The sample included 807 NHs from every U.S. state. A total organizational factors in health systems influence volume 00, number 00, month 2017 www.journalpatientsafety.com. A similar incentives to stimulate innovation in postacute care, the purpose of this model is to provide a framework for staging within an IT maturity model is in- health deficiencies and IT sophistication survey scores was examined, using weighted regression. Results: Controlling for registered nurse hours per resident day, deficiency scores decreased as total IT sophistication increased. Controlling for total IT sophistication score, deficiency scores decreased as registered nurse hours per resident day increased. Ownership status significantly influenced health deficiency scores. Conclusions: These results highlight the necessity to understand benefits of implementing NH IT and demonstrating its impact on patient safety. Key Words: quality measurement, patient safety, surveys

Quality of care in nursing home (NH) facilities is regulated by a set of standards at both federal and state levels. Compliance with these standards is monitored by state regulatory agencies through yearly standard and compliance-driven inspections. The results of these inspections provide information on health care deficiencies, related to the overall standard of care provided by NHs nationally. A 2015 assessment of long-term care facilities found that the percentage of NHs in a substandard quality of care classification had declined to 3.2% in 2014; however, the percentage of deficiencies graded at actual harm levels that were in a more severe category (G-L) (Table 1) had increased to 10.6%. In September 2016, growing awareness of continued substandard care led the Centers for Medicare and Medicaid to implement mandatory remedies and assessment factors to determine seriousness of health deficiencies in NH. The 3 most cited deficiencies included having a program that investigates, controls, and keeps infection from spreading, food safety, and that NHs are free from accident hazards and prevent avoidable accidents. More sophisticated mechanisms are needed to reduce deficiencies and improve patient safety in NHs to protect the 1.5 million residents nationally, whose average length of stay is just more than 2 years, and that reside in 1.7 million beds in more than 16,000 U.S. facilities.

Conclusions: These results highlight the necessity to understand benefits of implementing NH IT and demonstrating its impact on patient safety.

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A Report of Information Technology and Health Deficiencies in U.S. Nursing Homes

Objective: The aim of the study was to investigate the impact of nursing home (NH) information technology (IT) sophistication on publically reported health safety deficiency scores documented during standard inspections.

Methods: The sample included 807 NHs from every U.S. state. A total of 2187 health inspections were documented in these facilities. A national IT sophistication survey describing IT capabilities, extent of IT use, and degree of IT integration in resident care, clinical support, and administrative activities in U.S. NHs was used. The relationship between NH health deficiencies and IT sophistication survey scores was examined, using weighted regression.

Results: Controlling for registered nurse hours per resident day, deficiency scores decreased as total IT sophistication increased. Controlling for total IT sophistication score, deficiency scores decreased as registered nurse hours per resident day increased. Ownership status significantly influenced health deficiency scores.

Conclusions: These results highlight the necessity to understand benefits of implementing NH IT and demonstrating its impact on patient safety.

Key Words: quality measurement, patient safety, surveys

Quality of care in nursing home (NH) facilities is regulated by a set of standards at both federal and state levels. Compliance with these standards is monitored by state regulatory agencies through yearly standard and compliance-driven inspections. The results of these inspections provide information on health care deficiencies, related to the overall standard of care provided by NHs nationally. A 2015 assessment of long-term care facilities found that the percentage of NHs in a substandard quality of care classification had declined to 3.2% in 2014; however, the percentage of deficiencies graded at actual harm levels that were in a more severe category (G-L) (Table 1) had increased to 10.6%. In September 2016, growing awareness of continued substandard care led the Centers for Medicare and Medicaid to implement mandatory remedies and assessment factors to determine seriousness of health deficiencies in NH. The 3 most cited deficiencies included having a program that investigates, controls, and keeps infection from spreading, food safety, and that NHs are free from accident hazards and prevent avoidable accidents. More sophisticated mechanisms are needed to reduce deficiencies and improve patient safety in NHs to protect the 1.5 million residents nationally, whose average length of stay is just more than 2 years, and that reside in 1.7 million beds in more than 16,000 U.S. facilities.
few rigorous evaluations incorporating measures of NH IT use as independent variables and long-established NH quality measures as dependent variables. Furthermore, existing studies with these types of measures are limited in scope by number of facilities and geographic spread. Larger research studies, incorporating nationally representative samples of NHs with diversity of IT use, are needed to determine widespread effects of IT sophistication on quality. The current research surveyed a nationally representative sample to measure NH IT sophistication, which is linked to IT maturity. Total IT sophistication measures were used to examine relationships between deficiencies found during standard NH health inspections. The specific aim of the study is to investigate relationships between total NH IT sophistication and deficiencies found during standard NH health inspections in a national sample. The study addresses the question: Do relationships exist between total NH IT sophistication and deficiencies found during standard NH health inspections in a national sample?

METHODS

Information Technology Sophistication Measure

The IT sophistication survey, developed by the primary author through a series of rigorous studies, measures 3 IT sophistication dimensions (IT capabilities, extent of IT use, and IT integration) in 3 healthcare domains (resident care, clinical support, and administrative activities). The IT sophistication instrument is reliable, with good internal consistency in each healthcare domain including the following: resident care, 0.87 to 0.88; clinical support, 0.86 to 0.91; and administrative activities, 0.69 to 0.80. In addition, the IT sophistication instrument has been field tested using extensive observations of communication activities about pressure ulcer preventions used by NH staff in facilities with diverse IT sophistication measures. Results of these field tests verified that increased NH IT sophistication enhances efficiency in clinical workflow among nursing facility staff in NH with high and low levels of IT sophistication. The change in total and unique interactions among staff resulted in enhanced workflow and efficiencies in facilities with high levels of IT sophistication. Enhanced nursing staff workflow and efficiency lead to better quality.

Health Deficiency Measures

Nursing home quality indices, captured in a national public database called NH Compare, contain measures with weighted health inspection scores about health deficiencies discovered during standard state health inspections or investigations after a complaint. Health deficiencies are recorded by state surveyors in NH Compare. Surveyors rate the severity of each deficiency within 4 classifications ranging from no actual harm with potential for minimal harm to immediate jeopardy to resident health or safety. Furthermore, surveyors rate each health deficiency into 3 classes ranging from isolated to widespread incidents. A point system is used to classify deficiencies into 1 of 12 (4 × 3) classes (Table 1). More points acquired by a facility during health inspections mean that deficiencies have greater severity with wider scope of occurrence. Health deficiencies found during standard inspections were included in this analysis, whereas those found during complaint investigations were excluded.

Sample

These data are derived from a national study of NH IT adoption, using an IT sophistication survey, conducted January 2014 to July 2015 involving 815 NHs from every state in the United States. Health deficiency scores were computed for 815 NHs participating in the national IT sophistication survey. Nursing homes were excluded if identified as special focus homes (those with pre-existing quality problems), located in Guam, Puerto Rico, or Virgin Islands, or if deficiency surveys were 2 or more years before completion of the IT survey. After applying inclusion/exclusion criteria, there were 807 NHs with usable IT sophistication survey and health deficiency data included in the analysis.

Analysis

In this study, we analyzed whether the NH total IT sophistication score predicted the health deficiency score of the NH reported during standard safety inspections, controlling for NH staffing, bed size, location, and ownership. For staffing, NH hours per resident day for registered nurses (RNs), licensed practical nurses (LPNs), and certified nurse aides (CNAs) were obtained from NH Compare. Rural–urban Commuting Area Codes using ZIP code information were used to classify the homes into 4 regional locations on the basis of population size including the following: metropolitan, more than 50,000; micropolitan, 10,000 to 49,999; small town, 2500 to 9999; and rural, less than 2500. Bed size was collapsed into 3 categories including small (<60 beds), medium (60–120), and large (>120). We collapsed the type of ownership into 2 categories, including for-profit and nonprofit NHs (nonprofit included NHs with a government classification in NH Compare).

The total health deficiency scores were highly skewed; therefore, the analysis was conducted using the log transformation of the total deficiency score. The correlation estimates were found by taking the square root of the multiple R² obtained from the weighted regression analysis. Specifically, the SURVEYREG procedure of SAS v9 (SAS Institute Inc, Cary, NC) was used for this analysis. Procedures were approved by the university's ethics board (IRB #1209004 HS).

RESULTS

Table 2 presents the mean and median IT scores that NH administrators reported in each IT sophistication dimension and
TABLE 2. Nursing Home IT Sophistication Scores (N = 807 Nursing Homes)

<table>
<thead>
<tr>
<th>Administrative Activities</th>
<th>Mean</th>
<th>Median</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT capabilities</td>
<td>40.9</td>
<td>42.5</td>
<td>23.9</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Extent of IT use</td>
<td>36.0</td>
<td>35.9</td>
<td>15.7</td>
<td>0.0</td>
<td>94.2</td>
</tr>
<tr>
<td>IT integration</td>
<td>47.9</td>
<td>48.1</td>
<td>16.1</td>
<td>9.0</td>
<td>93.7</td>
</tr>
<tr>
<td>Resident care</td>
<td>43.5</td>
<td>42.8</td>
<td>21.5</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Extent of IT use</td>
<td>29.3</td>
<td>29.3</td>
<td>17.7</td>
<td>0.0</td>
<td>98.4</td>
</tr>
<tr>
<td>IT integration</td>
<td>44.9</td>
<td>44.0</td>
<td>28.1</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Clinical support</td>
<td>23.4</td>
<td>17.6</td>
<td>24.1</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>IT capabilities</td>
<td>19.3</td>
<td>11.9</td>
<td>22.0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Extent of IT use</td>
<td>14.7</td>
<td>0.0</td>
<td>22.9</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total IT sophistication</td>
<td>299.9</td>
<td>281.5</td>
<td>142.1</td>
<td>24.8</td>
<td>833.0</td>
</tr>
</tbody>
</table>

healthcare domain. In this sample, the highest median IT sophistication score includes technologies used in administrative activities, which are integrated internally and externally with other IT systems (e.g., IT backup systems). The lowest IT sophistication score was in use of clinical support technologies (e.g., laboratory and pharmacy), which are integrated internally and externally with other IT systems. In 6 of the 9 categories measuring IT sophistication, at least 1 NH administrator reported the lowest possible score, which was 0 (meaning no technology was present) in 8 of the 9 dimensions and domains of IT sophistication. Approximately half of the homes completed IT sophistication surveys within 109 days (~3.5 months) of their health inspection.

In the 807 NHs, there were 2187 health inspections documented. Only 11 (1.3%) of the homes in the study had no deficiencies reported. The top 10 most frequently cited health deficiency tags for our sample are listed in Table 3. Nursing facilities in the sample completing the IT sophistication survey have similar numbers of health deficiency citations (within 1%) as nonsample facilities that did not participate in the national survey. The most frequent citation in the sample facilities was related to infection control programs. The relative frequency of the scope and severity of the health citation tags in the sample are listed in Table 4. Most deficiency tags are within scope and severity level of D. At this level, deficiencies have isolated occurrences ranging from no actual harm to having potential for more than minimal harm that is not immediate jeopardy (Table 1). The most frequent tag with a scope and severity level of D relates to qualified persons providing care according to each resident's written plan of care. However, there are several facilities that have health citations tagged with scope and severity levels of F or higher, which indicates widespread occurrence of deficiencies with no actual harm with potential for more than minimal harm that is not immediate jeopardy. In particular, 4% of the health citations for tag number 323 had a scope and severity of J or higher, which is isolated to wide spread occurrences of deficiencies that have immediate jeopardy to patients. Tag number 323 is issued when a facility has not ensured that NH areas are free from accident hazards and are not providing adequate supervision to prevent avoidable accidents.

The mean deficiency score for our sample was 42.9. Study NHs had a mean of 6.2 total deficiencies. Nonstudy homes across the United States were comparable but had slightly worse health deficiencies, reporting a mean total deficiency score of 43.9 and an average count of 6.4 deficiencies.

To get a visual picture of the relationship between total IT sophistication and deficiency variables, box plots of total health deficiency scores were diagramed with deciles of increasing IT sophistication (Fig. 1). For the first decile, with the lowest total defici...
IT sophistication scores ranging from 0 to 129, the median total deficiency score was 32. Nursing homes reporting the highest total IT sophistication, greater than 487 and in the 10th decile, had a median health deficiency score of 24. Figure 1 includes a line connecting estimated mean values for total deficiency scores based on regression on the total IT sophistication score. The median deficiency count for all homes ranged from 4 to 6, across all deciles, indicating that there was not much difference in the total deficiency counts documented, but they seemed to be less severe and more isolated as total IT sophistication increased.

In other analyses, the correlation of the deficiency score with total IT sophistication score is \(-0.07\), which is weak, but approaching significance (\(P = 0.06\)). Additional analysis included correlations between deficiency scores and RN-, LPN-, and CNA-adjusted staffing hour's per resident per day. The estimated correlations for CNA and LPN hours per resident per day were small and not statistically significant (\(P > 0.60\)). For RN-adjusted hours, the estimated correlation was \(-0.11\) (\(P = 0.007\)). Consequently, in subsequent analysis, we used only RN-adjusted hours. For bed size, the \(P\) value was 0.07, which was not quite significant; however, there was some evidence that small homes have better scores than medium or large homes. There was no evidence of differences based on location in this sample (\(P = 0.25\)). There is evidence that nonprofit homes do better than for-profit homes (\(P = .0005\)). The mean health deficiency scores were 31 and 46, whereas the medians were 20 and 25 for nonprofit and for-profit homes, respectively.

To examine the joint effect of the independent variables, a model was fit with total IT sophistication, RN-adjusted hours, and ownership status included as predictor variables and the log of the deficiency score as the dependent variable. In this model, all \(P\) values were less than 0.10 with for-profit status being highly significant (\(P = .007\)). Although the coefficients for RN-adjusted hours and total IT sophistication were not significant at the 0.05 level, we examined this model further to get estimates of the effect on the deficiency score for each of these variables. Because RN-adjusted hours and total IT sophistication are continuous, the effect of each one was examined while holding the other fixed at its median value, .5 RN hours per resident per day and total IT sophistication score of 290, respectively. Based on the least squares means estimates for the effect of ownership, the estimated deficiency scores are \(\exp(3.33) = 28.1\) for for-profit

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**TABLE 4. Relative Frequency* and Scope of the Top 10 Deficiencies for the Nursing Facilities Participating in This Study**

<table>
<thead>
<tr>
<th>Deficiency Tag†</th>
<th>Scope of Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>0441</td>
<td>0.33</td>
</tr>
<tr>
<td>0371</td>
<td>0.24</td>
</tr>
<tr>
<td>0323</td>
<td>0.14</td>
</tr>
<tr>
<td>0309</td>
<td>0.17</td>
</tr>
<tr>
<td>0329</td>
<td>0</td>
</tr>
<tr>
<td>0431</td>
<td>1.02</td>
</tr>
<tr>
<td>0279</td>
<td>0.62</td>
</tr>
<tr>
<td>0241</td>
<td>1.12</td>
</tr>
<tr>
<td>0514</td>
<td>5.44</td>
</tr>
<tr>
<td>0282</td>
<td>0.31</td>
</tr>
</tbody>
</table>

*The frequency of occurrence of a given scope level relative to the total number of deficiencies with that tag among sample homes.

†For descriptions of deficiency tags, see Table 3.

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**FIGURE 1.** Box plot of nursing home total deficiency score versus decile of total IT sophistication score.
ownership and \( \exp(3.12) = 22.7 \) for nonprofit ownership. The graphs and values in Figures 2 and 3 give some idea as to the effect of RN for other variables fixed as well as total IT sophistication for other variables fixed. The range of values on the horizontal axis was chosen to include approximately 90% of the observed values. In terms of the amount of variation explained by IT as opposed to other predictors, the multiple \( R^2 \) with RN and for profit (but no IT) is 0.02. When IT is added, there is a small increase to 0.03. Using only IT, the \( R^2 \) is 0.01.

DISCUSSION

Current assessments of NH quality nationally continue to identify inadequacies and substandard care delivery.\(^2\) Although recent NH data compendiums show improvements for the past 10 years.\(^2\) One hope for better NH quality is health IT. Millions of dollars have been spent incentivizing IT implementation since 2009.\(^8\) The benefits of infusing financial resources for health IT are being realized in acute and ambulatory healthcare markets, but not as much in NHs, which has been ineligible for the same incentives. However, according to previous studies about NH IT use, especially in resident care, even without incentives, IT use in these settings is becoming more common.\(^21,24\) Our findings have been confirmed in other studies. For example, nursing facilities with higher Medicare populations, which have wider profit margins, also tend to have greater IT adoption rates than facilities with higher Medicaid patients, which have lower profit margins.\(^25\) Nevertheless, current models tracking health IT adoption nationally, called Maturity Models, are insufficient because they only capture information from acute care organizations, resulting in only partial estimates of the real impact of regulated incentives.\(^9,26\) Furthermore, these models have not been linked with quality measures, which is the ultimate desired outcome.

This research examined the hypothesis that increased IT sophistication would result in lower overall health deficiency scores in a national sample of NHs. The subtle shift in health deficiency scores with a downward trend as IT sophistication increases in Figure 1 seems to support the hypothesis. To corroborate this evidence, more rigorous models were tested. Ownership status seems to have the most significant effect on reducing health deficiency scores, with not for-profit homes having lower deficiency scores. When RN hours per resident per day is held constant, the model predicts that homes will have lower deficiency scores as total IT sophistication increases. Similarly, as total IT sophistication is

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**FIGURE 2.** Estimated deficiency score as a function of RN staffing hours per resident per day for median total IT sophistication score of 290.

**FIGURE 3.** Estimated deficiency score as a function of total IT sophistication for median RN staffing hours of 0.5 hours per resident day.
held constant, when RN hours per resident per day is increased deficiency scores are predicted to be lower. These results suggest that the IT sophistication survey instrument may be capable of identifying areas of technology innovation, which impact quality, as evidenced by changes in health deficiency scores. The identification of specific dimensions and domains of IT sophistication can provide a more targeted approach to isolating the impacts of increasing technological maturity, which can be linked to improved quality of care more directly. As Accountable Care Organizations flourish, where more stakeholders assume the responsibility for the quality, costs, and care of long-term care residents, improvements in quality and decreased health deficiency scores and technology use will become a more valuable characteristic to trend.27

PRACTICE IMPLICATIONS

Providing safer environments for residents in NHs has been a significant issue for many years. Although gains in safety have been achieved nationally in NHs, there continues to be serious concerns, especially related to the occurrence of widespread and severe safety incidents resulting in immediate jeopardy to residents. Information technology is a tool that health administrators and managers can choose to implement to reduce safety concerns and improve quality of care. However, there are few studies reporting how health IT impacts safety in NHs that can be used by leaders to help make decisions about adoption. Generalizable studies are needed in the literature to inform leaders about the effect growing IT maturity may have on safety and quality.

In this study, which has national representation of NHs from each state, health deficiency scores seem to be trending in a positive, downward direction as health IT matures across settings. Historically, most technologies in these settings have been implemented in administrative billing and procurement activities; however, in this sample, health IT seems to have a significant presence in resident care activities too. Maturing IT systems in resident care activities have an impact on care planning activities and communication between staff. For example, IT systems in resident care that optimize communication between caregivers may increase awareness of necessary care planning activities, such as turning and repositioning, which may be time critical to avoid pressure ulcer formation (tag 279). In this sample, 76% of health deficiencies for tag 279 were isolated events with no harm, which may have been influenced by IT maturity in resident care. However, there is room for improvement. The health deficiency tag with the highest percentage of occurrence in this sample was related to infection control. It is interesting that clinical support technologies, which includes laboratory results reporting in the IT sophistication survey used for this study, was found to have the lowest levels of capability, use, and integration across all facilities. An assumption could be made that clinical support technologies with laboratory capabilities that are used and integrated into clinical activities might enable leaders to optimize tracking mechanisms for residents susceptible to infections, allow them investigate the occurrence of infections, and implement controls to prevent infection rates, thereby making the environment safer and of higher quality for residents.

LIMITATIONS

We recognize that a failure to account for biases in our study can have important consequences that could lead to faulty conclusions about theoretical propositions we have made about the influence of IT sophistication on quality measures.28 For example, NHs that participated in the IT sophistication survey may have a vested interest by being early IT adopters. Inclusion of NHs at all stages of adoption is necessary to be able to determine true relationships between increasing IT sophistication and quality of care. To encourage participation, our research team provided assistance as needed by scheduling additional follow-up with NH respondents who had questions about some survey items, until the respondents were satisfied with their level of comprehension of survey questions. Our methods also included important exclusion criteria to have similar homes in the sample based on current quality improvement initiatives. For example, we excluded all the NHs that were special focus homes. Approximately 1.2% of the NHs nationally were considered Special Focus Facilities in January 2013.29

CONCLUSIONS

National assessments of NH IT are beneficial because they facilitate discoveries that would not otherwise be known. In this research, we have seen evidence in a national study that health deficiency scores may be lower as NH total IT sophistication and RN staffing hours per resident per day increase. This is especially true in nonprofit NHs. These results further highlight the necessity of creating tools to better understand the benefits and costs of implementing health IT and demonstrating its impact on patient safety in NHs.

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