Using a Systems Engineering Initiative for Patient Safety to Evaluate a Hospital-wide Daily Chlorhexidine Bathing Intervention

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We undertook a systems engineering approach to evaluate housewide implementation of daily chlorhexidine bathing. We performed direct observations of the bathing process and conducted provider and patient surveys. The main outcome was compliance with bathing using a checklist. Fifty-seven percent of baths had full compliance with the chlorhexidine bathing protocol. Additional time was the main barrier. Institutions undertaking daily chlorhexidine bathing should perform a rigorous assessment of implementation to optimize the benefits of this intervention.

Key words: chlorhexidine bathing, infection control, quality improvement, SEIPS, systems engineering

A PROVEN INTERVENTION for reducing health care-associated infections is daily bathing with chlorhexidine gluconate (CHG) for intensive care unit (ICU) patients, for which numerous studies, including a recent meta-analysis, have found reductions in bloodstream infections and colonization by multidrug-resistant organisms. Although some studies have conducted a limited assessment of compliance with this intervention, data regarding the facilitators and barriers to CHG bathing in the real world of health care within and beyond the ICU are limited.

The objective of this study was to evaluate the housewide implementation of daily

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CHG bathing in an academic teaching hospital. The Systems Engineering Initiative for Patient Safety (SEIPS) model was used to characterize the various elements of the CHG bathing process.

**METHODS**

We used direct observations of the bathing process and conducted provider and patient surveys to assess the implementation of daily CHG bathing.

**Setting**

Adult inpatient units of a large academic medical center (566 beds) began performing daily CHG bathing housewide using liquid 4% chlorhexidine 6 months prior to this study. The observations and surveys were developed using the SEIPS model to analyze the entire work system.

**The SEIPS model**

The SEIPS model was used as the overall framework for this study. Briefly, the model incorporates both the human and engineering aspects of systems in patient safety by considering how a multitude of factors affect patient safety individually and in combination. The SEIPS model focuses on 5 interacting elements of the work system: person, tasks, tools and technologies, physical environment, and organizational conditions. Interaction of these elements affects processes, resulting into patient outcomes, such as quality of care and patient safety, and organizational outcomes, such as more productivity and decreased errors.

Registered nurses (RNs), nursing assistants (NAs), and hospital patients were the persons involved in our analysis. Patients were divided into 3 categories: (1) patients who did not take an active role in their bathing (washing no parts of their body except the face) were considered “fully assisted”; (2) patients who washed part but not all of their bodies during bathing or showering were considered “partially assisted”; and (3) patients who showed or bathed completely without help from nursing staff were considered “independent.”

Tasks performed were the individual components of the CHG bathing protocol. Some of these included gathering necessary supplies, providing patient education, and maintaining proper hand hygiene. A complete outline of all the components of the CHG bathing process is shown in Table 1.

The supplies necessary for daily CHG bathing constituted the tools and technologies used. These supplies included CHG soap (Hibiclens 4%), a large sealable plastic bag, 10 to 15 washcloths, several large towels for drying, nonantimicrobial foam soap (Aloe Vesta), and CHG-compatible lotion. Adequate supply of these tools was evaluated. The physical environmental features considered were lighting conditions, room temperature, and use of the space for preparing and using CHG bathing supplies.

The required CHG bathing education provided to nursing staff by the hospital was part of the organization of the work system. The ICU and non-ICU units were considered to be 2 functionally different organizations, given the major differences in study populations and bathing process. Compliance with CHG bathing was compared between these 2 types of organizational units.

**Outcomes**

Compliance with CHG bathing was the main process measure. Using the SEIPS framework, a checklist was developed and used during patient bathing observations to record compliance with each step of the protocol, deviations from the protocol, and the order in which the steps of the bathing process happened. Compliance was assessed in 3 ways: (1) direct observations, (2) from the electronic medical records (EMRs), and (3) supply usage data. Specific observable components in the CHG bathing protocol were defined as critical for its intended outcome. These components included gathering the necessary supplies (points = 4), performing hand hygiene (points = 1), wearing gloves (points = 1), applying at least 2 pumps of CHG soap to
Table 1. Completion of Tasks of the Chlorhexidine Bathing Protocol

<table>
<thead>
<tr>
<th>Task and Assessment of Compliance</th>
<th>All</th>
<th>ICU</th>
<th>Non-ICU</th>
<th>Fully Assisted Bathing</th>
<th>Partially Assisted Bathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gathered all necessary supplies (Ziploc bag, washcloths, chlorhexidine, compatible lotion) = 4 points</td>
<td>25/28 (89%)</td>
<td>7/7 (100%)</td>
<td>18/21 (86%)</td>
<td>14/16 (86%)</td>
<td>11/12 (92%)</td>
</tr>
<tr>
<td>Gloves (1 point)</td>
<td>20/28 (71%)</td>
<td>5/7 (71%)</td>
<td>16/21 (76%)</td>
<td>13/16 (81%)</td>
<td>7/12 (58%)</td>
</tr>
<tr>
<td>Hand hygiene (1 point)</td>
<td>21/28 (75%)</td>
<td>6/7 (86%)</td>
<td>15/21 (71%)</td>
<td>14/16 (88%)</td>
<td>6/12 (50%)</td>
</tr>
<tr>
<td>Educated patient about rationale and process</td>
<td>4/28 (14%)</td>
<td>1/7 (14%)</td>
<td>3/21 (14%)</td>
<td>1/16 (6%)</td>
<td>3/12 (25%)</td>
</tr>
<tr>
<td>Applied ≥ 2 pumps chlorhexidine soap per washcloth (1 point)</td>
<td>26/28 (93%)</td>
<td>7/7 (100%)</td>
<td>19/21 (91%)</td>
<td>14/16 (88%)</td>
<td>12/12 (100%)</td>
</tr>
<tr>
<td>Used 1 washcloth with chlorhexidine per body part (1 point)</td>
<td>20/28 (71%)</td>
<td>4/7 (57%)</td>
<td>16/21 (76%)</td>
<td>12/16 (75%)</td>
<td>8/12 (67%)</td>
</tr>
<tr>
<td>Rinsed each washed area with a new washcloth (or rinsed in shower) (1 point)</td>
<td>19/28 (67%)</td>
<td>4/7 (57%)</td>
<td>15/21 (71%)</td>
<td>11/16 (69%)</td>
<td>8/12 (67%)</td>
</tr>
<tr>
<td>Applied lotion to all areas bathed with chlorhexidine soap (1 point)</td>
<td>8/28 (28%)</td>
<td>3/7 (43%)</td>
<td>5/21 (24%)</td>
<td>6/16 (38%)</td>
<td>2/12 (17%)</td>
</tr>
<tr>
<td>Average length of time chlorhexidine applied to 1 arm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average total time spent observing bath</td>
<td>17 min 45 s</td>
<td>14 min 27 s</td>
<td>18 min 51 s</td>
<td>19 min 30 s</td>
<td>15 min 26 s</td>
</tr>
<tr>
<td>Average time spent bathing</td>
<td>12 min 34 s</td>
<td>9 min 14 s</td>
<td>13 min 40 s</td>
<td>13 min 6 s</td>
<td>11 min 51 s</td>
</tr>
<tr>
<td>Average time spent preparing for the bath (supplies, setup)</td>
<td>6 min</td>
<td>6 min</td>
<td>6 min</td>
<td>6 min</td>
<td>6 min</td>
</tr>
</tbody>
</table>

Abbreviation: ICU, intensive care unit.

Steps not listed include performing hand hygiene and wearing gloves.

each washcloth (point = 1), using 1 CHG washcloth per body part (point = 1), rinsing each CHG-bathed area with a new washcloth (points = 1), and applying a CHG-compatible lotion (points = 1) to keep the patient’s skin moist. Compliance was defined as follows on a 10-point scale: full compliance = 9-10 points; partial compliance = 6-8 points; and noncompliance = less than 6 points.

In the absence of published validated instruments for assessing compliance with CHG bathing, the factors we included were chosen
on the basis of prestudy observations we performed of the bathing process. Points were decided on the basis of the clinical expertise of the infection control team that developed the intervention at our facility. They were agreed upon before direct observations were undertaken and focused on the tasks likely to be the most clinically important in the bathing process.

For charting purposes, compliance to the CHG bathing process was considered present if patients received a CHG bath as noted in the EMR. In addition, the hospital-wide cost of transitioning to CHG bathing protocol was compared with the previous, non-CHG bathing protocol.

Observation and survey methods

Observations were completed and surveys were distributed between May 27, 2014, and June 27, 2014. Observations were done on weekdays during the day shift (7:00 AM to 3:00 PM), as most bathing in inpatient units occurs during this time. A single, trained observer performed direct observations in all the 17 adult inpatient units that performed daily CHG bathing. This same individual randomly distributed written surveys to a sample of nursing staff and administered a survey to a random sample of patients on the same days as they were doing observations. Only nursing staff who had performed at least 1 CHG bath took the survey, and only patients who had received 1 bath or shower since arriving at the hospital were asked to complete the survey. Survey questions addressed components of CHG bathing education and procedure, and satisfaction about the process. Both of these can plausibly affect compliance to the bathing process. Surveys were conducted after the observations.

Statistical analysis

IBM SPSS Statistics, version 22.0 (Armonk, New York), was used for statistical analysis. The 2-tailed Fisher exact test and the Student t test were used to assess differences in proportions and continuous variables, respectively. A P value of .05 or less was considered statistically significant.

RESULTS

Twenty-eight CHG baths performed by RNs and NAs were observed in 17 adult inpatient units (4 ICU and 13 non-ICU units). Overall, 105 nursing surveys and 86 patient surveys were completed.

Observation results

Overall, 3 RNs and 31 NAs were observed. Most of the baths observed (27/28) were bed baths, and only 1 was a shower. Of these baths, 57% (16/28) were fully compliant, 36% (10/28) were partially compliant, and 7% (2/28) were noncompliant. There were no statistically significant differences in compliance between ICU and non-ICU units or between fully assisted and partially assisted bathing (Table 2).

Specific steps of bathing protocol

All nursing staff members performed hand hygiene, wore gloves, and changed gloves appropriately during observations. Comparisons of completion rates of tasks performed in the ICU versus non-ICU units and in fully versus partially assisted baths are shown in Table 1. None of the differences between unit types or levels of bathing assistance were statistically significant.

In 89% of baths, all necessary bathing supplies were collected. An appropriate amount of CHG soap was used for each washcloth in 93% of baths observed. Each body part was washed with 1 CHG-dipped washcloth in 71% of baths observed. Each area washed with CHG was rinsed with a new washcloth (or in the shower) in 68% of observed baths. Compared with non-ICU patients, a higher proportion of ICU patients had a lotion applied to all areas washed with CHG soap (24% and 43%, respectively).

Times of different aspects of CHG bathing recording are shown in Table 1. There were no statistically significant differences in average times between unit types or levels
of bathing assistance. The average length of time bathing occurred (excluding any other care activities) was 12 minutes 34 seconds (9 minutes 14 seconds on ICU units and 13 minutes 40 seconds in non-ICU units; 13 minutes 6 seconds for fully assisted baths and 11 minutes 51 seconds for partially assisted baths).

**Environmental notes**

For the majority of baths, nursing staff set up all supplies on the patient side table for easier access. However, for 5 of the 28 baths, bathing supplies were kept near the sink away from the patient, increasing the time spent between bathing steps.

**Nursing survey results**

Sixty-two percent (64/104) were RNs and the rest were NAs. Survey questions addressed components of CHG bathing education and procedure. Compared with ICU nurses, a higher proportion of non-ICU nurses reported reading about the CHG bathing process available on the intrahospital Web site (46% of ICU staff and 70% of non-ICU staff; \( P = .049 \)). Although all staff members were instructed to give information sheets about CHG bathing to patients, only 6% of nursing staff did so; this did not differ between ICU and non-ICU nurses.

**Process satisfaction questions**

Seventy-six percent (79/104) of nursing staff in all units agreed or strongly agreed that they can accomplish bathing in a timely manner (13% disagreed or strongly disagreed). Across all units, 32% of nursing staff agreed that CHG soap causes skin reactions in patients (30% disagreed or strongly disagreed) and 14% agreed or strongly agreed that CHG soap causes skin breakdown in patients over time (49% disagreed or strongly disagreed).

**Patient survey results**

Sixty-nine percent (57/83) of all patients agreed or strongly agreed they understood the importance of CHG bathing. No patients surveyed had an adverse reaction to the CHG soap. Overall, most of the patients (68/69) agreed or strongly agreed that they felt clean after bathing with CHG soap.

**Compliance with CHG based on EMR and CHG usage data**

The overall compliance, based on patient records indicating that a patient received CHG bathing, was 72% across all units and slightly higher in the ICU (77%) than in non-ICU units (70%). This compliance was computed for the period of 1 month after the daily CHG bathing intervention was first implemented to when this study was conducted. The noncompliance due to patient refusal was 8% in the ICU and 18% in the non-ICU units. On the basis of CHG soap usage data from December 2013 to May 2014 and equating each 16-oz bottle to 7 complete daily baths, we estimated CHG soap to be used for 56% of patient-days.
Cost of CHG bathing supplies

The cost of all bathing supplies from December 2012 to May 2013 (before CHG daily bathing implementation) was $175,580. In the 6-month period from December 2013 to May 2014 in which CHG bathing occurred across the hospital, the total cost of bathing supplies was $213,953 (a 22% increase).

DISCUSSION

This study assessed compliance to CHG bathing protocol mainly through direct observations of CHG baths. These were conducted in most adult inpatient units of a large academic facility. We found that 57% of the baths being undertaken were fully compliant with the CHG bathing protocol, 36% were partially compliant, and 7% were noncompliant. There was no marked difference in compliance rates between ICU and non-ICU units. Given the known efficacy of daily CHG bathing, this is a relatively low adherence to the bathing protocol and merits attention. Our use of a systems engineering approach to examine barriers, facilitators, and adherence to the intervention highlights several factors that should be considered when implementing daily CHG bathing in a health care institution.

While several studies have examined the efficacy of daily CHG bathing, few have delved into the implementation factors that are essential for translating evidence into practice. In a quasi-experimental study using 2% CHG-impregnated cloths, Montecalvo et al\(^8\)—82%—and Kasakian et al\(^5\)—77%. This fairly high level of compliance may be explained by the fact that CHG bathing was monitored in a “controlled” study environment setting.

Compared with the compliance noted in our study (57%), 2 of the studies mentioned previously demonstrated a fairly high level of compliance: Montecalvo et al\(^8\)—82%—and Kasakian et al\(^5\)—77%. This fairly high level of compliance may be explained by the fact that CHG bathing was monitored in a “controlled” study environment setting.

In our study, we examined the entire work system around the bathing process. With regard to the person element of the work system, all nursing staff members performed hand hygiene, wore gloves, and changed gloves appropriately. However, patient education about CHG bathing (ie, task in the work system) occurred in only 14% of observed baths, despite 89% of nurses reporting that they were confident educating patients about bathing. Furthermore, when patients were surveyed, only 8% reported receiving an information sheet about CHG bathing from nursing staff. This is an important finding because for an intervention such as CHG bathing, patient buy-in, especially in the non-ICU setting, is important.\(^14\) To our knowledge, previous studies have not examined patient perceptions regarding CHG bathing. Overall, CHG bathing was well tolerated by patients, and none of them experienced any adverse events. This is similar to other studies that have shown that CHG is well tolerated with minimal adverse events.\(^6,10,15\)

The most frequent barrier to CHG bathing mentioned by most nurses was that the...
bathing process is time consuming, a characteristic of the task element in the work system. The additional time may also be a consequence of the product chosen for bathing (liquid vs CHG-impregnated cloths). Unlike previous reports, in our study, lack of supplies was not a barrier to CHG bathing. We observed that the 6-month cost of all bathing supplies went up by $38,372 (22%) after CHG bathing was implemented. Given the overall reduction in health care-associated infections anticipated as a result of this intervention, this would be still be a cost-saving intervention.

Our study had several strengths. First, to our knowledge, this is the first study to apply a systems engineering approach to assess implementation of housewide CHG bathing through direct observations and surveys of health care workers and patients. We complemented this approach with assessment of bathing compliance using EMR documentation and chlorhexidine usage data. Our methods and findings may be used to create a generalizable framework for implementation assessment.

Regarding limitations, it is possible that the Hawthorne effect came into play for health care workers who knew that they were being observed. In that case, the compliance observed in this study could be an overestimation of the true compliance with CHG bathing. Only 28 baths were observed, which might have limited the level of variability in the observed baths. However, observations were performed in all adult inpatient units and are therefore likely to be representative of housewide CHG bathing practices. Another limitation is that we did not conduct a formal budget impact analysis of the intervention. Factors such as price increase might have contributed to the increase of the total cost of 6-month bathing supplies. However, the brand did not change. We plan to conduct future studies to address these gaps.

CONCLUSION

Low compliance with the CHG bathing protocol was a key finding in this study. Time was the main barrier identified by the nursing staff. Future studies to implement CHG bathing in the ICU or other settings should conduct an assessment of implementation to facilitate adherence and reduce variation.

REFERENCES


