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When do workarounds help or hurt patient outcomes? The moderating role of operational failures

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Abstract

Hospital providers often use workarounds to circumvent processes so that patients can receive care. Workarounds in response to operational failures enable care to continue and therefore may be indicative of workers' commitment. On the other hand, workarounds in the absence of operational failures may signal an ineffective approach associated with lower quality of care and worse patient outcomes. Working closely with healthcare providers, we developed a survey to measure workaround behaviors and operational failures on medical/surgical units. The lead author surveyed over 4,000 nurses from 63 hospitals throughout the United States. We matched this data with audit data on the incidence of pressure injuries among over 21,000 patients on 262 nursing units in 56 survey hospitals. Hospital-acquired pressure injuries are a significant risk to patient health and hospital costs. We do not find support for our hypothesis that workarounds are associated with a higher rate of hospital-acquired pressure injuries. However, when we take into account the moderating role of operational failures on the relationship between workarounds and pressure injuries, we find significant results. When nursing units have lower levels of operational failures, workarounds are associated with higher rates of hospital-acquired pressure injuries. Our results provide evidence that workarounds may be associated with negative patient outcomes, if they stem from a process-avoiding approach. The best results can be achieved by reducing both operational failures and workarounds via instilling a process-focused approach.

KEYWORDS
healthcare cost, medical error, operational failures, survey, workarounds

1 | INTRODUCTION

Even when there are established procedures for how work should be done, workers do not necessarily follow them. Noncompliance to set procedures can be a deliberate attempt to improve a local performance measure. This insight dates back at least to the 1980s, when studies of complex information technology systems found that users often "worked around" information technology systems in order to accomplish their own work goals (Gasser, 1986). Computerized material requirements planning systems of that era, for example, were notorious for having inaccurate information about manufacturing status and for inflexibility in adjusting to complex or rapidly changing situations. Users coped by creating their own unapproved techniques, such as systematically altering inputs or creating manual systems to work parallel to the formal system.

The concept of workarounds also appears in literature on healthcare services and service quality. Workarounds are actions taken by an individual or a group to accomplish a work goal when existing processes make it difficult to accomplish that goal (Halbesleben, Wakefield, & Wakefield, 2008). Workarounds may be used to address limitations or failures in work processes, to get by when workers lack knowledge of correct procedures, to bypass standards to meet alternative objectives, to save time, or to accomplish various other purposes. Although workarounds are often deviations from approved methods, workers' intentions in using them are usually to *improve* performance in some way. In nursing units, the intent is often to conduct a patient care task faster than the formal procedures allow, enabling clinicians to provide more care (Lalley, 2014).

One reason that workarounds are receiving research attention in healthcare settings is their seeming conflict with the important goals of improving patient safety and reducing mortality and morbidity caused by the healthcare system itself (McFadden, Henagan, & Gowen III, 2009). When a particular task, such as administering medication, has a high error rate, a common solution is to surround it with a formal procedure that checks for errors (Mazur & Chen, 2008). Another approach is mistake proofing (Grout, 2006), such as completely segregating medication-related activities for each patient and using barcode scanning to ensure that the correct patient receives the correct medications. In both cases, nurses may perceive the additional steps as nonvalue-added and time-consuming, and when rushed, they may bypass or work around the mistake-proofing activities (Koppel, Wetterneck, Telles, & Karsh, 2008).

However, the net effect of workarounds on performance is not straightforward. Workarounds can have mixed effects on health outcomes, on costs, and on measures of service quality. The presumption of the literature on process standardization is that workarounds have net negative effects. When safety procedures are bypassed in an effort to save time, workarounds can contribute to errors (Koppel et al., 2008; Tucker, 2016), safety risks (Brown, Willis, & Prussia, 2000), and poor patient outcomes. By reducing process standardization, workarounds increase process variation (Bendoly & Cotteleer, 2008). Process variation can decrease performance and stifle organizational learning (Mazur & Chen, 2008; Naveh & Marcus, 2005; Spear & Schmidhofer, 2005). But on the other hand, workarounds add flexibility and innovation to a system, enabling staff to respond to situations that were not considered when a procedure was created (Lalley, 2014; Morrison, 2015; Petrides, McClelland, & Nodine, 2004; Sarnecky, 2007). In the context of our study, workarounds may be logical and expedient responses to problems.

The overall effect of workarounds on outcomes of interest, especially patient health, can therefore only be resolved by research, which measures health outcomes. To our knowledge, there are a few if any tests of the impact of workarounds on actual health outcomes. We address this gap by measuring the incidence of a serious and relatively common complication in medical and surgical nursing units. Examining the effects of workarounds on an important health outcome pressure injuries. This also serves as a test of the theory of work standardization and quality. Deviations from process standards, which are not directly quality related harm nonquality measures of process performance but do they also actually harm final patient outcomes?

The theoretically mixed effects of workarounds suggest that *why* they are done may determine their impact. In this article, we examine workarounds as related to the frequency of operational failures. Operational failures include breakdowns in the supply of materials, equipment, and internal services needed to complete tasks (Tucker, 2004). Our premise is that to the extent that workarounds are responses to operational failures, they might be useful. When service providers encounter operational failures, they can choose to work around the failures. For example, taking supplies from other units (Survey question WA1) may be a response to out-of-stock supplies (Survey question OF1). Such workarounds in response to operational failures may be beneficial for patients because they enable service to continue more quickly than if the providers followed the official response. Units that have high levels of both operational failures and workarounds are using a fire-fighting approach to solving problems (Bohn, 2000). But when there is a high level of operational failures providers may choose not work around them. These decisions may signal an apathetic problem-solving approach that results in patients not getting the care they need in a timely fashion.

A third approach occurs on units where operational failures are rare but providers nonetheless decide to engage in workarounds for other reasons. Workarounds performed in the absence of operational failures might reflect an approach overly driven by corner-cutting (Oliva & Sterman, 2001), where employees either lack clear processes or ignore known policies and standard procedures (Mazur & Chen, 2008; Oliva & Sterman, 2001). Such a process-avoiding approach might result in lower service quality because of weak design of work processes and variability in their execution. Finally, a fourth approach occurs in contexts where there are few operational failures and providers abstain from using workarounds, signaling a process-focused approach that may result in higher service quality.

Many previous studies have looked at the causes of workarounds in healthcare processes, such as the blocks encountered after the introduction of new medication administration technology (Ash, Berg, & Coiera, 2004; Halbesleben, Savage, Wakefield, & Wakefield, 2010; Holden, Rivera-Rodriguez, Faye, Scanlon, & Karsh, 2013; Koppel et al., 2008). However, to the best of our knowledge, there are few tests of the impact of workarounds on actual health outcomes. We address this gap by examining the effects of workarounds on an important health outcome—pressure injuries—while taking into account the moderating role of operational failures.

Pressure injuries ("bedsores" or "pressure ulcers") result from inadequate microcirculation to the skin, even for a few hours, and are a particular problem for bedridden patients. If the injuries occur during a patient's hospital stay, they are called hospital-acquired pressure injuries (HAPI). HAPI are a serious problem in the American healthcare system. HAPI are painful for patients and lengthen their hospitalizations. They cause complications that lead to about 60,000 deaths annually, and their occurrence is on the rise (Sullivan & Schoelles, 2013). However, HAPI can be avoided through various actions by nurses, such as rotating immobilized patients every two hours, which is labor intensive but effective. After pressure injuries start, early detection and treatment can lessen their severity. For these reasons, the U.S. Medicare system considers serious HAPI as an avoidable condition and does not reimburse hospitals for the care and additional days in the hospital required to treat them (Levinson, 2010). Thus, HAPI are important outcomes, which affect patient health and hospital costs and income. In operational terms, a HAPI is a defect that forces the hospital to do "rework" for which it is not paid. HAPI raise healthcare costs by an estimated $11 billion annually in the U.S. healthcare system (Reddy, Gill, & Rochon, 2006; Sullivan & Schoelles, 2013). We use HAPI as a measure of hospital performance and as a direct health outcome related to poor quality of nursing care and increased costs.

To study the relationships among operational failures, workarounds, and patient outcomes, the first author, in conjunction with a medical/surgical nurse, developed a survey instrument, which was administered to over 4,000 nurses from medical/surgical units in 63 hospitals. In this article, we match the survey data with quarterly audit data on the incidence of HAPI among patients on the surveyed units at 56 of the 63 hospitals during the year surrounding survey administration. We find that workarounds in units with few operational failures are associated with more HAPI.

Our article makes several contributions to the operations management literature work processes and problem-solving approaches. Some prior studies use publicly reported, hospital-level data to measure both process quality (Boyer, Gardner, & Schweikhart, 2012) and outcomes (Senot, Chandrasekaran, Ward, Tucker, & Moffatt-Bruce, 2016) but do not study workarounds. In comparison, we gather primary data at the unit level to examine workarounds, a topic which has received scant attention by operations management scholars. Furthermore, many studies have to rely on staff perceptions to gather data on patient outcomes (Gowen Iii, McFadden, Hoobler, & Tallon, 2006; Stock, McFadden, & Gowen Iii, 2007). We are able to link workarounds to an objective measure of individual patient outcomes. We also develop a framework of four different problem-solving approaches to explain the relationship between operational failures, workarounds, and service quality outcomes. In the next section, we review the literature on workarounds and develop our hypotheses. We then explain our data and methods. We present results in Section 4 and discuss implications for research and practice in Section 5.

2 | LITERATURE REVIEW AND THEORY DEVELOPMENT

2.1 | Operational failures, workarounds, and the link to patient outcomes

Employees have at least two different reasons for performing workarounds. First, some workarounds occur when workers encounter and circumvent blocks in their work flow (Halbesleben, Rathert, & Bennett, 2013). Many blocks in healthcare are caused by operational failures related to breakdowns in the internal supply chains that provide medications, materials, and equipment to clinicians (Fredendall, Craig, Fowler, & Damali, 2009; Tucker, 2004). Employees are often motivated to work around operational failures so that they can complete the task at hand (Oliva & Sterman, 2001). Workers often face time pressure (Morrison, 2015), which can be exacerbated by operational failures. Operational failures interrupt providers' focus, increasing the time required to accomplish the original task (Froehle & White, 2014). In addition, the blocks can require service recovery to retain customers and regain their satisfaction (Miller, Craighead, & Karwan, 2000). The time spent working around operational failures consumes time that could have been used to provide service. Thus, both operational failures and workarounds may indirectly lead to lower quality and reduced outcomes.

Second, workarounds may occur as a result of employees wanting to cut corners, even if there is no operational failure (Oliva & Sterman, 2001). Studies have shown that pursuing operational effectiveness can pressure workers into taking safety short cuts (Mazur & Chen, 2008; Pagell, Klassen, Johnston, Shevchenko, & Sharma, 2015). Safety risks and short cuts can negatively affect providers and patients. However, the existence and costs of these workarounds may be invisible to managers, weakening their motivation to remedy the underlying causes (Tucker & Edmondson, 2003). In this manner, workarounds create self-reinforcing cycles that are difficult to end because they are effective in the short term (Morrison, 2015).

Despite their potential importance, a few studies investigate the impact of workarounds on actual patient outcomes. One study examines barcoded-medication administration systems and finds that nurses sometimes diverge from official medication administration processes in order to complete their work faster. Nurses overrode medication alerts for 4.2% of the medications administered (Koppel et al., 2008). The authors argue that such workarounds could lead to medication errors, although in their study it did not.

A second study is a laboratory experiment that illustrates how nursing workarounds can increase risks to patients (Tucker, 2016). Nurses were required to prepare and administer 8 units of insulin for a simulated patient, but their work station had syringes that were not properly calibrated. They could either walk to a distant storage location to get the proper syringe or calculate a conversion factor for using the inappropriate syringe (a quick but risky workaround). In one set of experimental conditions, 26% of participants used the risky workaround, of whom 22% (8 of the 137 nurses in the experiment) made a calculation error and administered a 10-fold insulin overdose of 80 units to the patient. Other participants did not administer any insulin, for a total error rate of 14%.

Other researchers have studied the drivers of workarounds through surveys. Halbesleben et al. (2013) asked whether the respondent altered her work processes because of problems with five domains: technology, work processes, people, rules/policies, and equipment. They found that higher levels of psychological safety were associated with a lower frequency of workarounds. They developed a second, larger survey scale containing 20 items (Halbesleben et al., 2013). For each of the five domains in their 2008 survey instrument, they asked participants about four cognitive processes associated with workarounds: (a) perception of a block; (b) altering their work process to work around the block; (c) their preference to follow the official procedure; and (d) their motivation to use the workaround to assist patients rather than to save time for themselves (Halbesleben et al., 2013). They found that workarounds were positively correlated with participants' self-reported number of patient safety events and were negatively correlated with the participant's self-reported level of patient safety on the unit (Halbesleben et al., 2013).

Additional research on the link between workarounds and actual patient outcomes is needed. First, workarounds may sometimes improve outcomes by enabling timely care. Second, even when there is a safety lapse (such as in Tucker, 2016), subsequent processes could prevent harm to the patient. Thus, the effects of workarounds must be measured empirically. It is challenging for the researchers to get approval to gather sensitive data related to workarounds, medical errors, and patient outcomes (Halbesleben et al., 2013). Consequently, most studies of workarounds rely on interviews or observations, limiting sample size and the ability of such studies to detect the impact of workarounds on patient outcomes (Halbesleben et al., 2008). Additionally, few studies examine interactions between workarounds and operational failures despite the risks from breakdowns in internal supply chains (Fredendall et al., 2009; Zheng et al., 2017).

2.2 | Causes of pressure injuries

The specific patient outcome that we study is HAPI. Pressure injuries are localized damage to the skin caused by prolonged pressure. They typically form over bony prominences, such as elbows and heels (National Pressure Ulcer Advisory Panel, 2016). Elderly people with limited mobility, circulation, and nutrition are particularly susceptible to pressure injuries, which can occur and progress within a few days (Edlich et al., 2004). Pressure injuries are a serious, painful concern for patient safety and can lead to further complications, such as infections. The severity of pressure injuries are rated on a scale ranging from Stage 1, which is reddened skin, to Stage 4, which is a deep ulcer that penetrates to the bone (National Pressure Ulcer Advisory Panel, 2016). The centers for nedicare & medicaid services (CMS) classify hospital-acquired, serious pressure injuries (Stage 3 and Stage 4) as medical errors because they could have been avoided with diligent care, either preventing Stage 1 entirely, or detecting them and stopping progression to Stage 3. CMS consequently stopped reimbursing for their care in 2008 (Rosenthal, 2007). The lack of payment further raises the importance of preventing HAPI for managing costs in healthcare facilities.

Careful monitoring of skin integrity by nurses is important to determine a patient's risk of pressure injury. Assessment of a patient's skin integrity may take 20 min and should be performed by a nurse upon a patient's admission to the unit. If the patient is deemed at-risk, assessment should occur each day thereafter to note any changes in skin condition (Sullivan & Schoelles, 2013). Once the patient is determined at risk, his nurse can administer treatments that reduce the likelihood that pressure injuries will develop or worsen. A key treatment is repositioning less mobile patients approximately every two hours (Edlich et al., 2004). Consequently, assessment and preventive treatment for pressure injury are both time-intensive and time-sensitive tasks for nurses.

Nurses' time constraints may make it difficult to consistently perform the necessary monitoring and treatment for pressure injuries (Lake & Cheung, 2006). Nurses on medical or surgical wards are often assigned six or seven patients at a time (Lake & Cheung, 2006). Immobile patients are likely to develop HAPI (Aydin, Donaldson, Stotts, Fridman, & Brown, 2015; Lake & Cheung, 2006). The multiple, competing priorities of all their patients make it difficult for nurses to consistently assess skin integrity, and turn their patients every two hours, especially because turning a patient requires at least two people (Edlich et al., 2004).

A high frequency of operational failures and workarounds on a nursing unit may exacerbate the time–pressure faced by nurses, increasing the likelihood of HAPI. Some operational failures can trigger pressure injuries, such as a patient lying on a urine-soiled sheet for too long due missing linen. Even operational failures and workarounds not directly related to clinical causes of pressure injuries may trigger HAPI. This is because operational failures and workarounds can consume up to 10% of a nurse's day (Tucker, 2004). Thus, on units with a high level of operational failures and workarounds, nurses will have less time available to complete patient care tasks. Furthermore, working around an operational failure takes the nurse away from the patient's bedside, making it more difficult for nurses to observe changes in patients' conditions. In summary, high levels of operational failures or workarounds may delay nurses in identifying at-risk patients, noticing that a pressure injury is beginning to form, and treating it so enough to prevent injury. Thus, we first hypothesize a main effect of workarounds in general on HAPI.

Hypothesis 1 *All else equal, patients who are cared for on units with a higher number of workarounds will have a higher number of hospital-acquired pressure injuries.*

We also hypothesize that the number of operational failures on a unit moderates the relationship between workarounds and HAPI. A nurse who encounters an operational failure is often unable to complete the patient care task (Gurses & Carayon, 2009). Workarounds—such as searching for missing equipment in patient rooms—consume the nurse's time but enables completion of the interrupted task faster than if the nurse simply waited for the responsible department to rectify the situation (Tucker, Heisler, & Janisse, 2014). Thus, a high frequency of workarounds in response to a high frequency of operational failures may be associated with better patient care than a low frequency of workarounds under these circumstances.

Conversely, if there is a low frequency of operational failures, workarounds will be needed less frequently to deal with such failures. However, nurses may use workarounds for other reasons, signaling that nurses on the unit violate standard processes, for example by engaging in time saving but quality-reducing shortcuts (Oliva & Sterman, 2001). We predict that this pattern of workaround behaviors will be associated with lower quality of care based on findings from prior research on workarounds (Halbesleben et al., 2008; Koppel et al., 2008).

Finally, the highest quality of care should occur when there are few occurrences of either operational failures or workarounds. Under those conditions, providers have the needed supplies and therefore have more time for direct care of patients (Tucker, 2004). Similarly, low frequency of workarounds means that providers do not spend time circumventing standard care processes, and thereby avoid the variability that workarounds introduce into daily operations (Mazur & Chen, 2008). Nurses on the unit focus on processes, such that patients are likely to get the care they need in a timely fashion because internal service and clinical processes are in order (Fredendall et al., 2009). Thus, we hypothesize:

Hypothesis 2 *The frequency of operational failures moderates the relationship between workarounds and the number of hospital-acquired pressure injuries per patient. Specifically, when there is a high frequency of operational failures, workarounds will be associated with fewer hospital-acquired pressure injuries per patient. Conversely, when there are fewer operational failures, workarounds will be associated with a higher number of hospital-acquired pressure injuries per patient.*

3 | METHODS

3.1 | Survey development

The first author developed a unique survey to measure operational failures and workarounds on hospital nursing units. She partnered with a hospital nurse to write the questions, drawing on the nurse's experience as well as descriptions of hospital nursing work in ethnographic studies (Hendrich, Chow, Skierczynki, & Lu, 2008; Tucker, 2004), thus increasing face validity of measures. They built on Halbesleben and colleagues' surveys by using their five domains of workarounds but addressed the methodological limitation of social desirability by providing specific examples of workarounds and asking participants to rate how frequently such behaviors occur on their unit, rather than asking how frequently participants themselves perform such actions, as was done in Halbesleben et al. (2013). The initial questions were refined by conducting five iterative rounds of cognitive interviews with a total of six different hospital nurses from April–August 2010. The cognitive interviews consisted of having the nurse read each survey question and talk out loud about how she would answer it (Drennan, 2003). Survey items and scales were modified after each round of interviews to reduce confusion and discrepancy between the researcher's intent in asking the survey question and the respondent's interpretation of the question (Drennan, 2003).

Next, multiple rounds of pilot testing with practitioners were conducted to further refine survey questions and response scales. The survey was administered to 158 nurses attending a national nursing conference (National Teaching Institute and Critical Care) in May 2011. Psychometric analysis of the survey questions was conducted, and only questions that had a loading of more than 0.4 on one construct were kept, and questions that cross-loaded across constructs were dropped. Scores for Cronbach's alpha (α), a measure the internal consistency among survey questions intended to measure the same construct (Malhotra & Grover, 1998), were all greater than 0.70 (Nunnally, 1978).

A second round of pilot testing was conducted at a large, academic medical center in December 2011. A total of 518 nurses completed the survey, with a response rate of 17%. To further establish validity of the constructs, the first author spent a day in February 2012 observing nursing care on each of two surveyed units, while blind to the survey results. Afterwards, she compared these observations to the survey results, which identified one unit as having a high frequency of operational failures and workarounds, and the second as having a low frequency of both constructs. The observational data confirmed the survey's rank ordering of the two units. This triangulation provided reassurance that the survey can distinguish between high and low frequency of operational failures and workarounds, and that the data collected by the survey is accurate. Psychometric analysis of the survey using the same methods as in the first round of pilot testing was conducted, resulting in modifying and dropping questions in response to the results.

3.2 | Survey sample

After finalizing the workaround survey (items shown in Appendix A), the first author contracted with the research arm of the american nurses association (ANA) at the University of Kansas to administer the survey. ANA conducts an annual survey on nurses' practice environment and job satisfaction (Montalvo, 2007). In addition, ANA gathers monthly and quarterly data from participating nursing units on patient-level clinical outcomes including HAPI. The resulting unit-level database is called the national database on nursing quality indicators (NDNQI)®. Internal review board (IRB) approval for the study was obtained from the University of Kansas and the first author's university.

Due to the confidentiality agreement between ANA and hospitals that participate in their nursing survey and NDNQI, ANA was unable to disclose the identities of participating hospitals. In November 2014, ANA contacted member hospitals with 100 beds or more located in the United States ($n = 1{,}539$) to describe the research study and to ask for participation. ANA stratified responding hospitals ($n = 197$) by number of beds and teaching status and randomly selected 100 hospitals for inclusion. ANA notified hospitals of their status and provided selected hospitals with all materials needed to administer our survey including a link to a website where the survey coordinators could enter the unit name and the number of eligible staff on each participating unit. In early February 2015, coordinators distributed the survey link to eligible nurses via email. The survey was open 5 weeks, closing on March 8, 2015. A total of 4,741 nurses out of 13,497 eligible participated (35% overall response rate). Respondents were from 292 medical or surgical nursing units at 63 hospitals. (37 of the 100 hospitals failed to participate in the survey for a variety of reasons including failure to get IRB approval in the required timeframe or competing priorities that prevented adequate preparation). The median number of respondents per unit was 12. The full data set was used to test the psychometric properties of the survey instrument (described below).

3.3 | Independent variables: Workarounds and operational failures

We measure the frequency of *workarounds* with nine questions (see Appendix A) that begin with "To what extent do the following behaviors happen on the unit(s) on which you work?" To mitigate social-desirability bias (Gittelman et al., 2015), respondents are prompted to answer in terms of general behaviors on their unit rather than on their own behavior. Sample questions include: "When the unit runs out of a supply item, supply items are taken from other units." The response scale is "1: No/Never"; "2: To a little extent"; "3: To a moderate extent"; "4: To a great extent"; and "5: Yes/ Always".

In addition to our collaborative efforts with practitioners to establish face validity, we conduct psychometric analysis on our full data set of 4,741 nurses. For *workarounds*, Cronbach's alpha is 0.73 and removing any of the items would reduce construct reliability, suggesting that all nine questions need to be included as a single construct of workarounds. Consequently, for each survey respondent, we take the mean of all nine questions to compute a workaround score.

To test whether data from individual respondents from the same units should be aggregated to the unit level, we compute several statistics. We calculated interrater agreement (r_{WG} values) for the *workarounds* construct for each nursing unit to examine the average level of agreement between nurses on the same unit. A median r_{WG} value of 0.70 or greater is generally considered sufficient agreement among respondents from the same unit to justify aggregating individual responses to the unit level (Bliese, 2000). For *workarounds*, the median r_{WG} is 0.83. In addition, we also compute the intraclass correlation coefficient (ICC1) and the reliability of the group mean (ICC2) to examine within and between-unit variance in assessment of the construct (Biemann, Cole, & Voelpel, 2012). ICC1 represents the percent of variance in the variable that comes from being a member of the nursing unit. ICC1 values greater than 0.05 are considered sufficiently high to warrant aggregation to the unit level (Biemann et al., 2012). For workarounds, ICC1 is 0.12. ICC2 represents the reliability of the group mean, where higher values represent a more reliable measure (Kozlowski & Klein, 2000). ICC2 for workarounds is 0.58, which is close to the recommended cutoff of

0.60. Finally, the group effect (F-value for the ANOVA) should also be significant at the $p < 0.05$ level, which it is for workarounds (F = 2.4, $p = 0.0000$). Collectively, these statistics indicate that nursing unit membership explains a significant portion of the variance in workarounds. We aggregate to the unit level by taking the mean of the construct from nurses on the unit.

We measure *operational failures* with the mean of 10 questions related to problems with supplies, equipment, personnel, and medications ($\alpha = 0.89$). The stem of the question is, "During a typical shift, to what extent does a nurse on your unit experience the following?" Questions include the following: "A supply item I need is out of stock" and "My work is delayed because people I need to help me do my job are not readily available (such as transport assistance, person to double check my work, or someone to help lift patient)." The response scale ranges from 1 to 5 with "1" representing "Rarely"; "2" representing "Occasionally (once per shift)"; through "5" representing "Frequently, 4 or more times per shift." We aggregate the construct to the nursing unit level as supported by the multiple statistical tests described previously ($r_{WG} = 0.66$, ICC1 = 0.23, ICC2 = 0.75, F = 3.98, *P*-value of F test = 0.0000).

3.4 | NDNQI data sample

The workaround survey data were matched with ANA's quarterly data on patient-level pressure injuries as well as nursing unit control variables. Out of the 63 hospitals that completed the workaround survey, 56 of them provided patient-level pressure injury data. Table 1 shows details of the 56 hospitals for which we have survey data and HAPI data. We test for response bias in section 4.1.

3.5 | Dependent variable: Count of HAPI

To assess the likelihood of a patient getting a HAPI, nurses inspect each patient's skin upon admission to the unit. The initial audit also documents whether the patient has an already-existing pressure injury. Preexisting pressure injuries do not count against the unit's quality score, and CMS will reimburse for their care. Most hospitals use the Braden scale to measure skin integrity (Bergstrom, Braden, Laguzza, & Holman, 1987). Higher numbers signify better skin integrity, which means that the patient is less likely to get a pressure injury. Scores of 18 or less signal that the patient is "at risk" for developing a pressure injury. When patients are at risk, they should receive treatment (such as turning every 2 hours and daily skin inspections) to prevent deterioration.

In addition to turning and inspecting patients, units participating in ANA's NDNQI pressure injury program conduct a pressure injury audit of all patients on the unit at the same set time each quarter. The nurses who conduct the audit have been trained in the method, which has been tested to ensure validity and reliability (Bergquist-Beringer, Gajewski, Dunton, & Klaus, 2011). During the audit, the nurse documents the count of HAPI for each patient. The data are entered electronically into the NDNQI database. This patient-level data serves as our outcome variable, "HAPI count," which is an integer value for each patient in the unit on the day of the quarterly audit.

Our HAPI data cover July 2014‐June 2015, which are the two quarters before, one quarter during, and one quarter after we administer our workaround survey. We have 21,965 patient assessments from a total of 262 nursing units. Of the patient assessments, 390 had at least one HAPI (1.78%), while the remaining patient assessments find no HAPI. Because some patients had more than one HAPI, the mean level was 0.022 per patient.

3.6 | Control variables

We include patient-level, unit-level, and hospital-level control variables in our analyses. The most important are the patient-level control variables because the risks and prevalence of HAPI vary considerably across individuals. The pressure injury data set includes gender (female = 1, male = 0), age (in years), whether the patient was "not-at-risk" of developing a pressure injury during the last skin assessment audit he received (not-at-risk = 1, at risk = 0), and his skin integrity "score upon admit." Because the pressure injury data sent to ANA are an audit conducted throughout the hospital on one day each quarter, and average hospital length of stay on medical and surgical units is generally less than five days (much shorter than three months), we assume that all observations are of different individuals.

All units in our study are medical and surgical inpatient units. Therefore, we have a more homogenous set of patients than if other types of clinical units had been included, such as intensive care unit or maternity patients. Nonetheless, we control for unit type using data from ANA. There are 19 different types of medical/surgical in-patient units in our ANA data set (e.g., surgical cardiothoracic, medical neurology, adult medical respiratory, etc.). Thus, we include 18 dummy variable in our regressions to control for type of unit. These variables account for clinical differences, such as differences in average length of stay, among the different types of medical/surgical units.

We also include two additional unit-level control variables in our analyses to reduce concerns about possible problems due to omitted variables that might be correlated with both the independent and dependent variables. We explain the endogeneity concerns in more detail in Section 3.9 and use this section to describe how we calculate the variables. First,

TABLE 1 Number of hospitals by characteristic (N = 56)

Bedsize	N	Teaching status	N	Ownership	N
100–199	23	Academic medical center	10	Not for profit	49
200–399	23	Teaching	24	Government federal	3
≥400	10	Non-teaching	22	Government non-federal	2
				For profit, investor owned	2

nurses' workload might impact both workarounds and pressure ulcers. To control for this, we include a unit-level workload variable, the quarterly average *registered nurse (RN) hours per patient-day.* The data to compute this variable is provided by ANA. We calculate it by dividing the total number of nursing hours worked on a unit during a month by the total number of patient days cared for on the unit that month; we then take the average of the three months in each quarter.

Second, unit leadership behaviors may influence both the nurses' likelihood of engaging in workarounds as well as the quality of care provided on the unit, which would influence HAPI. To control for this variable, we use our survey to gather measures of *unit leadership responsiveness* to concerns about work systems and patient care. We ask five questions on our survey including, "Leadership in our clinical area is responsive to our concerns about our work systems." The response scale is 1 (strongly disagree) to 5 (strongly agree). We follow the psychometric testing procedures discussed above. Based on the results, we take the mean of the five questions for each respondent ($\alpha = 0.94$) and aggregate these means to the unit level ($r_{WG} = 0.62$, ICC1 = 0.18, ICC2 = 0.69, F = 3.19, *P*-value of F test = 0.0000).

Hospital-level control variables come from the AHA data set and include categorical bed size (100–199 beds; 200–399 beds, 400 beds and more), teaching status (non-teaching, teaching, academic medical center), and ownership status (for-profit, not-for-profit, federal government, public non-federal). Table 2 reports descriptive statistics for these variables.

3.7 | Addressing single-source bias

We follow the methods of prior research to minimize the extent to which single-source bias may inflate the relationships in our model. More specifically, we randomly divide the survey respondents from each unit into two different groups (Klein & Sorra, 1996). We use one group's means as the measures for operational failures and leader responsiveness, and the second group's mean as the measure of workarounds. This approach helps reduce concerns about single-source bias that otherwise would arise due to using the same participants to gather data on theoretically related constructs in our model (e.g., operational failures and workarounds).

3.8 | Empirical model

To test our two hypotheses, we specify our model for a patient *i* in nursing unit *j* at hospital *k* as follows:

$$\begin{aligned} HAPI\,Count_{ijk} = {} & \beta_0 + \beta_1 Workarounds_{jk} \\ & + \beta_2 Operational\,failures_{jk} \\ & + Patient-level\,controls_{ijk}{}' \beta_3 \\ & + Unit-level\,controls_{jk}{}' \beta_4 + Hospital \\ & - level\,controls_k{}' \beta_5 + \varepsilon_{ijk} \end{aligned} \tag{1}$$

We fit Equation (1) using a negative binomial distribution where patient-level controls is a vector of variables that include patient age (in years); female gender (female = 1), a binary variable (= 1), if the patient was deemed "not-at-risk" of pressure injuries during the last assessment; and the patient's skin integrity "score on admission" to the nursing unit. Unit-level controls are a vector of variables that include RN hours worked per patient day and leadership responsiveness to work system issues. Hospital-level controls are a vector of variables that include categorical variables for bed size, hospital ownership, and teaching status. The variable of interest in Equation 1 is β_1, which will be significant and positive if hypothesis 1 is supported, meaning that workarounds increase the risk of HAPIs.

$$\begin{aligned} HAPI\,Count_{ijk} = {} & \Upsilon_0 + \Upsilon_1 Workarounds_{jk} \\ & + \Upsilon_2 Operational\,Failures_{jk} \\ & + \Upsilon_3 Workarounds_{jk} * Operational\,Failures_{jk} \\ & + Patient-level\,Controls_{ijk}{}' \Upsilon_4 \\ & + Unit-level\,Controls_{jk}{}' \Upsilon_5 \\ & + Hospital-level\,Controls_k{}' \Upsilon_6 + \varepsilon_{ijk} \end{aligned} \tag{2}$$

where the vectors of control variables are the same as for Equation 1. The variable of interest in Equation 2 is Υ_3, which will be significant and negative if hypothesis 2 is supported.

We estimate our models using multilevel mixed effects negative binomial modeling, which enables nesting of patients within units and the nesting of units within hospitals. We use

TABLE 2 Summary statistics at the individual patient-level

	Mean	*SD*	Minimum	Maximum
Pressure injury count per patient	0.022	0.198	0.000	8.000
Patient-level controls				
Patient age (years)	62.717	17.358	4.000	90.000
Female =1	0.523	0.499	0.000	1.000
Not-at-risk at last assessment[b]	0.644	0.479	0.000	1.000
Braden risk score on admit[b]	18.544	3.033	6.000	23.000
Unit-level controls				
RN hours worked per patient day	6.619	1.449	2.458	49.503
Leadership responsiveness[a]	3.455	0.564	1.300	4.750
Hospital-level controls				
Bed size				
100-199	0.185	0.388	0.000	1.000
200-399	0.417	0.493	0.000	1.000
$\geq$400	0.398	0.489	0.000	1.000
Ownership				
Not for profit	0.915	0.280	0.000	1.000
Government federal	0.017	0.131	0.000	1.000
Government non-federal	0.053	0.225	0.000	1.000
For profit, investor owned	0.015	0.120	0.000	1.000
Teaching status				
Academic medical center	0.359	0.480	0.000	1.000
Teaching	0.389	0.488	0.000	1.000
Nonteaching	0.252	0.434	0.000	1.000
Independent variables				
Workarounds[a]	2.523	0.325	1.722	3.556
Operational failures[a]	2.890	0.515	1.400	4.900

Note. n = 21,965 assessments, 262 medical/surgical units in 56 hospitals.

[a] Likert Scale, 1(least) to 5 (most).

[b] Higher number = healthier.

Negative Binomial regression instead of a straight Poisson regression because the variance of the injury count is larger than its mean (mean = 0.022, variance = 0.039) (Cameron & Trivedi, 2013). The actual number of HAPIs of each patient is an integer random variable (0,1,2, 3, 4, ….) so the dependent variable (HAPI Count) in Equations 1 and 2 has two meanings. First, it is the expected number of HAPIs for patient i, which is generally well below 1. Second, it is the exponential parameter in a Negative Binomial distribution for the number of actual HAPIs for patient *i*. The negative binomial also has the property that this parameter equals the expected number of occurrences. We will not distinguish between these two interpretations and simply talk about the effect of variables on “the HAPI Count.” In addition, we conduct robustness checks using slightly different functions, which we discuss in Section 3.10.

3.9 | Addressing endogeneity concerns

One endogeneity concern is omitted variables that could create a relationship between an independent variable and our outcome variable. For example, if nurses on the unit have a high workload, they may be more likely to engage in workarounds in an effort to save time, and they might also have less time to perform the activities required to reduce HAPI, such as checking patients' skin for redness, and moving patients every two hours. To control for this possibility, we rely on the variable, *RN hours per patient-day*. The lower the variable, the higher the nursing workload.

A second possible omitted variable is related to unit *leadership responsiveness* to nurses' concerns. If unit leaders are not responsive to preventing operational failures, this leadership behavior may also be associated with a higher level of workarounds because the leaders do not invest in creating good processes and ensuring process compliance (Mazur & Chen, 2008). At the same time, disengaged leaders might decrease nurses' commitment to their work. As a result, nurses may be less engaged in the detailed activities required to provide good patient care (Gowen Iii et al., 2006); decreased engagement may lead to increased HAPI.

Another cause of endogeneity is reverse causality. This specific concern is less of an issue in our study for two reasons. First, it is unlikely that patients getting HAPI would cause nurses to engage in workarounds as measured by the specific items in our survey scale, which asks about behaviors unrelated to pressure injuries, such as ordering nonurgent laboratories as needing to be done immediately. Furthermore, we collect pressure injury data from each quarter for a year surrounding implementation of our survey. Having multiple data collection points for our dependent variable helps to break any potential time relationship with workarounds where a high level of pressure injuries during one time period might cause some nurses to think during that time period that nurses on their unit frequently engage in workarounds.

4 | RESULTS

We present summary statistics of the main variables of interest at the individual patient level because that corresponds with the level of analysis in our regressions. Table 2 displays the means and *SD*. The average number of pressure injuries per patient is 0.022 (*SD* 0.2, minimum of 0, maximum of 8). Table 3 shows the correlations between the variables. Appendix B reports the summary statistics at the level of the nursing unit. These numbers may be of interest because operational failures and workarounds are reported as unit-level averages. Table A1 displays unit-level means and *SD*s. The unit-level average score on the operational failure scale is 2.8 (*SD* 0.5), which indicates that each type of operational failure that we ask about occurs several times per shift. The average on the workaround scale is 2.5 (*SD* 0.3), which is half way between workarounds occurring "to a little extent" and "to a moderate extent." Table A2 displays the correlation matrix at the unit level. The results from the individual-level and unit-level tables are similar.

To test our hypotheses, we first run multilevel mixed effects negative binomial modeling (Table 4). Each coefficient shows the log of the effect of a unit change in that variable on the number of HAPI. Each observation is a single patient, who is nested in a unit, which is nested in a hospital.

Model 1 shows regression results with only patient-level control variables. The two standard medical measures of individual patient injury risk show the expected signs and are statistically significant.

Holding all other variables constant, if a patient is deemed "not-at-risk" during the last assessment, it reduces the difference in the logs of the expected pressure injury counts by 1.88. This is equivalent to multiplying the HAPI count by a factor of 0.15 (exp(−1.88)= 0.15). Holding all other variables constant, a three-point increase in the Braden risk score when admitted decreases the HAPI count by a factor of 0.64 (exp (−0.15*3)= 0.64, $p < 0.001$). These large effects show the importance of analyzing patient-level causes and outcomes.

Model 2 adds unit-level control variables: the 18 different unit-type dummy variables, the average number of nursing hours worked per patient day that quarter, and leadership responsiveness. Nursing hours worked per patient day and unit leadership responsiveness are operationally small and not statistically significant at the $p < 0.10$ level, reducing concerns about their potential for omitted variable bias. Some of the hospital unit types are significant in explaining pressure injury count, which helps control for differences between different types of units. For brevity, we do not show the unit type dummy results as they are not of theoretical interest to our study.

We add hospital-level control variables in Model 3. A hospital's size is not significant at the $p < 0.10$ level. Compared with other hospital types, patients in the three federal hospitals are very unlikely to get HAPI (exp(−20.43)= 0, $p < 0.001$). Patients in nonteaching hospitals have a lower number of HAPI at only 0.26 times the HAPI count of those treated in academic medical centers (exp(−1.33)= 0.26, $p < 0.05$).

Model 4 shows the test of hypothesis 1. If we use this simple model with no interactions, hypothesis 1 is not supported because the coefficient for workarounds, $\beta_{1,}$ is positive but not statistically significant in predicting HAPI ($\beta_1 = 0.33, p = 0.22$).

Model 5 shows the test of Hypothesis 2. The hypothesis is supported because the interaction term of workarounds and operations failures is negative and statistically significant ($\Upsilon_3 = -0.67$, $p < 0.05$). To further validate this result, we perform a Wald test on the difference between the Wald Chi Square values in Model 5 versus in Model 4. We find that the increase in the Wald Chi Square is significant, and therefore conclude that including the interaction term in Model 5 results in a better fit than Model 4, ($\chi^2 = 4.38, p = 0.036$).

We run a margins test to better understand the impact of workarounds at low ($-2SD = 2.89–2 \times 0.515 = 1.86$) and high ($+2SD = 2.89 + 2 \times 0.515 = 3.92$) levels of operational failures. When operational failures are infrequent, workarounds increase the HAPI count, meaning that patients experience more HAPI when nurses use more workarounds in low-failure units (dy/dx = 0.020, delta-method $SE = 0.010$, Z = 2.00, $p = 0.046$). The 0.020 coefficient means that an increase of one unit *SD* (0.325) in the 5-point Likert scale measuring workarounds increases the number of HAPIs by an average of 0.6% (= 0.325 × 0.020 = 0.006). This may

TABLE 3 Correlation matrix at the individual patient-level

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	HAPI count	1.00								
2	Patient age (years)	0.00	1.00							
3	Female =1	−0.04	−0.15*	1.00						
4	Not-at-risk at last assessment	−0.16**	−0.34***	0.24***	1.00					
5	Score on admit	−0.24***	−0.17**	0.14*	0.61***	1.00				
6	RN hours worked per patient day	−0.10	−0.20**	0.00	0.17**	0.15*	1.00			
7	Leadership responsiveness	−0.09	−0.05	−0.01	−0.06	−0.02	0.01	1.00		
8	Bed size 100-199	−0.09	0.31***	−0.12	−0.04	0.10	−0.04	0.07	1.00	
9	Bed size 200-399	0.02	0.15*	0.14*	0.01	−0.03	−0.11	−0.11	−0.45***	1.00
10	Bed size ≥400	0.06	−0.43***	−0.04	0.02	−0.06	0.15*	0.05	−0.42***	−0.62***
11	Not for profit	0.11	−0.01	0.32***	0.19**	0.09	−0.16*	−0.05	−0.32***	0.28***
12	Govt federal	−0.12	0.12	−0.57***	−0.16*	0.06	0.01	−0.01	0.28***	−0.13*
13	Govt nonfederal	−0.05	−0.12	−0.07	−0.07	−0.08	0.23***	0.07	0.09	−0.21***
14	For profit, investor owned	−0.03	0.10	0.03	−0.13*	−0.13*	−0.06	−0.01	0.25***	−0.11
15	Academic medical center	0.02	−0.44***	−0.21***	0.04	−0.03	0.20**	−0.07	−0.30***	−0.26***
16	Teaching	0.12	0.17**	0.03	−0.16**	−0.07	−0.12*	0.05	−0.12	0.14*
17	Nonteaching	−0.15*	0.27***	0.18**	0.13*	0.10	−0.08	0.03	0.43***	0.12
18	Workarounds	0.17**	−0.10	−0.04	−0.08	−0.20**	−0.07	−0.18**	−0.19**	0.10
19	Operational failures	0.22***	0.00	−0.09	−0.15*	−0.23***	−0.09	−0.51***	−0.10	0.02
		10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
11	Not for profit	−0.04***	1.00							
12	Government federal	−0.11***	−0.44***	1.00						
13	Government nonfederal	0.17***	−0.78***	−0.03***	1.00					
14	For profit, investor owned	−0.10***	−0.40***	−0.02*	−0.03***	1.00				
15	Academic medical center	0.50***	−0.17***	0.11***	0.19***	−0.09***	1.00			
16	Teaching	−0.07***	0.17***	−0.04***	−0.19***	0.01	−0.60***	1.00		
17	Nonteaching	−0.47***	−0.00	−0.08***	−0.00	0.09***	−0.43***	−0.46***	1.00	
18	Workarounds	0.08***	−0.05***	−0.11***	0.12***	0.02**	0.32***	−0.15***	−0.18***	1.00
19	Operational failures	0.05***	0.04***	0.07***	−0.09***	−0.02*	0.23***	−0.09***	−0.15***	0.36***

Note. n = 21,965 patient assessments.
$*p < 0.05$.; $**p < 0.01$.; $***p < 0.001$.

sound small, but it corresponds to a 50% increase in the risk to individual patients [(2.41–0.67 × 1.86) × 0.325 = 0.41; exp(0.41) = 1.5]. Conversely, when the frequency of operational failures is high, workarounds are negatively associated with HAPI count, meaning that patients experience fewer HAPI when nurses use more workarounds in response to operational failures. However, this result is not statistically significant (dy/dx = −0.0042, delta-method $SE = 0.0070$, Z = -0.59, $p = 0.553$). This suggests that although some workarounds are harmful, others are helpful for the reasons discussed earlier. The overall effect of workarounds when operational failures are high is inconclusive. We discuss this further in robustness checks and in the conclusion.

Figure 1 shows these results graphically. At the lowest average level of operational failures reported by the nursing units in our study (represented by the dot-dash line, average score of 1.4 on the scale of 1 to 5), and lowest level of workarounds reported by the nursing units in our study (score of 1.8 on the scale of 1 to 5), the HAPI count is the lowest, at almost zero. Alternatively, when operational failures remain low (dot-dash line, score of 1.4), but workarounds are higher (scores from 2.6–3.4), the HAPI counts are at their highest—more than

TABLE 4 The impact on hospital-acquired pressure injury count using multilevel mixed effects negative binomial models

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
Variables	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***
Patient-level controls										
Patient age (years)	0.01***	(0.00)	0.01***	(0.00)	0.01***	(0.00)	0.01***	(0.00)	0.01***	(0.00)
Female =1	−0.45***	(0.11)	−0.45***	(0.11)	−0.46***	(0.11)	−0.46***	(0.11)	−0.46***	(0.11)
Not-at-risk at last assessment[a]	−1.88***	(0.29)	−1.90***	(0.29)	−1.89***	(0.29)	−1.89***	(0.28)	−1.88***	(0.28)
Braden skin score on admit[a]	−0.15***	(0.03)	−0.15***	(0.03)	−0.15***	(0.03)	−0.15***	(0.03)	−0.15***	(0.03)
Unit-level controls										
RN hours worked per Patient day			0.01	(0.06)	−0.02	(0.07)	−0.01	(0.07)	−0.01	(0.07)
Leadership responsiveness[b]			−0.07	(0.14)	−0.08	(0.13)	−0.03	(0.14)	−0.02	(0.14)
Hospital-level controls										
Bed size (100-199 is the reference group)										
200-399					−0.52	(0.47)	−0.57	(0.46)	−0.61	(0.45)
$\geq$400					−0.47	(0.55)	−0.48	(0.55)	−0.54	(0.54)
Ownership (*Not for profit* is the reference group)										
Government federal					−20.43***	(1.02)	−20.18***	(1.02)	−19.63***	(1.04)
Government nonfederal					−0.23	(0.35)	−0.30	(0.33)	−0.37	(0.30)
For profit, investor owned					−0.58^	(0.33)	−0.67^	(0.37)	−0.66^	(0.35)
Teaching status (Academic medical center is the reference group)										
Teaching					−0.55	(0.35)	−0.48	(0.37)	−0.49	(0.36)
Nonteaching					−1.33*	(0.54)	−1.24*	(0.58)	−1.23*	(0.57)
Independent variables										
Workarounds **(H1)**[b]							0.33	(0.27)	2.41*	(1.04)
Operational failures[b]							0.04	(0.21)	1.81*	(0.90)
Workarounds × Oper. Failures **(H2)**									−0.67*	(0.32)
Constant	−1.75***	(0.50)	−1.38*	(0.67)	−0.02	(0.90)	−1.20	(1.64)	−6.69*	(3.23)
Ln alpha constant	2.27***	(0.14)	2.27***	(0.14)	2.27***	(0.14)	2.26***	(0.14)	2.26***	(0.14)
Var(_cons[hospital]) constant	0.90**	(0.31)	1.04**	(0.34)	0.71*	(0.33)	0.71*	(0.32)	0.67*	(0.30)
Var(_cons[hospital>unit]) constant	0.21*	(0.09)	0.09	(0.08)	0.09	(0.08)	0.08	(0.08)	0.08	(0.07)
N	21965		21965		21965		21965.00		21965	
Wald Chi Square	401.83		153598.45		39013.72		51475.02		53986.66	
Log Pseudolikelihood	−1849.42		−1837.42		−1828.33		−1827.59		−1826.07	

Note. 262 units, 56 hospitals, 21,965 patient assessments. Models 2-5 control for 19 different types of medical/surgical units in our data set.

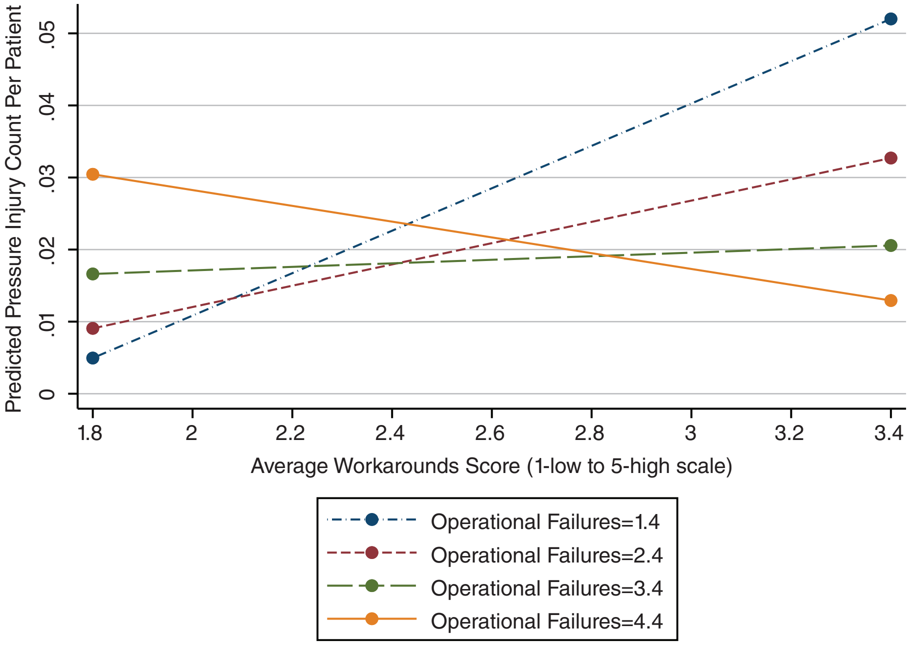
[a] Higher number = healthier.

[b] Likert Scale, 1(least) to 5 (most).

$^{*}p < 0.05$.; $^{**}p < 0.01$.; $^{***}p < 0.001$.; $^{\wedge}p < 0.10$.

FIGURE 1 The estimated impact of workarounds (x-axis) on hospital-acquired pressure injury count per patient (y-axis) at varied level of operational failures

Note: Mean HAPI level = 0.022; mean workaround level = 2.52, mean operational failure level = 2.89. Lower pressure injury count is better [Color figure can be viewed at wileyonlinelibrary.com]



5 pressure injuries per 100 patients for the highest workaround scores (3.4). This relationship is reversed when the level of operational failures on a unit is high (solid line, score of 4.4). At the lowest level of workarounds (score of 1.8), the HAPI count is more than 3 per 100 patients. That number drops to just over 1 HAPI per 100 patients when workarounds are at their highest level (score 3.4). The graph, which is based on the estimated coefficients of Model 5, displays that increased workarounds may be associated with reducing HAPI when the level of operational failures on the unit is high (solid line, score of 4.4). Workarounds are clearly related to increased HAPI when operational failures are low (dot-dash line, score of 1.4).

4.1 | Robustness checks

We conduct several robustness checks to address concerns about selection bias and model specification. First, to address the concern that hospitals that do not provide NDNQI with pressure injury data might differ systematically from those that do, we conduct chi-square tests to compare the two groups using hospital-level data that we have for all hospitals. We find no statistically significant differences between the two groups in terms of size and ownership status. However, hospitals that do not provide pressure injury data are all nonteaching hospitals ($\chi^2 = 9.23$, $p < 0.05$). As shown in Table A5, models 3–5, the nonteaching hospital dummy variable is significant and negatively associated with HAPI, indicating that the hospitals that do not provide pressure injury data are likely to have significantly *lower* rates of HAPI than the hospitals that do provide data to NDNQI. This reduces concern that units with a high level of HAPI opted out of the NDNQI data set. This minimizes concern that our findings on the association between operational failures, workarounds, and pressure injury are due to selection bias.

4.1.1 | Hurdle model

We also conduct three sets of additional analyses to make sure our results are not due to the specific model we chose. The first analysis uses multilevel, mixed effect hurdle modeling to address concerns over excessive zeros (Cameron & Trivedi, 2013). We find results similar to our main analyses, reducing concern that our results are dependent on our model specification. Specifically, we find that the main effect of workarounds on HAPI count is not statistically significant as shown in Appendix B, Table 3, Model 6 ($\beta_1 = 0.31$, $p > 0.10$) and Model 7 ($\beta_1 = 0.33$, $p > 0.10$). Hypothesis 1 thus remains unsupported. Hypothesis 2 is supported because the interaction term of workarounds and operational failures is negative and at least marginally statistically significant as shown in Appendix B Table A3, Model 8 ($\Upsilon_3 = -0.56, p < 0.10$) and Model 9 ($\Upsilon_3 = -0.67, p < 0.05$).

4.1.2 | Piecewise Linear Ratio Interaction Term

Equation 5 uses a conventional interaction term, the product of the two independent variables for workarounds and operational failures. As a second robustness check, we test our hypotheses using an alternative formulation for the interaction. We create a ratio, the unit's average score on workarounds divided by the unit's average score on operational failures (WA/OF). Recall that some workarounds are short-term fixes to operational failures but others will have different rationales. When the ratio is less than some threshold, it indicates that nurses perform fewer workarounds than needed to neutralize operational failures on the unit. Under this condition, we expect additional workarounds to reduce the rate of HAPIs. However, if the ratio WA/OF is higher than some threshold, each additional workaround is not solving an operational failure. This simple model corresponds to a piecewise linear function of pressure injuries as a function of the ratio WA/OF. The threshold where the slope changes from positive (helpful) to negative (harmful) is likely to be near 1.0, but because both are measured by ordinal Likert scales, it is unlikely to be exactly 1.0.

The results of this formulation are in Model 10 in Table 4. We define R1 as the effect of the WA/OF ratio below the critical threshold, and R2 as the effect above the threshold. The best threshold is at 1.06. R1 is negative as expected (−0.42) but is not statistically significant, suggesting that the beneficial and harmful effects of workarounds are approximately balanced. The coefficient on R2 is 1.64 and statistically significant ($p < 0.05$), suggesting that above a certain ratio, adding more workarounds becomes harmful to patient HAPI levels. These results support our original finding. We provide a third way of analyzing the interaction between operational failures and workarounds in the conclusion.

4.1.3 | Subscales of operational failures and workaround constructs using multilevel, mixed-effects negative binomial model

To further investigate the finding that workarounds in the absence of operational failures are associated with a higher level of pressure injuries, we redo our main analysis with subscales of the operational failure and workaround scales. We first create a subscale of operational failures that cause nurses to search for supplies. Specifically, we use operational failure survey items 1 (supply I need is out of stock), 2 (have to go two or more places to obtain materials), and 3 (search for equipment). The theory is that if nurses are searching for supplies, they are less able to provide care, such as turning and inspecting, that is needed to prevent pressure injuries. Thus, we would expect this subscale to have a stronger association with pressure injuries than the full scale of operational failures. Cronbach's alpha is 0.82, which is a strong indicator of the reliability of this new subscale.

We create a subscale of workaround survey items that are policy violations that can be performed in the absence of operational failures in order to save time. We use workaround survey items 2 (nurses use medications from other patients when their patient's medication is missing), 4 (violate medication administration procedures to have quicker access to medications), and 5 (nonurgent laboratories marked as urgent). These items demonstrate a focus on saving time rather than adhering to safety policies. Cronbach's alpha is 0.59, which is sufficient for new survey constructs (Singer et al., 2007).

Results are shown in Appendix B, Table A5. In Model 11, the coefficients on operational failures ($\beta = 0.22$ (0.18), $p = 0.21$) and workarounds ($\beta = 0.19$ (0.23), $p = 0.40$) are not significant. Therefore, Hypothesis 1 remains unsupported. In the regression that includes the interaction term (Model 12), operational failures ($\beta = 1.17$ (0.48), $p = 0.02$) and workarounds ($\beta = 1.75$ (0.76), $p = 0.02$) are both associated with a higher level of HAPI and the interaction term is negative and significant ($\beta = -0.52$ (0.24), $p = 0.03$). Thus, this analysis replicates our original findings.

For our second regression, we use workaround survey item 1 (when our unit runs out of a supply item, we take it from another unit), which is a workaround in response to an operational failure. We continue to use the same subscale for operational failures (Items 1, 2, and 3). In Model 13, the regression without an interaction term, operational failures ($\beta = 0.24$ (0.18), $p = 0.20$), and workarounds ($\beta = 0.01$ (0.17), $p = 0.96$) are not significant in predicting HAPI. In Model 14, we add the interaction term. The coefficients on operational failures, workarounds, and their interaction are not significant ($\beta = -0.44$ (0.68), $p = 0.52$; $\beta = -0.65$ (0.71) $p = 0.36$; $\beta = 0.21$ (0.21), $p = 0.30$, respectively). Comparing the two post-hoc analyses, we again infer that workarounds done in the absence of operational failures are likely to be harmful. Workarounds performed in response to operational failures have a net impact on pressure injuries close to 0.

5 | DISCUSSION AND CONCLUSIONS

We collaborated closely with healthcare practitioners and organizations to develop and administer a novel survey that measures unit-level workaround behaviors and operational failures in hospitals. We find no support for the general hypothesis that patients cared for on units where nurses engage in more workarounds will have more pressure injuries (HAPI). Instead, we find that operational failures moderate the effects of workarounds on HAPI. Higher levels of workarounds conducted on units that have a low frequency of operational failures is associated with worse patient outcomes. In these units, the formal procedures and systems are presumably well-designed and working effectively, so that workarounds create undesirable process variability and potential risks of bypassing safety procedures, without any compensating benefits for patients.

Our results suggest, but are unable to conclusively show, that workarounds on units with a higher frequency of operational failures may improve patient outcomes, as measured by fewer pressure injuries. In these situations, nurses appear

Operational Failures	High	Apathetic	Fire-fighting
	Low	Process-focused	Process-avoiding
		Low	High
		Workarounds	

FIGURE 2 Framework of workaround approaches and operational failures

to use workarounds to maintain patient care in spite of frequent operational failures. For example, a qualitative study of Vietnam nurses documents how violating formal procedures (i.e., using workarounds) is a virtue when the formal systems are not working well (i.e., there are many operational failures) (Sarnecky, 2007). Future research could continue to investigate whether workarounds under these conditions are helpful for patient outcomes.

5.1 | Contributions to theory

Our study makes several contributions to the operations management literature on workarounds. First, prior studies focus on the impact of patching problems on the recurrence of that specific problem (Bohn, 2000). Similarly, the health services literature that examines the impact of workarounds on patient safety looks at the direct impact of working around safety checks on errors made on that specific task (Halbesleben et al., 2010; Koppel et al., 2008; Spear & Schmidhofer, 2005). Ethnographic studies in hospitals examine various aspects of the link between operational failures and workarounds (Fredendall et al., 2009; Tucker, 2004). However, there is a lack of studies that directly measure the effects on objective patient outcomes such as pressure injuries. We extend perspectives on workarounds from prior studies by explicitly testing the interrelationships between operational failures, workarounds, and a patient health outcome from over 21,000 patients on 262 nursing units from over 50 hospitals.

Our study contributes to the emerging stream of research that seeks to develop a theoretical model linking operational failures, workarounds, and service quality. Existing theoretical models state that operational failures will take nurses away from patients and thus reduce quality of care when providers work around those failures. While supporting some aspects of this logic, our findings also provide important clarifications and nuanced perspective. At the unit level, we find evidence that operational failures can moderate the influence of workarounds on a nursing-intensive objective patient outcome. We find that the best patient outcomes occur when operational failures and workarounds are both infrequent (see Figure 1). However, contexts with low to medium frequency of operational failures (lines related to 1.4, 2.4, and 3.4 in Figure 1) have *worse* patient outcomes (i.e., higher counts of HAPI) as workarounds increase. The negative impact of workarounds is stronger the less frequently operational failures occur. For example, the worst patient outcomes occur when workarounds are used heavily (score of 3.4 on the *x*-axis of Figure 1) in contexts with few operational failures (dot-dash line, score of 1.4), suggesting that quality outcomes decrease when nurses do more workarounds that are not addressing operational failures.

To further explain our results, we propose a framework of four different approaches, characterized by the pattern of workarounds and operational failures (see Figure 2). If operational failures occur frequently but providers rarely use workarounds, we term this an *apathetic* problem-solving approach because employees appear to be less responsive to the operational breakdowns and immediate care needs in their systems. When both operational failures and workarounds are at high levels, we call it a *fire-fighting* approach (Bohn, 2000). When both operational failures and workarounds are infrequent, we consider the unit as having a *process-focused* approach. Having a process focus is associated with more reliable systems—and thus lower operational failures, as well as employees adhering to standard procedures (Spear & Schmidhofer, 2005; Stock et al., 2007). Finally, if operational failures are rare, but workarounds are common, we label this a *process-avoiding* approach, which is described by employees straying from standard procedures even though their internal supply systems are functioning fairly well.

To demonstrate the model, we create a binary variable for high operational failures (OF), which equals one if the unit's score on the operational failures scale is above the median value, and zero otherwise. We do the same for the workaround (WA) scale. We use the two binary variables to code each unit as one of the four problem solving approaches. Quality of care is represented by the mean HAPI score, where lower scores indicate better quality (i.e., lower frequency of pressure injury). We find that the best quality of care comes from a *process-focused* approach (low OF, low WA; mean HAPI = 0.016, *SD* = 0.17, *n* = 95 nursing units). The worst quality is associated with an *apathetic* approach (high OF,

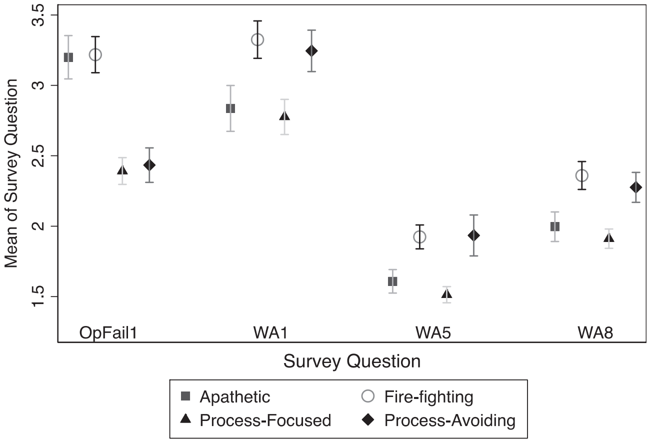


FIGURE 3 Mean and 95th percentile confidence interval of survey items by problem-solving approaches

low WA; mean HAPI = 0.026, *SD* = 0.23, *n* = 52 units). The remaining two approaches are in the middle: *process-avoiding* approach (low OF, high WA; mean HAPI = 0.023, *SD* = 0.20, *n* = 53 units); and *fire-fighting* (high OF, high WA; mean HAPI = 0.025, *SD* = 0.20, *n* = 78 units).

To demonstrate the operational and behavioral differences between the four approaches, in Figure 3 we plot the mean and 95th percentile confidence intervals of four individual survey items. For *apathetic* units (shown by the squares), operational failure item 1 (OF1: supply items out of stock) is high, but the workaround response (WA1: take supplies from other units) is low compared to other types of units. As expected, *fire-fighting* units (represented by the circles) are high on both of those two items, while *process-focused* units (shown with triangles) are low on both. Finally, *process-avoiding* units (diamond shapes) are relatively low on operational failures (OF1) but high on workarounds (WA1) including high on ordering nonurgent laboratory tests as being urgent (WA5) relative to other units. Note that *process-focused* units score the lowest on actions that are out-of-compliance with policies, such as giving extra supplies to patients upon discharge (WA8) and ordering nonurgent tests as being needed immediately (WA5). These details offer support for our proposed framework on workaround approaches.

We can use our 2 by 2 classification of approaches as a nonparametric way to analyze interactions between operational failures and workarounds. The process-focused approach, which has low workarounds and low operational failures, has a mean HAPI level of 0.016. The other three approaches have similar pressure injury levels, all considerably worse than with a process focus. We can restate this as:

- Workarounds are definitely bad for HAPI health outcome, if operational failures are low. (0.023 with high workarounds versus 0.016 with low workarounds)
- The effect of workarounds is minimal, if operational failures are high (0.025 versus 0.026). The net effect could be slightly positive or slightly negative.
- When operational failures are high, it is likely that the net effect of workarounds is positive for some units and negative for others, depending on what fraction of the workarounds successfully overcome operational failures.

5.2 | Contributions to practice

Providing effective patient care at lower cost is vital to individuals and healthcare organizations. Improving patient outcomes through reduced pressure injuries addresses clinical and financial goals of both patients and hospitals. One study estimated that pressure injuries add 4.3 days to average length of hospitalization (Graves, Birrell, & Whitby, 2005). Estimates of treatment costs vary widely, from $3,000 per case to $70,000 per stage 4 case. Estimates of annual costs include $11.5 million annually for a 548 bed system, and $11 billion annually for the United States as a whole (Reddy et al., 2006; Sullivan & Schoelles, 2013). Prevention programs are not free and making them more cost-effective is also desirable.

Our study suggests a potential avenue for reducing HAPI: creating a process-focused approach to problem solving that achieves a low frequency of both operational failures and workarounds. In the short-term, units that use a fire-fighting approach may benefit from doing workarounds in response to operational failures but the benefits of that approach are not yet fully substantiated. In the longer term, better results can occur with all approaches, if providers are able to reduce workarounds and operational failures in their units. Our results echo prior research on improvement efforts, which finds that routine task execution in combination with learning behaviors lead to better organizational outcomes (Linderman, Schroeder, Zaheer, Liedtke, & Choo, 2004).

Leaders must use caution during transitions to different approaches to problem solving. Our study suggests that with a fire-fighting approach, simply reducing workarounds without reducing operational failures might harm patient outcomes. Furthermore, although reducing operational failures may reduce pressure to engage in workarounds, it does not guarantee a reduction in workarounds or an improvement in outcomes, as evidenced by the process-avoiding units in our study that maintained high levels of workarounds despite low levels of operational failures.

5.3 | Limitations and conclusions

Our study has some limitations that may hinder its generalizability. First, we do not have direct measures of average patient acuity or length of stay on the different units in our study due to ANA member confidentiality agreements. However, this concern is partially mitigated by the fact that all the units are medical/ surgical units, and we also control for the different types of medical/surgical units. Second, the confidentially agreement means that we are unable to provide information on the geographical representativeness of the sample of hospitals for which we have workaround and pressure injury data. However, ANA has broad coverage of hospitals and the sampling of targeted hospitals was performed randomly so we do not believe the findings would be significantly influenced by regional differences. We are unaware of any evidence or theory for why the link between workarounds and clinical quality outcomes would be influenced by regional differences.

Reducing pressure injuries is a desirable outcome for patients and hospitals. We hope that our study sparks additional research on the links between operational failures, workarounds, and patient outcomes. We believe that doing so can improve the health and economic well-being of both individual patients and healthcare organizations.

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APPENDIX A: SURVEY SCALES

WORKAROUNDS

Question stem: To what extent do the following behaviors happen on the unit(s) on which you work? Answer in terms of general behaviors on the unit(s) rather than your specific behavior.

Response scale: “1: No/Never”; “2: To a little extent”; “3: To a moderate extent”; “4: To a great extent”; “5 Yes/Always”

1. When the unit runs out of a supply item, supply items are taken from other units.
2. While waiting for a medication ordered for a patient, nurse staff members use the same medication from another patient's supply until the missing medication is available.
3. Several different supplies are brought into the patient's room for a procedure when nursing staff are not sure exactly which ones the care provider (MD, PA, or NP) will want to use.
4. To have quicker access to medications, medication administration processes are shortcut (e.g., bar code scanning process, Pyxis machine doors left ajar, taking multiple patients medications at one time).
5. Nonurgent laboratories are ordered as “STAT”.*
6. To provide easy reference throughout their shift, nursing staff manually write down patient information that is already in the computer system.
7. Nursing staff members do tasks outside their scope of responsibilities because the responsible service is too slow.
8. Nursing staff give patients extra hospital supplies for their convenience upon discharge.
9. Nursing staff focus on daily work assignments rather than improving the unit's work systems.

**Note.* The term “STAT” indicates that the labs need to be done immediately.

OPERATIONAL FAILURES

Question stem: During a typical shift, to what extent does a nurse on your unit experience the following?

Response scale: “1: Rarely/Never”; “2: Occasionally (once per shift)”; “3: Several times (2 times per shift)”; “4: Many times per week (3 times per shift)”; “5: Frequently (4 or more times per shift)”

1. A supply item I need is out of stock.
2. I have to go to two or more different places to obtain the materials I need to complete a task (e.g., materials for dressing change).
3. I have to search for equipment that I need to do my job because it is not immediately available to me (e.g., glucometer, scales, wheelchairs, etc.)
4. I have to move other equipment out of the way to get to specific equipment I need to complete my care task.
5. I have to remind care teams (e.g., MD, PA, or NP) to put missing or verbal orders into the system.
6. I have to re-page care teams (e.g., MD, PA, or NP) because they do not respond in a timely fashion.
7. My work is delayed because people I need to help me do my job are not readily available (such as transport assistance, person to double check my work, or someone to help lift patient).
8. My work is unnecessarily interrupted by a patient's family or visitors.
9. I have to page the pharmacy to get the unavailable medications I need for my patients.
10. I document the same information in multiple places.

UNIT LEADERSHIP RESPONSIVENESS

Question stem: To what extent do you agree with the following statements about management?

Response scale: 1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

1. Leadership in our clinical area is readily accessible for us to discuss our area's work systems.
2. Leadership in our clinical area listens to our concerns about our work systems.
3. Leadership in our clinical area is responsive to our concerns about our work systems.
4. Leadership in our clinical area is an active contributor in bedside patient care.
5. Leadership in our clinical area responds effectively to proposed solutions that increase efficiency of care.

APPENDIX B: UNIT-LEVEL SUMMARY STATISTICS AND CORRELATIONS

TABLE A1 Unit-level summary statistics

	Mean	*SD*	Minimum	Maximum
Patient-level controls				
Pressure injury count	0.020	0.026	0.000	0.109
Patient age (years)	62.909	5.546	45.467	77.491
Female = 1	0.528	0.130	0.000	1.000
Not-at-risk at last assessment[a]	0.656	0.159	0.082	1.000
Braden skin score on admit[a]	18.637	0.947	15.650	21.354
Unit-level controls				
RN hours worked per patient day	6.829	2.752	2.671	46.594
Leadership responsiveness[b]	3.444	0.583	1.300	4.750
Hospital-level controls				
Bed size				
100-199	0.233	0.423	0.000	1.000
200-399	0.405	0.492	0.000	1.000
$\geq$400	0.363	0.482	0.000	1.000
Ownership				
Not for profit	0.897	0.305	0.000	1.000
Government federal	0.023	0.150	0.000	1.000
Government nonfederal	0.061	0.240	0.000	1.000
For profit, investor owned	0.019	0.137	0.000	1.000
Teaching status				
Academicmedical center	0.317	0.466	0.000	1.000
Teaching	0.382	0.484	0.000	1.000
Nonteaching	0.301	0.457	0.000	1.000
Independent variables				
Workarounds[b]	2.497	0.336	1.722	3.556
Operational failures[b]	2.843	0.535	1.400	4.900

n = 262 medical/surgical units in 56 hospitals.

[a] Higher number = healthier.

[b] Likert Scale, 1(least) to 5 (most).

TABLE A2 Unit-level correlation matrix

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	HAPI count	1.00								
2	Patient age (years)	0.04***	1.00							
3	Female = 1	−0.02**	0.04***	1.00						
4	Not-at-risk during last assessment	−0.11***	−0.28***	0.00	1.00					
5	Score on admit	−0.11***	−0.24***	−0.01	0.56***	1.00				
6	RN hours worked per patient day	−0.01	−0.07***	−0.02*	0.06***	0.06***	1.00			
7	Leadership responsiveness	−0.01*	−0.03***	−0.01	−0.01	0.00	0.06***	1.00		
8	Bed size 100-199	−0.01	0.10***	−0.02***	−0.01	0.04***	−0.10***	0.04***	1.00	
9	Bed size 200-399	−0.00	0.06***	0.04***	−0.00	−0.01	−0.13***	−0.11***	−0.40***	1.00
10	Bed size ≥400	0.00	−0.14***	−0.02*	0.01	−0.02**	0.21***	0.08***	−0.39***	−0.69***
11	Not for profit	0.01*	0.00	0.07***	0.07***	0.03***	−0.07***	−0.06***	−0.27***	0.26***
12	Government federal	−0.01*	0.04***	−0.13***	−0.05***	0.01*	−0.00	−0.01	0.28***	−0.11***
13	Government nonfederal	−0.01	−0.04***	−0.02*	−0.04***	−0.03***	0.13***	0.08***	0.04***	−0.20***
14	For profit, investor owned	−0.00	0.03***	0.01	−0.04***	−0.03***	−0.09***	−0.02*	0.26***	−0.10***
15	Academic medical center	0.00	−0.16***	−0.05***	0.03***	0.00	0.30***	−0.06***	−0.28***	−0.27***
16	Teaching	0.02**	0.07***	0.01*	−0.07***	−0.04***	−0.21***	0.05***	−0.08***	0.13***
17	Nonteaching	−0.02**	0.10***	0.04***	0.04***	0.04***	−0.10***	0.01	0.40***	0.15***
18	Workarounds	0.02*	−0.03***	−0.00	−0.02*	−0.06***	−0.02*	−0.21***	−0.21***	0.08***
19	Operational failures	0.03***	0.01	−0.02**	−0.06***	−0.08***	−0.02**	−0.53***	−0.08***	0.01
		10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
11	Not for profit	−0.01	1.00							
12	Governmentt federal	−0.12	−0.45***	1.00						
13	Government nonfederal	0.14*	−0.75***	−0.04	1.00					
14	For profit, investor owned	−0.11	−0.41***	−0.02	−0.04	1.00				
15	Academic medical center	0.53***	−0.15*	0.12	0.17**	−0.09	1.00			
16	Teaching	−0.04	0.16**	−0.02	−0.20**	0.01	−0.54***	1.00		
17	Nonteaching	−0.50***	−0.02	−0.10	0.04	0.09	−0.45***	−0.51***	1.00	
18	Workarounds	0.07	−0.05	−0.12*	0.13*	0.02	0.31***	−0.14*	−0.17**	1.00
19	Operational failures	0.07	0.06	0.05	−0.10	−0.02	0.24***	−0.10	−0.14*	0.35***

Note. n = 262 medical/surgical units in 56 hospitals.
*$p < 0.05$.; **$p < 0.01$.; ***$p < 0.001$.

APPENDIX C: ROBUSTNESS CHECKS

TABLE A3 The impact on hospital-acquired pressure injury (HAPI) count using multilevel mixed effects hurdle models

	Hypothesis 1				**Hypothesis 2**			
	Model 6		**Model 7**		**Model 8**		**Model 9**	
	Binary outcome variable (=1 if any HAPI)		**HAPI count given any**		**Binary outcome variable (=1 if any HAPI)**		**HAPI count given any**	
Variables	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***
Patient age (years)	0.01**	(0.00)	0.01***	(0.00)	0.01**	(0.00)	0.01***	(0.00)
Female =1	−0.45***	(0.12)	−0.46***	(0.11)	−0.45***	(0.12)	−0.46***	(0.11)
Not-at-risk during last assessment[a]	−1.82***	(0.30)	−1.89***	(0.28)	−1.81***	(0.30)	−1.88***	(0.28)
Braden skin score on admit[a]	−0.13***	(0.02)	−0.15***	(0.03)	−0.13***	(0.02)	−0.15***	(0.03)
RN hours worked per patient day	−0.02	(0.06)	−0.01	(0.07)	−0.02	(0.06)	−0.01	(0.07)
Leadership responsiveness	0.06	(0.13)	−0.03	(0.14)	0.08	(0.13)	−0.02	(0.14)
Bed size (100-199 is the reference group)								
200-399	−0.51	(0.40)	−0.57	(0.46)	−0.54	(0.39)	−0.61	(0.45)
≥400	−0.44	(0.48)	−0.48	(0.55)	−0.48	(0.47)	−0.54	(0.54)
Ownership (not for profit is the reference group)								
Government federal	0.00	(.)	−20.18***	(1.02)	0.00	(.)	−19.63***	(1.04)
Government nonfederal	−0.47*	(0.24)	−0.30	(0.33)	−0.53*	(0.22)	−0.37	(0.30)
For profit, investor owned	−0.65	(0.39)	−0.67$^{\wedge}$	(0.37)	−0.63$^{\wedge}$	(0.37)	−0.66$^{\wedge}$	(0.35)
Teaching status (academic medical center is the reference group)								
Teaching	−0.58$^{\wedge}$	(0.34)	−0.48	(0.37)	−0.58$^{\wedge}$	(0.33)	−0.49	(0.36)
Nonteaching	−1.15*	(0.52)	−1.24*	(0.58)	−1.13*	(0.52)	−1.23*	(0.57)
Workarounds[b]	0.31	(0.28)	0.33	(0.27)	2.04*	(1.00)	2.41*	(1.04)
Operational failures[b]	0.02	(0.19)	0.04	(0.21)	1.51	(0.94)	1.81*	(0.90)
Workarounds × operational failures					−0.56$^{\wedge}$	(0.33)	−0.67*	(0.32)
Constant	−1.85	(1.63)	−1.20	(1.64)	−6.51*	(3.20)	−6.69*	(3.23)
Ln alpha constant	0.54*	(0.23)	0.71*	(0.32)	0.53*	(0.23)	0.67*	(0.30)
Var(_cons[hospital]) constant	0.02	(0.06)	0.08	(0.08)	0.02	(0.05)	0.08	(0.07)
Var(_cons[hospital>unit]) constant			2.26***	(0.14)			2.26***	(0.14)
N	21309.00		21965.00		21309.00		21965.00	
Wald Chi Square	4296999.20		51475.02		221564.97		53986.66	
Log Pseudolikelihood	−1553.95		−1827.59		−1552.57		−1826.07	

Note. 262 units, 56 hospitals, 21,965 patient assessments. All models controlled for 19 different types of medical/surgical in-patient units in our data set.

[a] Higher number = healthier.

[b] Likert Scale, 1(least) to 5 (most).

$*p < 0.05.$; $**p < 0.01.$; $***p < 0.001.$; $^{\wedge}p < 0.10.$

TABLE A4 The impact on hospital-acquired pressure injury (HAPI) count using kinked ratio workarounds/Op failures

Variables	Model 10 coefficient	Robust *SE*
Patient age (years)	0.01***	(0.00)
Female =1	−0.46***	(0.11)
Not-at-risk during last assessment[a]	−1.90***	(0.28)
Braden skin score on admit[a]	−0.15***	(0.03)
RN hours worked per patient day	−0.02	(0.07)
Leadership responsiveness[b]	−0.07	(0.13)
Bed size (100-199 is the reference group)		
200-399	−0.53	(0.47)
>400	−0.53	(0.56)
Ownership (not for profit is the reference group)		
Government federal	−21.38***	(1.02)
Government nonfederal	−0.19	(0.32)
For profit, investor owned	−0.54	(0.33)
Teaching status (academic medical center is the reference group)		
Teaching	−0.58	(0.36)
Non-teaching	−1.39*	(0.55)
Workarounds/Op. Failures < 1.06 (R1)	−0.42	(0.58)
Workarounds/Op. Failures > 1.06 (R2)	1.64*	(0.78)
Constant	−0.19	(0.91)
Ln alpha constant	2.27	(0.14)
Var(_cons[hospital]) constant	0.74	(0.34)
Var(_cons[hospital>unit]) constant	0.07	(0.08)
N	21965	
Wald Chi Square	47527.53***	
Log Pseudolikelihood	−1827.20	

Note. 262 units, 56 hospitals, 21,965 patient assessments. All models controlled for 19 different types of medical/surgical in-patient units in our data set.

[a] Higher number = healthier.

[b] Likert Scale, 1 (least) to 5 (most).

*$p < 0.05$.; **$p < 0.01$.; ***$p < 0.001$.; ^$p < 0.10$.

TABLE A5 The impact on hospital-acquired pressure injury (HAPI) count using subscales for operational failures and workarounds

	Model 11		Model 12		Model 13		Model 14	
Variables	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***	**Coefficient**	**Robust *SE***
Patient age (years)	0.01***	(0.00)	0.01***	(0.00)	0.01***	(0.00)	0.01***	(0.00)
Female =1	−0.46***	(0.11)	−0.46***	(0.11)	−0.46***	(0.11)	−0.46***	(0.11)
Not-at-risk during last assessment[b]	−1.89***	(0.29)	−1.89***	(0.28)	−1.89***	(0.28)	−1.89***	(0.28)
Score on admit[b]	−0.15***	(0.03)	−0.15***	(0.03)	−0.15***	(0.03)	−0.15***	(0.03)
RN hours worked per patient day	−0.01	(0.07)	−0.00	(0.07)	−0.02	(0.07)	−0.03	(0.07)
Leadership responsiveness[a]	−0.00	(0.14)	−0.01	(0.14)	−0.02	(0.12)	−0.02	(0.12)
Bed size (100-199 is the reference group)								
200-399	−0.54	(0.46)	−0.56	(0.45)	−0.53	(0.45)	−0.53	(0.44)
≥400	−0.52	(0.56)	−0.54	(0.55)	−0.48	(0.55)	−0.45	(0.54)
Ownership (not for profit is the reference group)								
Government federal	−21.30***	(1.01)	−21.35***	(1.01)	−21.30***	(1.02)	−22.85***	(1.01)
Government nonfederal	−0.26	(0.36)	−0.28	(0.36)	−0.24	(0.35)	−0.19	(0.37)
For profit, investor owned	−0.61	(0.35)	−0.57^	(0.34)	−0.60^	(0.35)	−0.66^	(0.35)
Teaching status (academic medical center is the reference group)								
Teaching	−0.46	(0.35)	−0.42	(0.34)	−0.49	(0.35)	−0.47	(0.54)
Non-teaching	−1.21*	(0.55)	−1.14*	(0.54)	−1.26*	(0.56)	−1.24*	(0.55)
WA [a](items 2, 4, and 5 models 11, 12; item 1 models 13, 14)	0.19	(0.23)	1.75*	(0.76)	0.01	(0.17)	−0.65	(0.71)
OF [a](items 1, 2, and 3)	0.22	(0.18)	1.17*	(0.48)	0.24	(0.18)	−0.44	(0.68)
WA× OF			−0.52*	(0.24)			0.21	(0.21)
Constant	−1.34	(1.16)	−4.22*	(1.79)	−0.97	(1.14)	1.08	(2.26)
Ln alpha constant	2.26	(0.18)	2.26	(0.14)	2.26	(0.14)	2.26	(0.14)
Var(_cons[hospital]) constant	0.66	(0.29)	0.63	(0.27)	0.66	(0.29)	0.64	(0.27)
Var(_cons[hospital>unit] constant	0.09	(0.08)	0.09	(0.08)	0.09	(0.08)	0.10	(0.08)
N	21965		21965		21965		21965	
Wald Chi Square	75232.99***		122853.02***		68945.51***		88850.41***	
Log Pseudolikelihood	−1827.05		−1825.84		−1827.27		−1826.73	

Note. 262 units, 56 hospitals, 21,965 patient assessments. All models controlled for 19 different types of medical/surgical in-patient units in our data set.

[a] Likert Scale, 1(least) to 5 (most).

[b] Higher number = healthier.

*$p < 0.05$.; **$p < 0.01$.; ***$p < 0.001$.; ^$p < 0.10$.