can be estimated from the unit's patient census and patient-to-nurse ratio. These data can be used as denominators in calculations of hand hygiene compliance rates from electronic monitoring using the "Five Moments for Hand Hygiene" methodology.

Substantial efforts are being made to reduce health care-acquired infections (HAIs). A critical component of these efforts is the emphasis on improving hand hygiene (HH) compliance among health care workers (HCWs).[1-4] The Centers for Disease Control and Prevention (CDC) has outlined a method describing multiple opportunities for HH.[5] Similarly, the World Health Organization (WHO) has developed the "Five Moments for Hand Hygiene" (WHO5) method that requires the HCW to clean their hands at various points inside the patient room during the care of the patient.[6-8]

Accurate, reliable, affordable, and timely HH compliance measurement systems are essential to these efforts. The measurement of HH compliance is often difficult to achieve, and various methods (ie, direct observation, product utilization, and survey methods) have fallen short with regard to validity and practicability.[9-11] Direct observation is considered the gold standard for HH monitoring, but it has several drawbacks. It requires substantial resources to train, employ, and monitor observers. Additionally, the data collation and reporting are often delayed significantly from the actual patient care. Finally, it is difficult to perform necessary observations within the patient care environment, and when the observer enters the patient room, compliance may be

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Supported by Deb Worldwide Healthcare, Inc, which had no influence on the design, conduct, analysis, or results of the study.

Conflicts of interest: None to report.

0196-6553/$36.00
http://dx.doi.org/10.1016/j.ajic.2014.02.020

Table 1
Comparison of study characteristics: Derivation study vs validation study

Study characteristic	Derivation study	Validation study
Data collection methodology	Random sampling whereby observer follows HCW involved in patient care activity	24-hour video surveillance of HCW care activity in patient rooms
Type of unit (adult medical)*	Adult medical	Adult medical
Unit average daily census	29.3 Patients	29.1 Patients
Total hours of data collection	81.3	1,510.8
Total number of HHOs	1,740	4,522
Total number of indications	2,879	6,117
Indications: No. (%) of indications		
Before patient contact	607 (21.1)	1,294 (21.2)
Before aseptic technique	178 (6.2)	476 (7.8)
After body-fluid exposure	239 (8.3)	300 (4.9)
After patient contact	767 (26.6)	344 (22.0)
After contact w/pt surroundings	1,088 (37.8)	2,703 (44.2)
HCW HHOs: No. (%) HHOs		
Nurses†	1,367 (78.6)	3,302 (73.0)
Physicians‡	80 (4.6)	259 (5.7)
Auxiliary personnel§	48 (2.8)	312 (6.9)
Therapists‖	120 (6.9)	452 (10.0)
Other¶	125 (7.2)	197 (4.4)

*Derivation study done primarily on an adult nephrology unit and the validation study done on an adult pulmonary unit.
†Nurses, patient care technicians/nursing assistants, and nursing students.
‡Physicians, residents, medical students, and physician assistants.
§Environmental services/housekeeping personnel, dietary aides, and volunteers.
‖Therapists (eg, physical therapists, occupational therapists, audiologists).
¶Other (technicians, dieticians, unit secretaries, transporters, and any other type HCW).

overestimated because of the change in HCW behavior when being observed (ie, the Hawthorne effect).[12,13]

The default method for HH compliance monitoring has become the direct observation of the cleaning of hands by HCWs as they enter or exit a patient room. A commonly observed effect is that the HCWs now only clean their hands at entry and exit. Although this method is relatively easy to understand, it significantly increases the risk of the HCW becoming recontaminated after entry to the room.[14]

Various electronic methods have been developed to measure HH compliance in the attempt to develop less expensive and more accurate, reliable, and timely monitoring systems. These methods typically measure HH compliance upon the entry or exit of a HCW from the patient's room.[10] In most of these methods, the numerator is measured by an electronic signal with the activation of a soap or alcohol dispenser. The denominator is obtained through the electronic recognition of a HCW's badge entering or exiting the room.[11] Once implemented, these systems are usually relatively inexpensive to maintain, are able to collect large amounts of data that can be interpreted in near real time, and likely minimize the Hawthorne effect.

No one has developed a reliable electronic monitoring system for HH compliance using the WHO5 methodology. The present work explored the possibility of developing such a system. Monitoring HH compliance involves accurate assessment of HH events, as well as simultaneous HH opportunities (HHOs). HH events may be electronically measured based on activations of the alcohol or soap dispensers. Measuring HHOs is more difficult because they will vary based on the frequency and intensity of patient care and the work flow of the HCW. In a previous publication, we reported the estimated HHOs per patient-day on various types of hospital units using the WHO5 methodology.[1] We found that 2 readily available unit-specific factors, patient census and the patient-to-nurse ratio, could be used to estimate the expected number of unit-specific HHOs. These estimates were determined using a previously published WHO5 sampling technique.[6] To validate these estimates, a second study was conducted using 24-hour video surveillance of entire patient care episodes.

METHODS

Sample and setting

Both the HOW2 Benchmark Study and the validation study were conducted within an adult medical inpatient unit at Greenville Memorial Hospital, a 746-bed teaching hospital, in Greenville, South Carolina. The adult general medical unit was chosen for the validation study because it is the most commonly occurring unit within most acute care hospitals. Institutional Review Board (IRB) approval was obtained for both studies, and all patients in the validation study provided written informed consent.

In the validation study, video surveillance footage was obtained using cameras (Speco Technologies Model VL648IRVF; Speco Technologies, Amityville, NY) with infrared wide-angle dome 2.8- to 11-mm lenses mounted in 12 of the 32 patient rooms on the study unit. Cameras were motion activated and equipped with infrared capability to allow videotaping in a dark room; however, no audio was recorded. Each camera was positioned to allow a view of the room doorway; the patient's bed; and all sink, soap, and alcohol dispensers. A curtain was attached to each camera so that patients, family members, or HCWs could draw the curtain to block videotaping during any activity requiring privacy (eg, bed baths, bed-pan use, or other).

If a patient was assigned to 1 of the 12 study rooms and provided informed consent, the camera curtain was drawn open to uncover the lens, and videotaping ensued 24 hours a day for the remainder of their unit stay. For participants, a sign was posted on the door informing staff, family, and visitors that there was a camera videotaping in the room. In addition, cameras were in plain view of anyone entering the room.

Data collection

The WHO method of defining HHOs based on the "Five Moments for Hand Hygiene" was used in both studies.[6] The derivation study (HOW2 Benchmark Study) utilized random convenience sampling, whereby observers walking onto the study unit would

Table 2
Average number of HHOs, with 95% confidence intervals: Derivation study vs validation study

HHOs per patient-day	Derivation study Mean (95% CI)	Validation study Median (95% CI)	Statistical difference
24-hour period	71.6 (64.9-78.3)	73.9 (69.1-84.1)	No
Shift 1 (7:00 a.m.-6:59 p.m.)	33.3 (30.3-36.3)	46.7 (41.0-51.8)	Yes
Shift 2 (7:00 p.m.-6:59 a.m.)	40.7 (32.9-48.5)	28.0 (25.2-31.2)	Yes
Weekday (Mon-Fri)	71.0 (64.1-77.9)	76.5 (70.8-89.5)	No
Weekend (Sat-Sun)	76.3 (51.2-101)	68.2 (65.0-88.0)	No

follow the first HCW involved in patient care activity and watch the activity while maintaining a discreet presence. Sampling occurred weekly throughout the day and evening shifts from January to March 2010.[1] The validation study utilized 24-hour video surveillance recordings of 26 patients from December 2011 to December 2012. In both studies, the number and date/time of HHOs, HHO indications, HCW types, and compliance activity were collected. No personal identifying data on HCWs were ever collected. Staff completing the data collection was the same for both studies and included 2 quality management nurses and an infection control nurse who were all trained extensively on the WHO5 methodology. Inter-rater reliability was assessed on 20 occasions during the derivation study and 12 occasions during the validation study, and reliability was found to be ≥97% on all occasions.

Video footage for the validation study was stored directly to a dedicated secure server within the hospital's security department. Footage was viewed through a secure hospital network system using software provided by the camera company. Videotapes were declared to be "patient safety work product" through our institution's Patient Safety Organization, and access to videotapes was limited to direct study personnel.

Estimation of HHOs

Unit-specific estimates of HHOs per patient-day in the derivation study were calculated using the number of HHOs per sampling time frame, the units' patient census and patient-to-nurse ratio, adjustment factors for activity-based random sampling versus systematic surveillance sampling, and extrapolation of HHOs per minute to the 24-hour clock.

In the validation study, each HHO was categorized into date and hour-specific time intervals. Total number of HHOs was divided by the total number of hours of data collection per calendar subject date to obtain an average HHO estimate per subject date (N = 94). The time the curtain was closed per subject date was subtracted from the total observation time. These 94 estimates were not normally distributed; thus, medians, instead of means, were used for reporting.

Statistical analysis

Ninety-five percent confidence intervals were used to assess differences between HHO estimates of the 2 studies. Parametric confidence intervals using mean and standard error were constructed for HHO estimates from the derivation study. Nonparametric confidence intervals, using medians and the binomial distribution, were constructed for the HHO estimates from the validation study.[15] Overlapping 95% confidence intervals were interpreted as not being significantly different.

Bivariate analysis of possible predictors of HHOs was completed using the Kruskal-Wallis test for differences in medians of greater than 2 groups; P values $< .05$ were deemed indicative of statistical significance. Inter-rater reliability was assessed using Pearson correlation coefficient. The Kolmogorov-Smirnov D Statistic was used to test normality of distributions. All statistical analyses were completed using SAS statistical software (version 9.3; SAS Institute, Cary, NC).

RESULTS

Descriptive comparisons of the derivation study to the validation study are provided in Table 1. Differences in data collection methodology were specific to the study design and purpose of each study. Both studies were conducted on adult medical units with an average daily census of 29 patients. Total hours of data collection were 81.3 and 1,510.8 hours, resulting in 1,740 and 4,522 HHOs in the derivation and validation studies, respectively. Distributions of the indications for the WHO5 moments within HHOs were similar between the 2 studies. The majority of indications were after patient contact and/or patient surroundings (64% and 66%, respectively). The derivation study had a slightly higher rate of "after body fluid exposure" (8.3% vs 4.9%, respectively). Types of HCW involved in patient care activities were also similar between the 2 studies, with nurses and physicians accounting for ~ 75% and ~ 5% of HHOs, respectively. Therapists and auxiliary and other personnel composed the remainder of HHOs.

Twenty-six patients agreed to participate in the validation study. Video surveillance data for these patients were distributed over 94 separate dates (subject dates), and hours of video footage per patient ranged from 5 to 408 hours (median, 45 hours). Curtains were closed to block videotaping a median of 1.8 hours (4.7%) per patient stay. Overall, curtains were closed 160 hours of 1,671 potential hours of videotaping (9.6%). Study participants were compared with nonparticipants on demographic characteristics, severity of illness, and discharge status. Nonparticipants were defined as patients who were assigned to 1 of the 12 study rooms during the study time frame but did not provide consent. Study participants were significantly younger (56 vs 64 years, respectively) and more likely to be female (73% vs 49%, respectively) than nonparticipants. In addition, participants were slightly healthier than nonparticipants as evidenced by a shorter hospital length of stay (7 vs 9 days, respectively) and greater percentage of discharges to home (62% vs 46%, respectively).

Comparisons of the numbers of HHOs found in the 2 studies are provided in Table 2. Mean and median HHOs per 24-hour period did not differ significantly; HHOs were 71.6 and 73.9 in the derivation and validation studies, respectively. In addition, there were no significant differences in HHOs on weekdays (71.0 vs 76.5, respectively) or weekends (76.3 vs 68.2, respectively). Significant differences were found between the 2 studies by 12-hour shift; the validation study showed a greater number of HHOs on the first shift (46.7 vs 33.3, respectively), and the derivation study showed a greater number of HHOs on the second shift (40.7 vs 28.0, respectively).

A scatterplot of the 94 average HHO estimates per subject date in the validation study are provided in Figure 1. The test for normality of this distribution indicated non-normality ($P < .01$). The median of the 94 estimates was 73.9 HHOs; 25th and 75th percentiles were 63.0 and 94.6, respectively, and the range was 27.4 to 242 HHOs.

The distribution of the percent of HHOs occurring by clock hour during a 24-hour period is presented in Figure 2. Peak HHO activity hours were 7 a.m., 8 a.m., 11 a.m., 4 p.m., and 8 p.m. Approximately

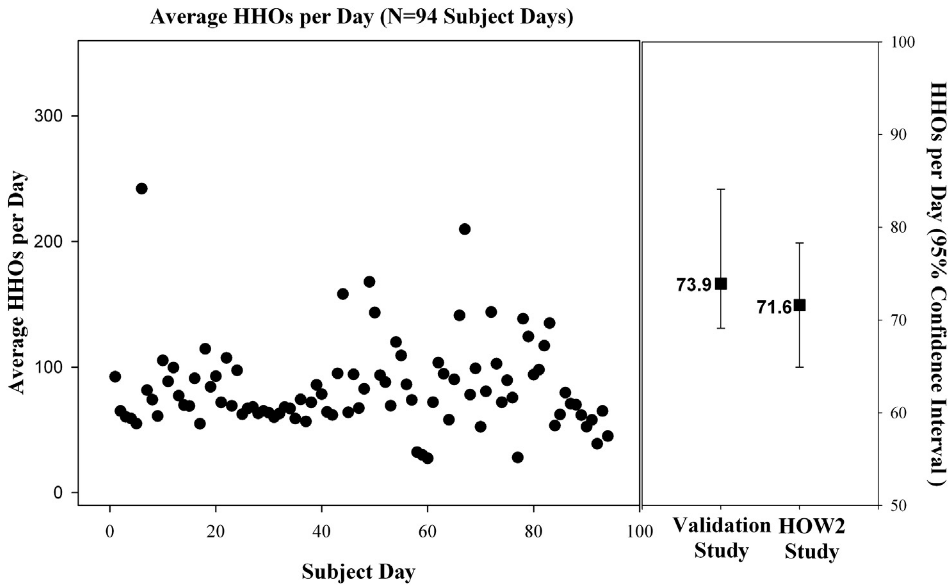

Fig 1. Average HHOs per day: N = 94 subject-days.

13% of all HHOs occurred between 7 a.m. and 8 a.m., and minimal HHO activity occurred between midnight and 4 a.m.

Statistical analyses of the validation study data for possible predictors of the number of HHOs are presented in Table 3. Age group was the only statistically significant predictor, with median HHOs increasing by age; median HHOs were 64.2, 67.3, and 80.1 for age groups <50, 50 to 64, and ≥65 years, respectively. No associations were found for gender, number of diagnoses or procedures, contact precautions, primary diagnosis, or other measures of illness severity.

DISCUSSION

There is much interest in the reduction of HAIs through efforts to improve HH compliance. Numerous studies summarized by The Joint Commission[9] indicate baseline HH compliance rates often approximate 50%.[16] Some studies are now demonstrating significant reductions in HAIs when entry/exit HH compliance rates approach 90%.[17,18] A critical problem with the entry/exit method is that there is significant risk of recontamination of HCW hands while inside the patient room.[14] The WHO5 method has been promoted to account for this risk, and we believe that this methodology is preferable. Monitoring HH compliance based on the WHO5 is more difficult than monitoring entry/exit because it requires the observer to enter the room with the HCW. This intrudes on patient privacy and care, is labor intensive and expensive, and introduces the potential for the Hawthorne effect. Thus, the development of an electronic mechanism to measure WHO5 compliance would be a significant step forward to facilitate its widespread use.[19]

To electronically measure WHO5 compliance, the expected number of HHOs must be estimated based on unit-specific information. It would be logical to assume that the number of HHOs would correlate with the intensity of care delivered to the patient. In the original derivation study (HOW2 Benchmark Study),[1] it was shown that the number of HHOs could be calculated based on a unit's patient census and the specific patient-to-nurse ratio on that unit. That study utilized random convenience sampling, whereby observers walking onto the study unit would follow the first HCW involved in patient care activity and watch the activity while maintaining a discreet presence. Thus, there was the potential for biased estimation of HHOs because HCW "activity" was being followed and recorded. This follow-up validation study was designed to calculate the HHOs over a continuous time that included both periods of care activity and inactivity.

The results of this validation study demonstrate that HHOs for the WHO5 method can be accurately estimated using a unit's patient census and the patient-to-nurse ratio. Somewhat surprisingly, it was found that other measures of the patient's severity of illness and intensity of care did not correlate with the expected number of HHOs. Consequently, this validation study confirms that the original formula detailed in the HOW2 Benchmark Study is a valid derivation of HHOs based on the WHO5 methodology and can be used in the application of electronic monitoring systems.

A particular strength of this study is the use of 24-hour video surveillance. Although several studies have used 24-hour video monitoring to measure HH compliance using the entry/exit method,[20-22] our study is the first to use 24-hour video for collection of HHOs based on the WHO5 methodology. In addition, with more than 1,500 hours of video footage and over 4,500 HHOs, our study has ample statistical power to justify our conclusions.

Other strengths of this research are the similarity between the 2 clinical units and the 2 populations studied in the derivation and validation studies, respectively. In addition, demographic and clinical characteristics of patients in the 12 video-monitored rooms were similar to those of patients in the remaining nonmonitored rooms on the validation study unit. The 2 groups were similar on age, length of hospital stay, and case-mix index.

The validation study has several limitations. The primary limitation is that only 26 patients were studied, and there were some differences between the consented and nonconsented patients. The consented patients were younger, more likely female, and less sick. Because age was associated with the number of HHOs, and younger patients had fewer HHOs, our validation estimate may be underestimated. Of note, the derivation study did not include patient age as a possible predictor of HHOs. This measure is typically not available in real time. Thus, it would be very difficult to factor it into the predictive formula for HHOs.

A second limitation is that the validation study was completed only on one type of unit, an adult medical ward of a large teaching

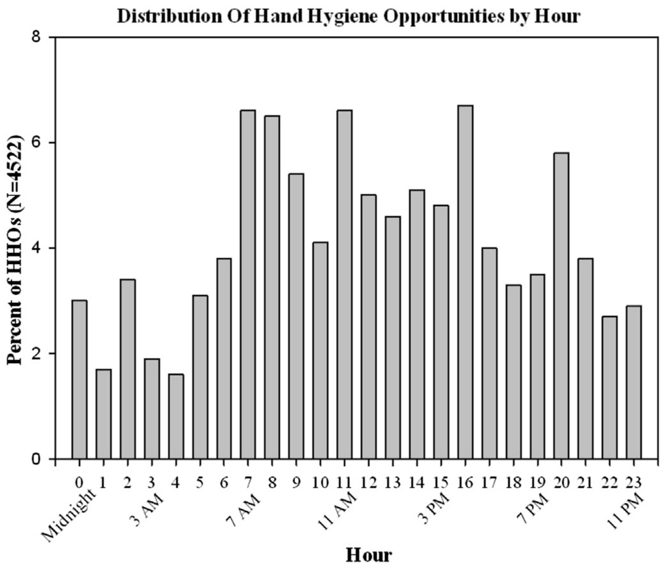

Fig 2. Distribution of hand hygiene opportunities by hour.

Table 3
Analysis of possible predictors of HHOs/patient-day: n = 26 patients

Study characteristic	No.	Median HHOs/patient-day (25th, 75th percentile)	*P* value
Age group, y			
<50	9	64.2 (55.4, 70.1)	.015
50-64	9	67.3 (63.7, 86.2)	
≥65	8	80.1 (75.7, 106)	
Sex			
Female	19	74.9 (64.2, 78.0)	.623
Male	7	69.0 (52.4, 91.5)	
Number of diagnosis codes			
≤12	7	70.1 (52.4, 77.8)	.627
13-18	10	66.4 (57.7, 86.2)	
≥19	9	75.8 (67.3, 78.0)	
Number of procedure codes			
0	10	75.0 (57.7, 82.2)	.902
1	8	73.5 (58.1, 106)	
≥2	8	69.3 (66.9, 76.1)	
Number of consulting MDs			
0	13	75.0 (69.0, 86.2)	.137
1	5	56.6 (54.9, 67.3)	
2	4	76.1 (71.2, 89.9)	
3	4	62.0 (42.6, 75.4)	
Contact precautions			
No	20	72.5 (64.0, 84.2)	.429
Yes	6	71.1 (52.4, 76.5)	
Primary diagnosis			
Acute respiratory failure	6	84.9 (70.1, 91.5)	.383
COPD	4	69.3 (60.7, 80.5)	
Pneumonia	6	70.7 (64.2, 77.8)	
Sepsis	3	69.0 (52.4, 103)	
Other	7	67.3 (55.4, 76.5)	
APR-DRG case-mix index			
<1.0	8	70.7 (57.2, 94.7)	.972
1.0-1.9	9	75.0 (64.2, 82.2)	
≥2.0	8	69.3 (66.9, 76.1)	
APR-DRG severity of illness			
1, 2-Minor, moderate	6	69.3 (57.7, 77.8)	.467
3-Major	12	67.8 (56.0, 84.2)	
4-Extreme	8	75.4 (69.3, 84.0)	
APR-DRG risk of mortality			
1-Minor	5	74.9 (63.7, 77.8)	.159
2-Moderate	9	66.5 (56.6, 70.1)	
3-Major	7	68.5 (55.4, 86.2)	
4-Extreme	5	76.5 (75.8, 109)	

APR-DRG, all patient refined diagnosis related groups; *COPD*, chronic obstructive pulmonary disease.

hospital. Thus, it is possible that expected numbers of HHOs may not be as statistically correlated on other types of units (eg, pediatric, surgical, and others) or other types of hospitals (eg, small community, specialty, and others). It is important to note, however, that the purpose of this study was to compare the average number of HHOs per patient-day derived through "sampling" observation with the actual number of HHOs per patient-day recorded through 24-hour video.

Last, the video footage captured in our study did not represent 100% of all potential footage; thus, 100% of HHOs were not captured. Patients, visitors, and staff were allowed to block videotaping for any reason, and this occurred 9.6% of the time (160 of 1,671 potential hours). There is no reason to believe that the missing footage would differ substantially from the remaining footage; however, this possibility cannot be ruled out.

Finally, the fact that there was considerable shift-to-shift variation of HHOs in the validation study leads us to the conclusion that HHO estimates derived from sampling are not reliable for periods of less than 24 hours. Shift-to-shift variation found in the 24-hour video footage was attributable to the relative absence of HHOs during inactive patient care periods (eg, patient sleeping). Thus, we believe that the HH compliance index should only be calculated for a minimum time frame of 24 hours and, preferably, for longer periods of time (eg, weekly). Implementation of HH compliance via electronic monitoring and WHO5 methodology requires an accurate denominator (ie, expected number of HHOs) for calculation of a compliance rate. The data from our 2 studies (derivation and validation) demonstrate that the expected number of HHOs can be accurately estimated from the unit's patient census and patient-to-nurse ratio. Additional research is now needed to extrapolate our findings to other types of units (eg, pediatrics, rehabilitation, and others) and, most importantly, on how to operationalize an electronic measurement system to improve HH compliance and reduce HAIs.

Acknowledgments

The authors thank Karen Hudson, RN, and Lynda Bingham, RN, for their dedication and fortitude in the collection of data; Sharon Dunning, RN, MBA, for her oversight and scheduling of data collection; Betsy Holbrook and Robert Craigo for their assistance in the study logistics; Shannon Wheeler, RN, and the staff and physicians of 5C for being willing participants in the study; Paul Alper and his team for their support and encouragement; and all of the above for their many contributions, without which this work could not have been accomplished.

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