Implementing Goal-directed Protocols Reduces Length of Stay After Cardiac Surgery

Anne Miller, PhD,* Chad E. Wagner, MD,* Yanna Song, MS,† Kathleen Burns, RN,‡ Rashid Ahmad, MD,§ C. Lee Parmley, MD, JD,* and Matthew B. Weinger, MD*  

Objective: To test the effect of a high reliability organization (HRO) intervention on patient lengths of stay in the CVICU and hospital. The authors proposed that (1) higher safety related evidence based protocol (SREBP) team compliance scores and (2) lower SREBP milestone scores are associated with shorter lengths of CVICU and hospital stay. Design: A prospective, longitudinal observational evaluation was used to assess the effects of SREBP-focused rounding processes and a milestone-tracking tool. Setting: United States, university academic medical center’s 27-bed CVICU. Participants: Six hundred sixty-five adult cardiac surgery patients and the CVICU care team (100 registered nurses and 16 clinical providers) participated. Measurements and Main Results: Team compliance was the proportion of SREBP-related team behaviors exhibited during daily rounds. Patients’ milestone scores were the cumulative difference between actual and expected times for 4 SREBP milestones over 48 hours. Milestones achieved earlier than expected indicated reduced complication risk, and milestones achieved later than expected indicated increased risk. As team compliance increased, CVICU length of stay decreased 0.66 (95% CI: 0.04 to 1.28; p = 0.08) days; hospital stay decreased 0.89 times (95% CI: 0.77-1.03; p = 0.008). As the mean milestone scores increased from -7 to 12, length of ICU stay increased 2.63 (95% CI: 1.66-3.59; p < 0.001) days; hospital length of stay increased 1.44 times (95% CI: 1.23-1.7; p = 0.05). Conclusions: A milestone-driven pathway supported by team rounding was associated with decreased lengths of CVICU and hospital stay. However, tracking patient trajectories by milestones suggests a more complex relationship than anticipated and presents new opportunities for SREBP implementation and research. Published by Elsevier Inc.  

KEY WORDS: cardiac surgery, quality improvement, intensive care, high reliability organizations, bundled payment

The benefits of safety-related, evidence-based protocols (SREBP) in intensive care unit patients are well established for preventing ventilator-associated pneumonia (VAP), ICU delirium, venous thromboemboli (VTE), catheter-associated bloodstream (CLABSI), and catheter-associated urinary tract infections (CAUTI). However, despite widely disseminated protocols with well-documented compliance rates as low as 10% and rarely greater than 50%, are still reported; thus, the risks associated with these complications remain. This study’s main objective was to evaluate the effects of using high reliability organization (HRO) approaches to implement a bundle for postoperative cardiac surgery patients. Instead of monitoring task completion, HROs reliably achieve desired outcomes by tracking the occurrence of expected milestone events and adaptively modifying work processes and priorities in response to adverse deviations. Increasingly, patient care is evolving toward routine and complex practice based on milestone event trajectories. In HROs, adaptation requires the collective sensitivity of frontline workers and managers to anticipate expected events, and it requires relationships among people that foster the communication and trust needed to anticipate and intervene on potentially adverse deviations. Although HRO approaches have been implemented in some healthcare Microsystems, healthcare organizations have struggled to translate HRO tools and processes into sustained improvement with only a few documented successes.  

The present study was designed to evaluate HRO approaches for integrating complex SREBPs into routine care. Consistent with HRO approaches, the authors’ interventions provide CVICU nursing and medical team members with a quantitative tool for prospectively tracking patient progress towards SREBP milestone events and an interdisciplinary team process for integrating outcome-oriented discussion into daily practice. This study does not evaluate the actual tasks that compose milestone events. These have been and will continue to be the subject of extensive research elsewhere. Consistent with other HRO approaches, the authors’ interventions emphasize tool-supported, team-based, outcome-driven behaviors that support coordinated patient care delivery. To evaluate these interventions, the authors tested the following primary hypotheses:  

H1: Higher team SREBP compliance scores are associated with shorter patient lengths of ICU and hospital stay.  
H2: Low milestone scores (milestones achieved earlier than expected, hence reduced risk of complications) are associated with shorter lengths of patient ICU and hospital stay.  
H3: Patients with high milestone scores (delayed achievement and higher risk of complications) have higher levels of comorbidity than patients with low milestone scores.  

METHODS  
Following IRB approval, the study was conducted in a university academic medical center in the United States. The medical center’s CVICU is a 27-bed unit that admits about 25 postcardiothoracic
surgery patients per week. The unit has 2 care teams: Cardiothoracic/vascular surgery and cardiology. The authors studied the surgical team, which includes 8 midlevel providers and 8 intensivist attendings. Approximately 100 staff nurses manage cardiology and surgery patients on a 1:1.2 ratio depending on acuity.

Adult Cardiac Surgery Pathway Form

The pathway form was designed from a pre-existing, 7-page cardiac surgery pathway document developed by senior CVICU medical leadership and nursing staff. The research team, composed of senior medical and nursing practitioners and a human factors researcher, redesigned the original pathway document to improve its utility in daily practice. Preliminary drafts of the pathway phases, milestones, and other interventions were subjected to iterative feedback from physicians and nurses following short in-practice trials. During the trials, the researchers provided a one-on-one orientation to the pathway form to new staff and used this opportunity to elicit further feedback. This approach circumvented the need for an extensive education campaign.40 New staff were introduced to the form and processes as part of their unit orientation.

Developing each phase’s milestones required integrating dependencies across each of the SREBPs (VAP, 1 of their unit orientation.

Approximately 100 staff nurses manage cardiology and surgery patients in vascular surgery and cardiology. The authors studied the surgical team, which viewed SREBPs as sets of independent tasks that are isolated from temporal and interdisciplinarity dependencies.

The resulting pathway form (Appendix 1) was a single page, double-sided worksheet printed on yellow paper to enhance its visibility. The final worksheet was introduced into the CVICU on March 1, 2011. bedside nurses could check off the tasks needed to achieve milestone outcomes. However, it was not mandatory that they do so, especially if outcomes were being achieved earlier than expected. The task checklist tended to serve a more effective role in diagnosing reasons for delayed goal achievement. Nurses were required to monitor and calculate milestone scores.

During twice-daily interdisciplinary rounds,14,15 nurses presented each patient’s milestone score and status as an on or off the pathway. If off pathway, nurses reported the major problem keeping the patient from progressing to the next milestone; the task checklist supported this assessment. The senior physician leading the round acknowledged the problem and discussed relevant mitigation strategies. The overall objective was to have patients ready for transfer from the CVICU to the step-down unit within 48 hours following stabilization.

Post-surgical stabilization is variable. Some patients are physiologically stable on CVICU arrival; others stabilize after some hours, and a small number of patients remain unstable for days. Patients were excluded from further participation if they were not physiologically stable within 48 hours of CVICU admission. Such patients were assessed as requiring a non-routine post-surgical pathway.

When physiologic stability was achieved (defined as the point at which the patient was neurologically intact, not on a peep greater than 8 and/or FIO2 greater than 0.4, escalating doses of vasopressors, or a rising or unexplained lactate), the time was declared to be time zero and written beneath the stabilization phase. Expected phase achievement times were calculated in 6-hour intervals from time zero for the first 24 hours and then in 24-hour intervals until 48 hours after stabilization. The decision to use 6-hour intervals was based on clinical experience informed by evidence.14,15

The time a phase actually was achieved was noted beneath the expected time. Milestone scores were calculated by subtracting the actual achievement time from the expected time. A negative sign was given to the score indicating that a phase milestone was achieved earlier than the expected time, thus reducing SREBP complication risk, whereas a positive sign indicated a phase milestone achieved later than the expected time potentially increasing SREBP complication risk. Cumulative milestone scores indicated overall progress. The back of the worksheet was used for explanatory notes and further instruction.

SREBP Team Compliance

A trained research assistant joined all weekday morning and most afternoon rounds from March through August 2011 and from December 2011 through February 2012 to record team compliance using the team compliance worksheet. Afternoon rounds did not always occur due to competing priorities and other pressures, so some afternoon compliance data could not be included. The research assistant did not attend rounds between September and November 2011 to assess any observer effects. The same research assistant participated throughout the study.

These interventions are consistent with the following HRO principles:24 (1) Improve sensitivity to current operational outcomes. The prospective pathway form emphasized milestone outcomes (extubation, decatheterization) as the criteria for evaluating patient progress. The Interventions and Achievement Criteria checklists in Appendix 1 could be helpful in diagnosing team or patient reasons for a patient’s failure to progress. (2) Sensitivity to relationships. The longitudinal trajectory of care spans work shifts. Along with the inclusion of pathway status in major daily rounds, this emphasizes the continuous and team nature of care delivery. Daily inclusion in rounds was important in diagnosing reasons for failure to progress as either patient deterioration or deficits in team behavior and for considering changes in care.

Data Analysis

Hypothesis 1 and 2 were addressed by fitting regression models for patients’ lengths of ICU and hospital stay to mean cumulative milestone and team compliance scores. Potential patient confounding variables (Table 1) were prespecified and included in modeling along with the independent variables. A log transformation was applied to hospital length of stay to meet normality and constant variance assumptions. To allow the nonlinearity of continuous covariate, linear tail-restricted cubic spline with three knots were used.42 Quantile regression models with the same patient covariates were fitted to ICU length of stay because no suitable transformation was found. Unlike ordinary least squares regression models, quantile regression estimates the median (or other quantiles) of the dependent variables instead of the mean without making normality and equal variance assumptions.42 Missing data were handled by complete case analysis and multiple imputation method.43 Because conclusions based on these 2 methods were not significantly different, results reported in this paper were based on complete case analysis. To test hypothesis 3, the authors added an additional milestone by compliance score interaction term into their main models. The interaction was considered significant if the p value was less than 0.05.

Milestone scores for each patient were coded as missing or not, and a binary logistic regression model with compliance scores, patient covariables and admission time (quarters) was fit.42 Huber-White cluster sandwich covariance estimates were used to take account of correlations within patients.41 All analyses were performed using statistical software R version 2.15.1 (2012-06-22).

A Monte Carlo-based simulation was used to calculate the power to detect differences between the standardized global compliance scores (S) and hospital LOS (H). These values were generated randomly from normal distributions: \( S \sim N(\mu = 0, \sigma = 1) \) and \( H \sim N(\mu = 9.59 + S \cdot \tau, \sigma = 9.29 - \delta) \) where \( \mu \) is mean, \( \sigma \) is standard deviation, \( \tau \) is compliance effect size, and \( \delta \) is reduction factor associated with being compliant. The \( H \) constants were estimated from the 1,200 CVICU patients admitted over 1 year (1/1/09-12/31/09). In this simulation, \( \tau \) ranged between 0.25 and 2.00, \( \delta = 1 \) with sample sizes between 100 and 1,200.
Model parameters with robust standard errors were estimated using a linear regression model (compliance regressed on LOS or log[LOS]) with the significance assessed using the Wald test (two-sided; \( \alpha = 0.05 \)). The process was repeated 5,000 times for each parameter combination. The resulting power was the proportion of observed significant replicates. For 1,200 patients during a 1-year period, this study has more than 90% power to detect a 1-day change in LOS and even higher power to detect meaningful 2-day changes. A simulation using the least powerful analysis strategy (e.g., a t-test comparing LOS between those patients who were and were not SREBP-compliant) also showed a 90% power to detect a 2-day difference in LOS.

### RESULTS

Eight hundred surgical patients were enrolled between March 1, 2011 and February 29, 2012. However, 46 pathway forms had no identifying information, and 89 patients did not have compliance or milestone data. Thus, 665 patients admitted to the CVICU for cardiothoracic surgery (e.g., coronary artery bypass grafts, valve replacements) were included. Non-cardiothoracic surgery and cardiology patients were excluded as this study focused on postoperative milestones. No information identifying clinicians was collected. Table 1 provides a summary of patient demographic data obtained from the Society of Thoracic Surgeons' (STS) database at the study hospital.

<table>
<thead>
<tr>
<th>Patient Risk Variables</th>
<th>N</th>
<th>% (n)</th>
<th>Q1</th>
<th>Median</th>
<th>Q3</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>608</td>
<td>—</td>
<td>54</td>
<td>64</td>
<td>71</td>
<td>62</td>
<td>± 13</td>
</tr>
<tr>
<td>Gender: Male</td>
<td>608</td>
<td>62 (376)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>583</td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>90 (522)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>8 (45)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1 (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native American</td>
<td>1 (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>1 (5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1 (4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>665</td>
<td>—</td>
<td>23</td>
<td>27</td>
<td>31</td>
<td>26</td>
<td>± 11</td>
</tr>
<tr>
<td>Smoker: Yes</td>
<td>607</td>
<td>22 (131)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes: Yes</td>
<td>607</td>
<td>36 (213)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyslipidemia: Yes</td>
<td>607</td>
<td>34 (207)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension: Yes</td>
<td>607</td>
<td>73 (443)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Previous MI: Yes</td>
<td>607</td>
<td>27 (164)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart failure (CHF): Yes</td>
<td>607</td>
<td>10 (60)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta-blockers: Yes</td>
<td>596</td>
<td>63 (376)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACE/ARB inhibit: Yes</td>
<td>592</td>
<td>44 (260)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ejection fraction %</td>
<td>656</td>
<td>—</td>
<td>50</td>
<td>55</td>
<td>65</td>
<td>51</td>
<td>± 15</td>
</tr>
<tr>
<td>Coronary artery bypass graft: Yes</td>
<td>606</td>
<td>51 (312)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valve surgery: Yes</td>
<td>606</td>
<td>47 (286)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IABP: Yes</td>
<td>604</td>
<td>4 (27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reintubation during stay: Yes</td>
<td>392</td>
<td>8 (32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last creatinine level</td>
<td>601</td>
<td>0.83</td>
<td>0.99</td>
<td>1.25</td>
<td>1.12</td>
<td>± 0.71</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin-receptor blocker; BMI, body mass index; CHF, congestive heart failure; IABP, intra-aortic balloon pump; MI, myocardial infarction; SD, standard deviation.

Table 1 shows the individual milestone trajectories of the 665 patients. The sample of patients was not large enough to undertake a detailed statistical analysis of these trajectories, and subsequent analyses were based on the cumulative and not individual milestone scores. Figure 1 shows that patient trajectories appeared to unfold in 3 bands that have blurred edges to indicate that divisions currently are subjective. Patients in the lower grey band (milestone scores of less than about 10) achieved all milestone scores within or earlier than expected. Patients in the upper grey band with scores greater than about 35 did not achieve the phase-4 milestone within 48 hours post-stabilization and, as shown, some did not even achieve the phase-1 milestones within this timeframe. The patients in the middle white band show highly variable milestone scores. Even with apparently severe milestone delays (high scores), some patients were able to achieve the phase-4 milestone at or about 48 hours post-stabilization. Other patients did not achieve the phase-4 milestone within 48 hours even though they achieved some milestones as expected.

Table 2 shows descriptive statistics for independent and dependent variables. This study’s independent variables were each patient’s team compliance score collated from the team compliance worksheet and each patient’s milestone scores from the cardiac surgery pathway form. Team compliance scores were the number of criteria behaviors actually observed (pathway form present, milestone score presented, acknowledged, and discussed) divided by the number of opportunities observed for the team to achieve all compliance criteria. For example, a team that was observed to be compliant with 8 items from a possible 12 (4 items per round for 3 observed rounds) would have a compliance score for this patient of
H1: Association Between Team Compliance and Lengths of Hospital and ICU Stay

Figure 2 shows the predicted length of ICU and hospital stay as a function of team compliance. As team compliance scores increase from 0.25 to 0.88, the estimated mean cumulative milestone score increased by 3.14 (95% CI: 0.74-8.41; p = 0.002), and for patients who were reintubated during the admission, the estimated cumulative milestone score increased by 4.57 (95% CI: 0.74-8.41; p < 0.0001) on average higher than patients who were not reintubated.

H2: Association Between Milestone Scores and Lengths of ICU and Hospital Stay

Figure 3 shows the predicted median length of ICU and hospital stay as a function of the mean cumulative milestone scores, which were used to avoid co-linearity. As the mean milestone scores increased from -7 to 12, the estimated mean cumulative milestone score increased by 3.41 (95% CI: 0.47-6.35; p = 0.008). Both complete case analysis and the multiple imputation method were applied to missing values. Results based on these 2 methods were not significantly different statistically for ICU and hospital lengths of stay. The results shown in Figure 2 are based on a complete case analysis.

H3: Association Between Patient Factors and Milestone Scores

Patients who were older and/or underwent valve surgery and/or were reintubated during the admission episode had higher milestone scores than patients without these comorbidities. As age increased from 54 to 71.25 years, the estimated mean cumulative milestone score increased by 1.51 (95% CI: 1.51-4.77; p = 0.038). For patients undergoing valve surgery, the estimated mean cumulative milestone score increased by 3.41 (95% CI: 0.47-6.35; p = 0.002), and for patients who were reintubated during the admission, the estimated cumulative milestone score increased was 4.57 (95% CI: 0.74-8.41; p < 0.0001) on average higher than patients who were not reintubated.

DISCUSSION

This study investigated the relationship between HRO approaches to SREBP bundle implementation and patient lengths of CVICU and hospital stay. The authors’ results suggest that patients who achieved SREBP milestones with the expected 48 hours after stabilization had shorter lengths of CVICU and hospital stay than patients who did not achieve this milestone. This result is consistent with previous studies. However, this study focused on tracking trajectory milestone events and compliance with team processes. It was designed to promote adaptation as a means for reducing complication risk and, subsequently, increased length of stay.

However, the cumulative milestone scores used in the authors’ statistical analysis may not adequately capture and may even hide significant underlying dynamics in patients’ recovery trajectories. The relationship between milestone achievement and lengths of stay appear to be more complex than expected. Figure 1 shows that there were patients who achieved milestone outcomes in times that were better than expected (lower grey band). These patients did well and could be discharged from the CVICU quickly. Similarly, there were patients who rapidly deviated from the pathway and did not achieve even the early milestones (upper grey band). These patients may fall into a completely separate bundle of care with different endpoints and milestones. Finally, there was a third group of patients with uncertain trajectories (white band in Fig 1). Although these patients deviated from the expected trajectory, they were identified quickly so that deviations could be recovered. This group may benefit most from a milestone-oriented adaptive care pathway.

It was a limitation of this study that the authors were unable to investigate these patterns in more detail. However, their
findings, including insights in relation to Figure 1, suggested that (1) tracking patient progress by milestone events may distinguish patients who are progressing from those who may be deviating from the expected course and, (2) using an expected outcome approach, deviations may be identified early in the postsurgical period. With earlier identification of trajectory deviation, team members are better able to reprioritize or modify their activities to reduce deviations. In this way, deviations may be recovered before they lead to adverse complications.

Using HRO implementation approaches requires a cultural shift in orientation from a task checklist to an adaptation and outcome or event-driven approach. Central to the operations principle of an HRO approach, overall outcomes (eg, length of stay) are determined by actively tracking micro-outcomes (time to extubation, time to decatheterization etc.) and by adapting care delivery or care delivery priorities in response to milestone deviations.

This study suggested a number of research questions that could be addressed with a better-targeted study design. For example, it is unclear why some patients in the white band in Figure 1 recovered from milestone deviations and others did not. It is unclear what team members did to achieve milestone recovery. The Adult Cardiac Surgery Pathway form was paper-based, so milestone scores could not be calculated continuously. The effect of computerizing the pathway scores on team effectiveness and adaptability and patient outcomes is unclear. Research currently is being undertaken to explore these issues in greater depth. The institution is partnering with CMS to trial bundle-of-care payments in cardiac surgery. The authors have taken what they have learned from this study and, with the information technology department, developed an electronic
of Caucasian patients. Resolving sampling concerns would also enhance the generalizability of the authors’ results.

Research observers may also have affected team behavior. However, there were no observed differences in milestone achievement or lengths of stay between September and November when observers were withdrawn.

CONCLUSION

A milestone outcome-driven cardiac surgery pathway supported by effective team rounding processes was associated with decreased lengths of ICU and hospital stay. However, tracking patient trajectories by milestone outcomes suggests that this relationship is more complex than anticipated. Using a HRO approach can present new questions about SREBP implementation research.

REFERENCES

GOAL-DIRECTED PROTOCOLS AND LENGTH OF STAY


