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A Novel Clinical Decision Support System for Gastrointestinal Bleeding Risk Stratification in the Critically Ill

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Introduction: Acid suppression therapy can reduce the development of stress and medication-related mucosal disease when prescribed appropriately. Suboptimal inpatient prescribing of acid suppression therapy therefore may lead to increased development of gastrointestinal hemorrhage in high-risk populations. The aim of this quality improvement study was to improve appropriate acid suppression therapy in patients admitted to ICUs in an academic medical center.

Intervention Development, Implementation, and Adaptation: An adaptable, multifaceted implementation strategy guided by unit-based root cause analysis was initially developed in a single ICU with a high-risk population. Identifiable targets of intervention, including provider awareness, unstructured rounding protocols, and electronic communication tools, were augmented by the development of an automated alert system. This electronic dashboard risk-stratified patients based on information derived from the electronic medical record (EMR). The dashboard then offered clinical decision support. Use of the dashboard and percentage of appropriate acid suppression therapy prescriptions were tracked over time.

Results: Appropriate acid suppression therapy prescribing was improved from 72.9% to 86.0% ($p < 0.001$).

Conclusion: Automated technology including an EMR-supported electronic dashboard was the foundation of successful intervention. Considering the deleterious effects of both under- and overprescribing of acid suppression therapy, particularly in high-risk patient populations, this type of technology may lead to enhanced patient outcomes.

INTRODUCTION

Framing the Problem

Gastrointestinal hemorrhage is a rare but clinically significant complication of hospitalization linked to increased morbidity, mortality, and health care costs.[1] It is most prevalent in patients who are critically ill or take certain high-risk medications, such as nonsteroidal anti-inflammatory drugs (NSAIDs), antiplatelet agents, or anticoagulants.[2,3] Risk can be mitigated by acid suppression therapy, though these medications are associated with adverse outcomes, including increased risk of enteric infections such as *Clostridium difficile*.[4] It is therefore important to differentiate the patients who will derive the most benefit from acid suppression therapy from those who will not to maximize clinical effectiveness and associated outcomes.

Impact and Setting

Our health care system is a large academic medical center consisting of multiple hospitals and ambulatory centers. Patients commonly have advanced multiorgan disease, and the hospital system serves as a large referral center for the surrounding area. Inpatient complications of hospitalization are tracked routinely and reviewed for potential targets of intervention. During the 2015 academic year, gastrointestinal hemorrhage was the second most common complication in patients admitted for another indication, affecting 5.85 patients/1,000 admissions. Each occurrence of inpatient bleeding led to an estimated additional cost per complication of $16,800 and an additional length of stay of 14.2 days.

On further analysis of this complication, it was noted that patients admitted to a cardiac service, either the cardiac intensive care unit (CCU), cardiothoracic surgery unit (CTSICU), or cardiac intermediate care unit (CICU), bled at nearly twice the rate of other hospitalized patients, with 11.56 bleeds/1,000 admissions. To determine why these patients had higher bleeding rates, a chart audit was conducted in January 2016. The audit found that cardiac patients were significantly more likely to be prescribed high-risk medications. These patients were also less likely to be prescribed appropriate acid suppression therapy. This included both under- and overprescription of acid blocking medications based on individualized risk assessment. Considering the disease burden of gastrointestinal hemorrhage in this population and the intervenable target–inappropriate acid suppression therapy–a quality improvement initiative was developed.

INTERVENTION DEVELOPMENT, IMPLEMENTATION, AND ADAPTATION

Each unit in question was analyzed in terms of culture, resources, and structure, with considerable differences noted between sites. Because the CCU was a small, closed unit staffed by a single medical team, it was chosen as an initial site of intervention. Surveys and root cause analyses were

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used to understand variability in local acid suppression therapy prescribing habits. This analysis revealed a multifactorial problem stemming from the hospital system's lack of a standardized acid suppression therapy guideline and an appropriate and adaptable means of high-risk patient identification (Figure 1). This absence of a standardized process laid a foundation for intervention development.

Guideline Creation

Intervention efforts began with the development of a multidisciplinary task force consisting of cardiologists, gastroenterologists, pharmacy leads, and nursing specialists. This task force confirmed the need for a standardized guideline for acid suppression therapy to improve provider prescribing habits and ensure an evidence-based approach to care delivery. Through a series of consensus meetings, which analyzed published literature and national society recommendations, a guideline was created for the unit.[5,6] This guideline was approved for use in January 2017 by the hospital system's pharmacy consortium (Figure 2).

Intervention Development and Implementation

After a guideline was created, the task force discussed effective dissemination of the information. Education through the dedicated CCU pharmacist was the initial means of intervention. These education efforts, however, did little to change provider behavior. Patient acuity was high, limiting teaching efforts, and house staff rapidly cycled between clinical rotations, reducing continuity of care and guideline awareness. An alteration of how care was delivered was then targeted, with a restructuring of morning rounds. A paper checklist was developed, which emphasized standardized components of critically ill patient care, including pharmacological prophylaxis, antibiotic administration, intravenous access, mobility, and intubation status. The clinical team, which consisted of an attending physician, fellows, residents, and a dedicated pharmacist, used this checklist for crafting patients individualized care plans starting in early February 2017. The process owner of this intervention was the cardiology fellow, who rounded with the team daily and remained on service longer than resident house staff members. Although this intervention continued to increase awareness of the need for appropriate acid suppression therapy in these patients, it only moderately improved delivery of care.

At this point, our innovation center was brought in as a consulting partner, with additional analysis of process and previous implementation efforts. It was noted that although providers were now more likely to address the question of acid suppression therapy during morning rounds, patient acuity remained high and components of the checklist were often skipped secondary to time constraints. In addition, there was no easy means of obtaining individualized risk stratification information, which led to continued inappropriate acid suppression therapy ordering practices. Based on these principles, an electronic dashboard was created in late February 2017 that risk-stratified patients based on prespecified guideline criteria (Figure 3). The dashboard interfaced with the existing electronic medical record (EMR) (Eclipsys Sunrise Clinical Manager Enterprise) to pull information in real time so that it was available during rounding. This supplemental dashboard was part of a larger, systemwide effort to standardize care of critically ill patients through electronic interventions. This specific project tracked only information regarding acid suppression therapy, though additional clinical

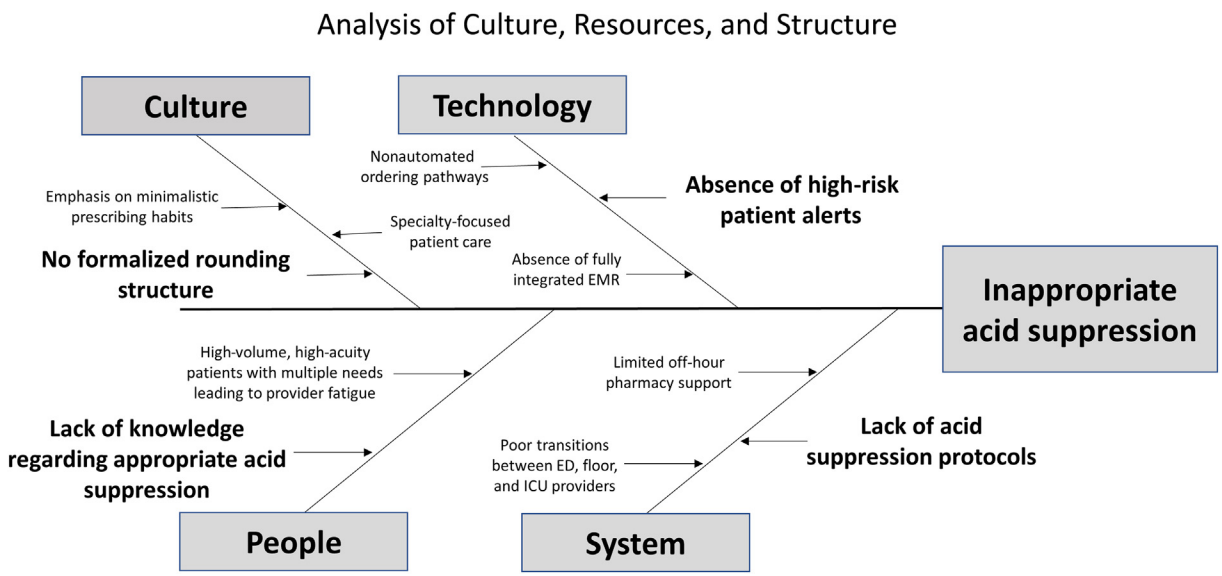

Figure 1. An analysis using surveys and root cause analyses revealed a multifactorial problem resulting from the hospital system's lack of a standardized acid suppression therapy guideline and an appropriate and adaptable means of identifying high-risk patients. EMR, electronic medical record; ED, emergency department.

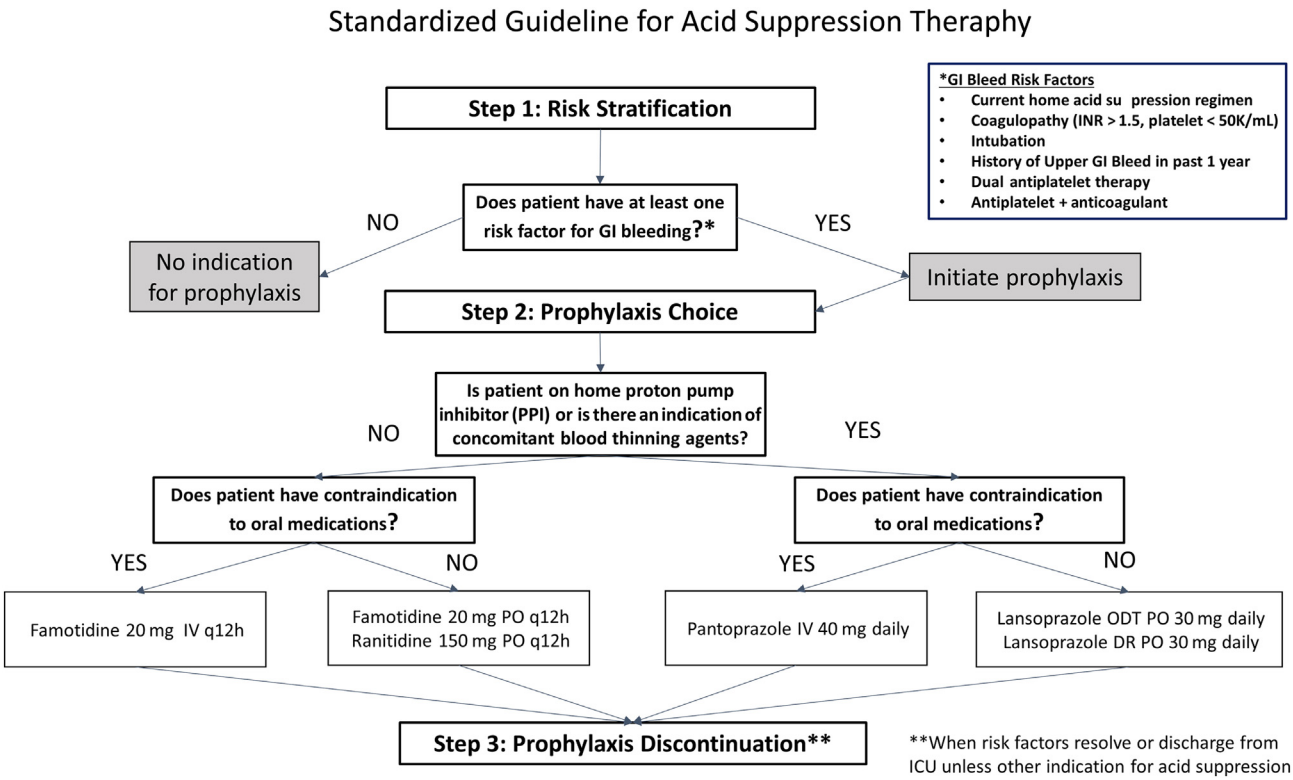

Figure 2. After a task force confirmed the need for a standardized guideline for acid suppression therapy, the guideline shown in this figure was created through a series of consensus meetings and was approved for use in January 2017. GI, gastrointestinal; INR, International Normalized Ratio.

information is being considered for future projects.[7] In terms of dashboard utilization, the previously mentioned itemized checklist triggered discussion of acid suppression therapy for each patient. The rotating CCU pharmacist would then access the dashboard, which would provide real-time clinical decision support. The pharmacist would document this discussion and its outcome, a parameter that was tracked over time.

During the intervention period, the dashboard was accessed once daily during morning rounds for all consecutive patients admitted to the CCU. This intervention period was followed by a hospitalwide transition to an alternative EMR system (Epic Systems), which required the dashboard to be reconfigured. During this transitional time, standardized rounding efforts were continued, as were brief educational sessions by the CCU pharmacist. The dashboard was reinstated in June 2017 with an updated interface. Information derived from the EMR, both old and new, was queried to track compliance over time.

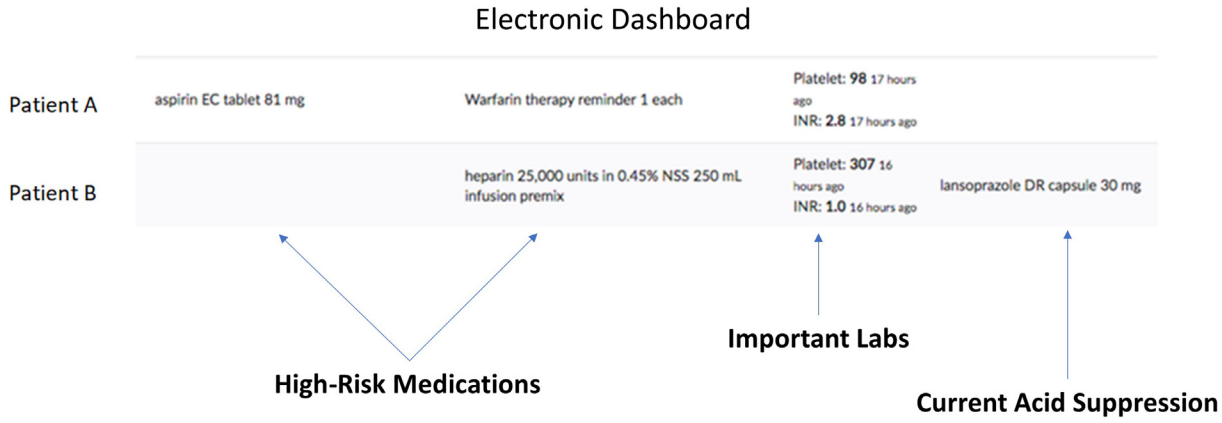

Figure 3. An electronic dashboard designed to risk-stratify patients based on prespecified guideline criteria was created in February 2017. The dashboard interfaced with the electronic medical record. INR, International Normalized Ratio.

Table 1. Demographic and Clinical Characteristics of Study Population

	Preintervention (*N* = 292)	Postintervention (*N* = 529)	*p*
Demographics			
Female *n* (%)	98 (33.6)	179 (33.8)	0.936
Median age in years (IQR)	61 (52–69)	61 (50–70)	0.344
Bleeding Risk			
Home acid suppression *n* (%)	40 (13.7)	71 (13.4)	0.911
Intubation status *n* (%)	51 (17.5)	55 (10.4)	0.004
Concomitant blood thinners *n* (%)	114 (39.0)	223 (42.2)	0.385
Nonpharmacological coagulopathy (INR > 1.5 or platelets < 50,000) *n* (%)	28 (9.6)	43 (8.1)	0.476

IQR, interquartile range; INR, International Normalized Ratio.

METHODOLOGY AND RESULTS

Methodology

After obtaining approval from the hospital's Institutional Review Board, we analyzed our intervention in the CCU to guide additional intervention efforts in other ICUs. This led to the review of the EMR of all patients admitted to the CCU between September 1, 2016, and January 1, 2017. During this review, targets of intervention were recorded, including basic demographic information, admission date, home acid suppression regimen, and the presence within 24 hours of admission of inpatient medications, including all anticoagulant, antiplatelet, and acid suppressing agents; intubation status; International Normalized Ratio (INR); and platelet count. This information was again collected during the initial intervention phase between January 2, 2017, and August 31, 2017. The information was used to calculate a percentage of appropriate acid suppression therapy by week, our primary outcome, based on the approved consensus guideline document. Appropriate acid suppression was defined as the prescription of an acid blocking agent when it was indicated and the absence of prescription when it was not. These data were graphed into a statistical process control (SPC) chart using standardized Shewhart control chart rules. Rates of acid suppression therapy prescription when they were not indicated (overuse) and *C. difficile* infections were tracked, serving as balancing metrics. Rates of gastrointestinal hemorrhage were tracked as additional outcome metrics. Outcomes pre- and postintervention were compared using a Student's *t*-test for continuous variables and Pearson's chi-square test for binary variables.

Results

During the preintervention phase, 292 patients were admitted to the CCU for care. Of these patients, 33.6% were female with a median age of 61 years (interquartile range

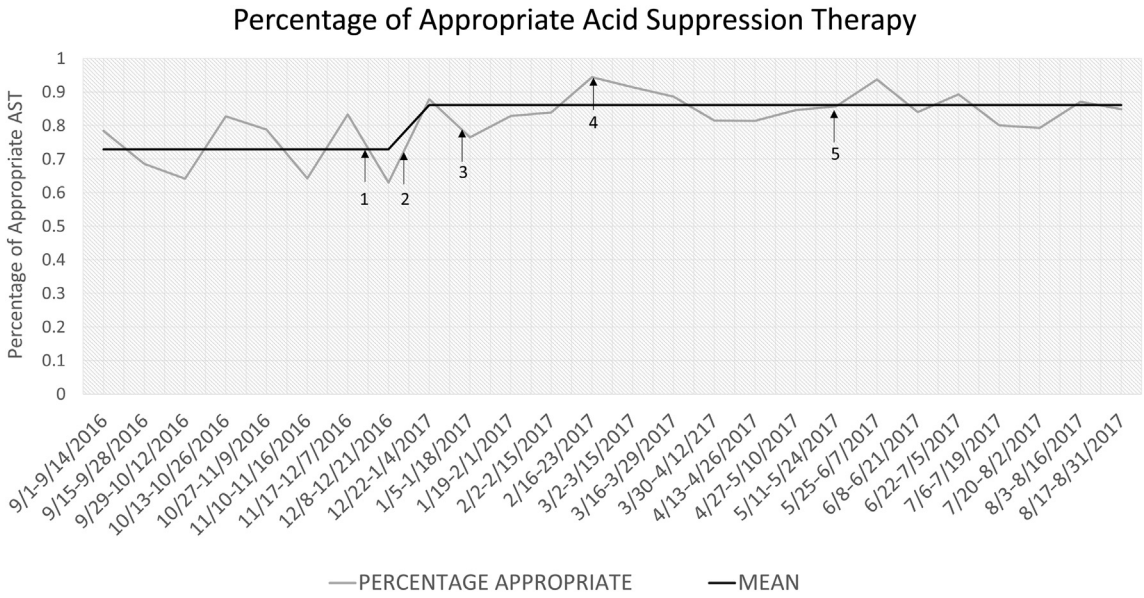

Figure 4. The chart demonstrates the improvement in the rates of appropriate acid suppression therapy (AST). The initial intervention phase was from January 2, 2017, through August 31, 2017. The numbers refer to specific time points during the study: (1) guideline introduction; (2) rounding restructuring; (3) dashboard implementation; (4) change of electronic medical record; (5) dashboard reintroduction.

[IQR]: 52-69 years). About one fifth (17.5%) were intubated. Regarding anticoagulation treatment, 24.3% of patients were not on any anticoagulant or antiplatelet agent, 39.7% were on a single agent, and 39.0% were on at least two agents. In addition, 13.7% of patients were on a home acid suppression regimen, and 9.6% of patients had an organic coagulopathy (defined as an INR > 1.5 or platelet count < 50,000). When compared with the postintervention population (529 patients), results were similar, apart from intubation status, which was more prevalent in the preintervention group (p = 0.004) (Table 1). Rates of appropriate acid suppression therapy improved from 213/292 patients (72.9%) to 455/529 patients (86.0%) with intervention, with durability of results over time (p < 0.001) (Figure 4). Appropriate therapy included patients being prescribed the medication when it was indicated (132/213 patients [62.0%] preintervention vs. 315/455 [69.2%] postintervention) and not being prescribed the medication when it was not indicated (81/213 [38.0%] preintervention vs. 140/455 [30.8%] postintervention). In terms of overprescription of acid suppressing agents, although there was a trend in increased rates, this was not statistically significant (0.6% vs. 1.1%; p = 0.530). *C. difficile* infection rates also remained stable (0.5% vs. 0.3%; p = 0.546).

In terms of incidence of gastrointestinal bleeding while hospitalized, bleeding rates in all admitted patients remained stable (5.85 patients/1,000 admissions vs. 5.22 patients/1,000 admissions; p = 0.762). Rates in the cardiac population decreased in absolute number; however, this was not statistically significant (11.56 patients/1,000 admissions vs. 5.96 patients/1,000 admissions; p = 0.155). It should be noted that cardiac patients still included both CCU patients (the site of intervention) and CICU and CTSICU patients (where intervention had yet to be carried out). Bleeding rates in CCU patients specifically were unavailable secondary to coding limitations.

CONCLUSION

Using a multifaceted implementation strategy that included development of a working group, defining consensus guidelines, altering rounding structure, and refining an electronic dashboard to highlight opportunities for intervention, our group increased appropriate acid suppression therapy from 72.9% to 86.0% of all patients admitted to our hospitals CCU, with overall reduction in bleeding incidence. Based on these results, additional sites of intervention have been targeted with adaptation of our implementation strategy based on unit culture.

Our overall goal is to implement elements of this electronic dashboard throughout the health care system to standardize ICU medication ordering practices and improve delivery of evidence-based care. We believe improvement in prophylactic efforts will improve outcomes in critically ill patients who are at high risk for gastrointestinal bleeding, such as those in the CCU, though we acknowledge data are still limited regarding best practices in this population. Recent literature has questioned the need for routine acid suppression in ICUs, though limited data exist regarding specific bleeding risk factors, including the use of dual or triple blood thinning agents in critically ill cardiac patients.[8] Confounding variables such as increased use of early enteral nutrition may also play a role in decreasing the utility of acid suppression in these populations.[9] A strength of our intervention is its adaptability–even if guidelines evolve, our electronic dashboard can be altered to identify high-risk patients based on current best practices.

We understand that our study has limitations, including heterogeneity of the populations pre- and postintervention, and confounding factors such as alteration in the EMR during the study. Despite these limitations, we believe the dissemination of a multifaceted implementation strategy to alter current ICU medication ordering practices has high potential to improve patient outcomes.

Lessons Learned

Our initial intervention relied on education efforts to disseminate information and alter provider prescribing habits. Limitations to this method include its reliance on continued education to reinstate ideas, particularly in clinical sites with high personnel turnover, as well as an absence of sustainability measures. Alternatively, using a personalized and adaptable strategy that factored in the internal and external environment proved to be more successful, aligning with previously published literature on quality improvement implementation.[10-13] In addition, the use of technology to augment clinical decision making and automate time-consuming processes was necessary to increase the sustainability of the intervention. This type of clinical decision support system allows for integration of patient-specific data with a computerized clinical knowledge base to guide provider behavior for sustainable change.[10,13-16] It also enhances provider knowledge and pattern recognition, which led to increased appropriate acid suppression therapy percentages over baseline, even when the tracker was off-line (Figure 4).

Next Steps

Based on our success in the CCU, a hospital system-wide consensus guideline for acid suppression therapy in the critically ill was developed and approved for use in January 2018. This guideline is being used to direct acid suppression therapy efforts across ICUs with a goal to implement the electronic dashboard in all units. It has become evident to us that multifaceted implementation strategies like this one benefit from continued analysis and adaptation. A brief trial of our protocol was conducted in our neurological ICU

(NICU) during the study period; however, this failed in the setting of alternative unit culture and rounding structure. Use of the electronic dashboard in this new unit was adapted to this alternative clinical setting. For instance, rather than triggering discussion of acid suppression therapy on rounds, patients were risk-stratified virtually by an intern who accessed the dashboard twice daily, during specific time periods. Using this information, the intern created actionable tasks within an electronic sign-out document that was already part of standard clinical work flow. In addition to modifiable tasks in the sign-out document, text messaging using a HIPAA-compliant messaging software was trialed. Based on feedback from primary providers, communication tactics and scripts were altered over time.

As the pilot in the NICU was brief (four weeks in duration), it was not possible to obtain meaningful data regarding outcomes. However, the pilot provided insight into how best to address intervention in other hospital units through continued unit culture analysis with appropriate alterations in process, usability testing among new stakeholders, and adaptations to current practices. Concomitant with awareness of standardization of acid suppression therapy delivery to patients using an electronic dashboard, definitive outcome and balancing metrics continue to be tracked as interventions are carried out in hospital units.

Conflicts of Interest. All authors report no conflicts of interest.

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