Technology to Improve Medication Safety in Nursing Homes

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Structured Abstract

Purpose: Nursing home residents have more illnesses and take more medications; thus, they have more risk for adverse effects. Recognizing the heightened risk for medication error and related consequences, this study sought to focus on nursing homes' unique medication administration challenges.

Scope: There are 1.6 million US nursing home residents at high risk for adverse effects from medication errors.

Methods: In an attempt to bring innovation to nursing homes' unique medication administration challenges, the study partnered with five Midwestern nursing homes to explore the impact of an electronic medication administration record and a focused quality improvement team on medication errors.

Results: Nearly 16,000 administered medications were observed over 2 years. Technology and related process improvements increased the efficiency of medication administration across all nursing homes. Additionally, four of five nursing homes demonstrated statistically significant improvement at some point during the study. However, the pattern of improvement varied, suggesting that many factors were influencing the impact of technology and focused quality improvement activities on medication errors. Organizational factors, such as nursing leadership and effective teamwork, appeared to be closely link to the pattern of improvement. Nurse leaders were critical to improvement and were varied in their skills, suggesting that nurse leader development is essential.

Key Words: medication safety practices, medication errors, nursing homes, technology, and quality improvement

Purpose

There is an increasing demand for nursing home services as the proportion of citizens age 85 years old or greater grows larger. Nursing home residents have more illnesses and take more medications; thus, they have more risk for adverse effects. The results of nursing home medication error can lead to greater consequences than have been reported in other healthcare settings (Bates, Cullen, Laird, 1995; Gurwitz, Field, Judge, et al., 2005). Recognizing the heightened risk for medication error consequences, the study sought to focus on nursing homes' unique medication administration challenges. In an attempt to bring innovation to nursing homes' unique medication administration challenges, the study partnered with five Midwestern nursing homes to explore the impact of an electronic medication administration record (eMAR) and a focused quality improvement team on medication safety practices and medication errors. The specific aims of the study were to:

1. Determine baseline medication safety practices (order entry, alerts to prevent adverse drug events and to highlight special medication precautions, resident identification, and dispensing) in the nursing home setting.
2. Evaluate eMAR and focused quality improvement efforts in the nursing home setting as they relate to improved medication safety practices and reduction of medication error rates.
3. Elicit the organizational and individual barriers to safe medication practices within the nursing home setting.
4. Assess the nursing home climate and culture to determine organizational readiness to embrace innovation and new quality improvement strategies.
5. Explore the costs of medication administration and error in the nursing home setting.

Scope

Earlier research suggests that medication errors, excluding wrong-time errors, average 10% or more of administered doses (Barker, Allan, 1995). In addition to medication errors, even relatively minor discrepancies in medication administration may negatively affect outcomes of frail nursing home residents (Bates et al., 1995). Fortunately, a significant proportion of nursing home medication errors are preventable (Barker, Flynn, Pepper, et al., 2002a; Gurwitz et al., 2005). Medication errors are preventable through the continuous improvement of the complex structures and processes that underpin nursing home medication administration (Vogelsmeier, Scott-Cawiezell, Zellmer, 2007; Vogelsmeier, Scott-Cawiezell, 2006). These complex structures and processes include receiving an order (typically from a remote provider); transcribing an order; communicating an order to remote pharmacies; dispensing a medication by one of several remote pharmacies; transporting the medication to the nursing home; placing the medication into the nursing home medication administration system; and, finally, administering the medication in the midst of lengthy, noisy, and often disrupted medication passes.

Because most healthcare providers underestimate the complexity of nursing home medication administration, little attention has been given to bringing integrated technological solutions to this setting. Technological solutions lag despite Berwick (2001) and others' (Institute of Medicine, 2006) suggestion that the remedy for medication error requires redesigns that incorporate the alerts and signaling of interactive technology, the integration of communication patterns, and the integration of systematic task redesign (Scott-Cawiezell, Madsen, Pepper, et al., in review).

Methods

To test the premise that technology and focused quality improvement efforts could decrease the complexity of nursing home medication systems, improve medication safety practices, and reduce medication error, a longitudinal intervention study was completed. The intervention study examined the implementation of the electronic medication administration record (eMAR), which was embedded in the larger implementation of the complete Optimus EMR, Inc. (formerly,

OneTouch Technologies) electronic medical record (EMR), and focused quality improvement efforts among a convenience sample of five Midwestern nursing homes. Nursing homes were selected based upon their desire to engage as partners in the implementation of a complete EMR. Although the nursing homes were early adopters, they represented both urban and rural areas, various nursing home bed sizes (60 to 180 beds), various states, and various ownership structures. In addition, the nursing homes varied on the level of education of those that actually administered the medications.

The study used a multi-method approach to explore the nursing home environments, including key informant interviews, focus groups, and staff surveys prior to the implementation of technology. To evaluate the intervention, the research team conducted onsite naïve observations of medication administration over multiple shifts and units at baseline, 3 months post-implementation of eMAR, 6 months post-implementation of eMAR, and 9 months post-implementation of eMAR.

Interventions

Electronic Medication Administration Record (eMAR) is an electronic point-of-care tool directing and recording medication administration through a medication cart touchscreen application via a wireless laptop computer. The eMAR system provides several alerts and signaling features that prompt staff of potential medication safety issues. These features included color codes that alert the provider of medications due, medications past due, medications that needed follow-up documentation, and new medication orders. Medication monitoring parameters required for certain medications, such as blood pressure or heart rate, were documented before the provider prepared the medication for the patient.

Focused Quality Improvement/Medication Safety Teams were established using a multidisciplinary approach. The medication safety teams were trained in rapid-cycle quality improvement strategies and systematic error assessments, such as root cause analysis to monitor medication safety practices and medication error patterns. The medication safety teams monitored the implementation of technology, the related communication patterns, and the related processes through a safety lens. In addition to monthly reviews of nursing staff's reported and/or observed medication errors, the nursing home teams were provided extensive data from direct observation of medication administrations. Using traditional medication error reporting, naïve observation findings, and technologically generated reports, the teams monitored medication errors and medication safety practices to maximize the impact of technology and the redesigned structures and processes.

Primary Measures

Communication, Leadership, and Teamwork were measured using an adaptation of Shortell and colleagues' Organization and Management Survey (Shortell, Rousseau, Gillies, et al., 1991; Shortell, Zimmerman, Rousseau, et al., 1994). Earlier nursing home research suggested that it was the interplay of these organizational elements that created the culture and climate that influenced an organization's capacity to create and sustain improvement (Scott, Schenkman, Moore, et al., 2004; Scott, Vojir, Jones, et al., 2005; Shortell et al., 1991 & 1994). The interplay was noted during observation and psychometric testing that reconstituted Shortell and colleagues' original subscales during earlier AHRQ- and Centers for Medicare & Medicaid Services (CMS)-funded work. The reconstituted subscales have been discussed in earlier publications and are labeled as connectedness (seven items), organizational harmony (10 items), clinical leadership (four items), and timely and understandable information (five items) (Scott et al., 2005).

Measuring Improvement in Medication Error Rates: Although each nursing home had an established method of collecting medical error information, each nursing home reported a small sampling of actual medication errors. To supplement the traditional methods of reporting

medication error, naïve observation (Barker, Flynn, Pepper, 2002: 2002b) was used to provide extensive feedback to the medication safety teams. Naïve observation allowed the researcher to unobtrusively observe a complete medication administration without preconceived ideas of what medication should be administered. The nurse observer walked with the medication administrator and watched the medication administration for each resident encounter, recording what medication was given, the dose, the route, the time, and any other noteworthy issues, such as distractions or interruptions. The nurse observer avoided any contact with the medication administration record or medication orders until the observation was completed. At the end of the observation, the nurse observer compared the previous 90 days of the resident's medical record to determine if the observed medication administration matched the active medication orders.

Medication error was defined as a dose that was discrepant to the medication order. The rate of error was computed by dividing the number of medication doses with any discrepancy from the medication order (e.g., wrong dose, wrong route) by the opportunities for error (OE). Opportunities for error were defined as the sum of the number of medication doses administered and the number of medication doses ordered but omitted. In addition to monitoring the medication administration, distractions and interruptions to medication administration were noted. Distractions were defined as an event that did not stop the medication administration but could have diverted the medication administrator's attention, and interruptions were defined as events that stopped the medication administration. During the analyses, medication error was considered with and without wrong-time medication error, because wrong-time error reflects many specific system and timing issues that are often out of the control of the medication administrator. To further explore the variables of interest, statistical comparison of error rates by credentialing was done using a generalized linear modeling package (GENMOD in SAS v9.1) to allow for modeling the dependencies in observations of the same medication administrators.

Limitations

As with all sampling techniques, there are limitations to capturing all aspects of the observed phenomenon. Although naïve observation provided a rich source of information and has facilitated reliable extrapolation, there was reason to believe that the observational method did not fully capture the true proportion of medications errors as it related to omitted medication doses. Naïve observation required that only observed medication errors were recorded despite the observers' encounter with earlier medication errors when medical records were reviewed. During the medical record review, it was noted that omitted errors seemed to be more *clustered* in their occurrence, leaving our research team concerned that we were not truly quantifying the proportion of omitted medications to the same degree as other types of errors. Specifically, if a medication was ordered to be given every 4 hours and the medication was unavailable for 24 hours, our observation could only count the medication that was omitted during our observation (one error) and not the other five doses that were omitted (five additional errors). To further clarify causes of omitted medications, other methods of data collection, such as focus group findings (Vogelsmeier, Scott-Cawiezell, Zellmer, 2007), supplemental data from the monthly incident reports, and observations from the medication safety team, were used.

Another limitation related to the inability of our team to capture accurate cost information related to medication errors. Aim Five indicated that we would attempt to explore the costs of medication administration and error in the nursing home. In reality, because of the very limited nursing home cost accounting systems and the complexity of pharmaceutical interfaces, we were only able to explore the costs related to the implementation of technology. Attempts to explicate the costs of medication errors were further complicated by many contributing factors that included inconsistent error reporting and only periodic (monthly) engagement of the research team with the research site. Finally, creating the causal link between a medication error and the adverse outcomes required a more complex identification process than the

research team was prepared for or resourced to complete (Gurwitz, Field, Avorn, et al., 2000; Gurwitz, Field, Judge, et al., 2005). Even in cases when an unquestionable causal link to adverse outcomes was found, limited cost accounting systems and the inability to interface effectively with transferring hospitals and remote pharmacy cost accounting structures precluded quantification of related costs.

In addition to the limitations noted with our observational method and our inability to capture costs related to medication error, the research team made a decision to analyze medication errors differently than earlier studies guided by observational methods, which will limit some comparison studies. Although the research team does not believe that medication errors are directly linked to individuals, a careful review of the data indicated that there was a nested or clustered structure to the data. Using Hierarchical Linear Modeling, the within-cluster dependency was further explored to estimate the intracluster correlation (ICC). A random-intercept model-to-baseline observation found an ICC of 0.23 when considering all medication errors, including wrong-time errors. Although the ICC was lower when considering medication errors without wrong-time medication errors (0.11), the finding did not go to zero, further suggesting the presence of within-cluster dependency. Because the study centered on nursing home change over time, the cluster effect due to medication administrator was accommodated using a method of generalized estimating equations (GEE) called alternating logistic regression. This approach accounted for the within-cluster dependency. However, despite approximately 16,000 observed medication administrations, the multiple levels of nesting in the data and the scarcity of errors precluded full modeling of data.

Results

As noted in Table 1, five nursing homes, representing various geographic locations, size, and ownership statuses, constituted the sample. The five volunteer nursing homes varied in three commonly reported elements. The nursing homes ranged in bed size between 60 and 180 beds; three nursing homes were not-for-profit and two were for-profit; and three of the nursing homes were urban and two were rural. The nursing homes were located in Missouri, Iowa, and Kansas. The five nursing homes employed approximately 340 clinical staff and provided care for approximately 600 residents, who were approximately 17% racially and ethnically diverse.

Table 1. Overview of Nursing Homes in the Study

	Nursing Home One	Nursing Home Two	Nursing Home Three	Nursing Home Four	Nursing Home Five
Bed Size	60	180	120	120	180
Ownership	Not-for-profit	Not-for-profit	For-profit	For-profit	Not-for-profit
Urban/Rural	Urban	Urban	Rural	Urban	Rural

Selected Pre-Intervention Findings

Communication, Leadership, and Teamwork (Aim 4)

We recognized the critical nature of communication, leadership, and teamwork in the assessment of a nursing home's ability to create and sustain improvement, so staff members were surveyed at baseline to determine how strongly the nursing home staff members agreed or disagreed that these critical elements were present. The research team had a great deal of experience exploring nursing homes' organizational capacity to create and sustain improvement and hoped to use the information about the current staff perceptions of communication, leadership, and teamwork to provide insight into how to develop the medication safety team (Scott, Schenkman, Moore, et al., 2004; Scott, Vojir, Jones, et al., 2005; Scott-Cawiezell, 2005; Scott-Cawiezell, Main, Vojir, et al., 2005).

In total, 253 staff members responded to the survey (overall response rate, 68.7%; range, 59.2% to 84.4%). The sample included 33 registered nurses (RNs), 39 licensed practical nurses (LPNs), 151 certified nursing assistants (CNAs), and 30 others (including department managers, other allied healthcare providers, and those not declaring a job title). A substantial portion of the respondents (72.1%) had worked with elderly individuals for more than 3 years. Many of the respondents (49.2%) had been in the same job for more than 3 years, and 38.6% had worked in the same nursing home for more than 3 years. The findings presented in Table 2 are very similar to findings from an earlier AHRQ-funded study (Scott-Cawiezell, Jones, Vojir, et al., 2004) and several studies funded by CMS (Scott, Schenkman, Moore, et al., 2004; Scott-Cawiezell, 2005).

Table 2. Nursing Home Communication, Leadership, and Teamwork Survey Mean Scores

Subscale and Sample Question	Prior AHRQ Study	Nursing Home					Overall Mean
		1	2	3	4	5	
Connectedness (7 items) *I am a part of this team. I feel I am a part of this team.*	3.7	3.8	3.8	4.0	3.7	3.4	3.7
Organizational Harmony (10 items) *Nursing leadership often makes decisions without my input.*	3.2	3.0	3.1	3.0	3.1	2.7	3.0
Clinical Leadership (4 items) *Nursing leadership provides strong clinical guidance and advice to the nursing staff.*	3.3	3.0	3.2	3.5	3.2	2.9	3.2
Timeliness and Understanding (5 items) *When a resident's condition changes, I get the right information quickly.*	3.4	3.2	3.2	3.2	3.1	2.3	3.0

1 (strongly disagree) to 5 (strongly agree)

Pre-Intervention Barriers to Safe Medication Practices (Aims 1 & 2)

Seventy-six staff members from the five nursing homes participated in either key informant interviews or focus groups. Key informant interviews were completed with selected nurse leaders in each nursing home. Two focus groups were also completed in each nursing home. One focus group addressed the issues of managing medication administration among RNs and pharmacists, and a second focus group specifically addressed medication administration issues among LPNs and CMT/As.

Common themes were elicited across the five nursing homes. The common barriers to safe medication practices related to communication, competing demands, and paper-based documentation systems (Vogelsmeier et al., 2007). In addition, barriers were considered as they related to the complex structures and processes embedded in medication administration. The understanding of barriers provided specific points for action as the medication safety teams sought to maximize the impact of eMAR on medication safety practices. A full discussion of the barriers to safe medication practices can be found in Vogelsmeier et al., 2007.

Prior to the intervention, two additional safe medication practice barriers were hypothesized: the credential level of the medication administrator and/or the number of interruptions or distractions the medication administrator faced during each medication administration. Based upon the initial naïve observation findings, the team sought to determine if level of credentials, interruptions, and/or distractions should be more carefully explored. When medication errors were considered by level of credential, RNs had an error rate of 34.6%, LPNs had an error rate (% of medications administered in error) of 40.1%; CMT/As, 34.2%. However, when

wrong-time errors (typically out of the control of the medication administrator) were removed, RNs had the largest percentage of error (7.4%). Despite the noted differences in medication error rates, there were no statistically significant differences by level of credential (p=0.82) when effects of dependence of multiple observations of the same administrator were statistically controlled (Scott-Cawiezell et al., 2007).

Factors such as interruptions and distractions were also explored. Over 2,200 distractions or interruptions were observed prior to implementation of eMAR. Among these observed distractions and interruptions, RNs had the highest percentage of doses interrupted (39.9%), and LPNs had the highest percentage of distractions (41.6%). In order to investigate the relationship between medication errors by credential level and distractions or interruptions, the Cochran-Mantel-Haenszel (CMH) statistical procedure was used. The CMH statistic assessed the association between variables after adjusting for the stratification on level of credential, thus allowing us to control for the effect of medication administrator. When considering the relationship between interruptions and the rate of medication error, it was interesting to note that, although the relationship between interruptions and medication errors was significant with (p=.0099) and without (p=.035) wrong-time errors, there was an inverse relationship between the rate of interruptions and medication errors when wrong-time medication errors were included (Scott-Cawiezell et al., 2007).

Select Post-Intervention Findings

Medication Error Rates (Aim 2)

In total, 160 staff members participated in naïve observations over the four observation periods. This sample included 26 RNs, 64 LPNs, and 70 CMT/As. Staff members' years of experience varied among the three groups, and RNs' experience levels were substantially more than those of LPNs or CMT/As. RN staff members had a median of 17 years of experience; LPNs had a median of 4 years, and CMT/As had a median of 6.5 years. Median staff member years at the nursing homes had less variance; RNs had at 2 years, and LPNs and CMT/As each had 2.5 years.

Table 3 provides an overview of the medications observed during eight to 10 unique medication administrations at each observation point.

Table 3: Overview of Medication Dose Administration Observations

	Pre-eMAR	3-Month Post-eMAR	6-Month Post-eMAR	9-Month Post-eMAR	Total
Opportunities for Error	3,395	4,320	3,864	4,226	15,805
Medication Administrations	44	51	54	46	195
Resident Encounters	912	1025	860	888	3685
Hours Observed	84.5	80.9	68.3	74.7	308.4

Following each naïve observation, detailed feedback was provided to the medication safety team for ongoing rapid-cycle process improvement. Many types of errors were monitored from the viewpoint of the resident, including unauthorized drug, wrong dose, wrong route, wrong preparation technique, wrong time, wrong monitoring technique, and omitted drugs (excluding resident refusals). There were three wrong route errors observed when medications ordered per g-tube were given orally (likely reflecting the need to update orders more than being clinically significant). Fifteen unauthorized drug errors were observed. Finally, only 10 monitoring errors were observed, and they appeared to be linked to the lack of monitoring orders or standard

protocols more than to the effective monitoring of medications. Table 4 provides an overview of key observed errors.

Table 4: Percentage of Observed Medications in Error Across Observation Periods

Medication Error Type	Pre-eMAR	3-Month Post-eMAR	6-Month Post-eMAR	9-Month Post-eMAR
Dose Error	1.2%	1.6%	0.6%	0.1%
Preparation Technique Error	0.6%	2.2%	2.4%	1.3%
Late Medications	22.3%	24.5%	15.1%	21.0%
Omitted Medications	1.1%	2.2%	2.8%	1.1%
Total Errors with Late Medications	34.5%	34.8%	27.6%	31.0%
Total Errors without Late Medications	4.7%	8.8%	7.2%	3.7%

An unexpected finding was the number of medication errors related to wrong preparation technique. At every nursing home, medications that were on the standard “do not crush” list were being crushed for patients who could not swallow. The crushing of these medications resulted in residents getting time-released medications in bolus doses---hence, a wrong-dose error. However, these types of medication errors were counted separately to provide the medication safety team with more information about this clinically significant finding.

Late medications (defined as medications given more than 1 hour after the designated time) dropped from 24.5% of medication doses observed (1,058) to 15.1% (583) of medication doses observed at 6 months post-eMAR implementation. There was an increase in late medications at 9 months for one nursing home related to two clinical emergencies during the observations and implementation of a completely new medication dispensing system 1 week prior to the last medication observation. The medication safety teams also monitored the number of medications that were delivered in an hour during the observations to determine if technology was improving the efficiency of the medication administration system, because wrong-time medication errors could be related to many other factors. Prior to eMAR, approximately 40 medications were given per hour of medication administration observed. This continued to rise throughout the study, with medication administrators averaging 57 medications per hour at the end of the study, suggesting that the medication administration process had become more efficient.

The pattern of performance for each nursing home was also explored across the observation periods and is presented in Table 5. Each nursing home faced unique challenges and brought unique strengths to the intervention study. Although Nursing Home Five started with the lowest medication error rate, it showed no statistically significant improvements or declines during the study. Nursing Homes One and Three actually had statistically significant declines in performance (more errors) from the initial assessment to the 3-month and 6-month post-implementation measurements. However, Nursing Homes One, Three, and Four did show significant improvement from their low point in their performance to the final measurement. The only nursing home to show statistically significant improvement between the pre-implementation measure and the final post-implementation measurement ($p<.05$) was Nursing Home Two.

Table 5: Percentage of Non-Time Medication Errors Among the Study Nursing Homes

Nursing Home	Pre-eMAR	3-Month post-eMAR	6-Month post-eMAR	9-Month post-eMAR
1	3.73% **Pre & 3 mo *Pre & 6 mo	8.22% **3 & 9 mo	7.98% **6 & 9 mo	1.51%
2	4.75% *0 & 9 mo	4.21%	5.50% *6-9 mo	2.02%
3	3.63% *Pre & 3 mo *Pre & 6 mo	6.99% *3 & 9 mo	9.36% *6 & 9 mo	4.27%
4	4.85%	10.84% **3 & 9 mo	5.01% **6 & 9 mo	2.45%
5	2.40%	2.58%	5.46%	4.82%

**Statistical Significance <.05*
***Statistical Significance <.01*

Organizational and Individual Barriers to Safe Medication Practices (Aim 3)

After the initial observation that level of credential, distractions, and interruptions could be clinically significant, barriers to safe medication practices were considered throughout the study. Table 6 provides an overview of the distribution of interruptions and distractions at each observation point according to level of credential of the medication administrator. Total interruptions and distractions decreased across the four observations. RNs had the most interruptions at all observation points except 6 months post-intervention and had the least distractions at all but 3 months post-intervention. However, no other potential patterns of interruptions and distractions were noted across levels of credential and observation points (Scott-Cawiezell, Pepper, Madsen, et al., 2007).

Table 6: Percentage of Medication Doses Interrupted or Distracted across Four Observations.

	Pre-eMAR	3-Month Post-eMAR	6-Month Post-eMAR	9-Month Post-eMAR
Interruptions Total	32.0%	22.0%	15.6%	7.6%
RNs	38.6%	28.2%	6.6%	33.9%
LPNs	32.7%	16.1%	19.4%	6.4%
CMT/As	30.2%	24.5%	14.4%	6.1%
Distractions Total	35.5%	20.4%	19.8%	14.3%
RNs	24.9%	16.8%	9.9%	8.3%
LPNs	41.5%	15.8%	22.1%	12.7%
CMT/As	36.0%	23.3%	17.8%	15.7%

When considering all observed medication errors associated with an interruption (and including wrong-time medication errors), 29.2% (RN 24.6%, LPN 44.3%, and CMT/A 25.1%) of medication errors were associated with an interruption. However, when excluding late medications, the rate of medication error when interruptions were present was 8.1% (RN 6.9%, LPN 7.9%, and CMT 8.4%). The effect of interruptions was further investigated using logistic regression with medication error as the outcome variable and interruptions as an independent variable. Level of credential, nursing home, and observation point were also included in the model. The coefficient for the interruption variable was not significantly different from zero when considering the variable that included medication errors, including wrong-time medication errors;

however, it was significant when considering the variable that only included medication errors excluding wrong-time errors (p=0.007). The logistic regression analysis described above also allowed us to examine the effect of level of credential of the medication administrator on error rates. Exploring the variation of error rates among the three levels of credential was completed, again excluding wrong-time medication errors (5.2%). Across all observations, RNs (n=26, 16.4% of medications observed) had a medication error rate of 4.6%, LPNs (n=64, 24.9% of medications observed) had a medication error rate of 4.3%, and CMT/As (n=70, 65% of medications observed) had an error rate of 5.6%. There were no statistically significant relationships between medication error rates and level of credential noted. The same conclusions held whether interruptions were included or excluded from the logistic regression model.

Costs of Embracing Technology (Aim 5)

As noted in the limitations, the attempt to explore the costs of medication administration and medication error in the nursing home was an insurmountable challenge. However, tracking the costs of implementing technology was completed. Costs related to the implementation of nursing home technology can provide information to quantify the cost/benefit ratio of technology implementation. The total costs of the project across the five nursing homes that could be directly linked to the implementation of the EHR are noted in Table 7. Of these total costs, $1,121,125 (70.8%) was incurred by the five nursing homes participating in the project. Of the total costs, $68,500 (4.3%) reflected monthly support to the nursing home by the vendor, and $394,194 (24.9%) represented incentives provided by the grant to the nursing homes.

Table 7: Sources of Aggregate Nursing Home Technology Costs

Type of Expense	Total Costs	Percentage of Total Facility Costs
Staffing	$336,101	30.0%
Software	$264,000	23.5%
Training	$165,000	14.7%
Hardware	$155,600	13.9%
Additional Hardware & Supplies	$56,777	5.1%
Additional Computers & Network Equipment	$143,646	12.8%
Total Expenditures by Facility	$1,121,125	100.0%

Because the nursing homes participating in the project varied in bed size, the costs incurred by the nursing homes also varied in amounts ($143,704 to $287,998). Table 8 provides information on costs per bed for each nursing home. Note that there was economy of scale to be gained related to training fees, hardware, additional hardware and supplies, and additional computers and networking equipment. Software fees were a flat rate per nursing home bed.

Table 8. Costs per Nursing Home Bed by Facility

Bed Size	Staff Costs	Software	Training	Hardware	Additional Hardware & Supplies	Additional Computers & Network Equipment	Total Cost Per Bed
60	$656.94	$400.00	$550.00	$331.67	$122.63	$360.90	$2,422.14
180	$600.52	$400.00	$183.33	$250.19	$62.57	$307.90	$1,804.51
120	$489.84	$400.00	$275.00	$315.88	$167.96	$270.19	$1,918.87
120	$724.70	$400.00	$275.00	$273.88	$51.53	$290.18	$2,015.29
180	$238.03	$400.00	$183.33	$266.08	$25.27	$420.63	$1,533.34

Discussion

The nursing homes in the study represented various bed sizes, various ownership statuses, and both rural and urban locations; by embracing full EMR implementation, they may not be considered typical of the industry as "early adopters" of technology. However, despite early technology adoption, these nursing homes were observed to be typical in such challenges as nurse leadership turnover. When the study's nursing homes were compared with data from an earlier AHRQ nursing home study (Scott-Cawiezell, Jones, Vojir, et al., 2004), the current nursing homes had lower mean scores on three of the four communication, leadership, and teamwork subscales, suggesting that the current study's nursing homes may have been organizationally less prepared to create and sustain improvement than many other US nursing homes.

Creating and Sustaining Improvement to Improve Medication Error Rates

Earlier nursing home studies have reported the critical nature of communication, leadership, and teamwork in the creation and sustainment of nursing home organizational improvement (Scott, Schenkman, Moore, et al*.* 2004; Scott, Vojir, Jones, et al., 2005; Scott-Cawiezell, 2005; Scott-Cawiezell, Main, Vojir, et al., 2005). Struggles with communication, leadership, and teamwork further complicated the challenges the study's nursing homes faced in their completion of the large-scale change involved in EMR implementation. Specific challenges observed throughout the study included ineffective communication within the nursing home and between the nursing home and the pharmacy, nurse leadership style and turnover, and minimal experience in quality improvement for the medication safety teams. As noted in Table 5, the pattern of improvement across the observation points varied greatly among the five nursing homes.

The only nursing home to show significant improvement between the baseline observation and the final observation was Nursing Home Two. Although Nursing Home Two had similar problems with nurse leader turnover, Nursing Home Two varied from the other nursing homes in two noteworthy ways that ultimately impacted communication and the performance of the medication safety team. First, Nursing Home Two was the only nursing home to have a pharmacy as part of their corporate structure. Although the pharmacy was still physically remote from the nursing home, the pharmacists and technicians considered themselves part of the team and, accordingly, they were very responsive to making rapid and necessary structural and process changes. The second noteworthy difference was the decision to hire a clinical nurse specialist (CNS) with expertise in informatics. The CNS remained focused and effective at communicating issues surrounding technology implementation throughout the study. The presence of an effective team, a strong nurse leader advocate, and good communication about the changes related to medication administration and technology all contributed to sustainable improvement.

Nursing Homes One and Three both had statistically significant declines in performance for the first two observations after the implementation of technology. Both nursing homes had stable leadership during the implementation of technology, yet in both nursing homes the research team observed a top-down communication approach between clinical leadership and nursing home staff. Additionally, both nurse leaders made choices to address the redesign of the medication administration and technology interfaces without the input of the medication safety teams, which ultimately led to unintended consequences. Nursing Home One and Three also shared the challenge of complex pharmacy partnerships that were less amendable to good teamwork. Because of top-down communication, poor teamwork between the nursing home and pharmacies, and unilateral nurse leader choices, medication administration remained destabilized for a longer period of time, leading to more medication errors. Technology only amplified medication administration issues. However, once medication safety teams were able to address the interface between medication administration and technology using observational data, eMAR safety features were maximized and medication errors significantly improved.

Although Nursing Home Five began the study with the best medication error rate, the nursing home demonstrated no statistically significant improvement or decline in performance throughout the study. Nursing homes were supposed to implement eMAR 6 months after the implementation of the EMR; however, Nursing Home Five was well past this targeted eMAR implementation date because of the turnover of two nurse leaders between the initial implementation of the EMR and the second phase of implementation of the eMAR. Although eMAR implementation was delayed, the nursing home's medication safety team met monthly and developed excellent skills in communication and teamwork through the interim between the initial and eMAR implementation phases. However, well into the study, the medication safety team lacked a clinical leader to advocate and communicate change to the entire nursing home. With more months to prepare for the eMAR implementation and the opportunity to learn from the other nursing homes that had already implemented eMAR, Nursing Home Five did avoid statistically significant declines in performance. Despite the medication safety team's good performance and the medication team's additional information from other nursing home's lessons learned, clinical leadership lagged behind in supporting and advocating for the intervention well into the study. Thus, regardless of their high-performing medication safety team, Nursing Home Five was unable to effectively communicate and embed the necessary changes needed to maximize eMAR's ability to impact medication safety practices. The delayed presence of the nurse leader definitely impacted the intervention and was a likely explanation of no real improvement in medication errors in Nursing Home Five.

Nursing Home Four was the only nursing home to demonstrate what the research team hypothesized would be the predictable pattern of medication error during the implementation of the eMAR. Although the increase in medication errors 3 months post-implementation was statistically insignificant, it still had the predictable increase in medication errors as medication administration destabilized and was redesigned. Nursing Home Four had both a strong and committed pharmacy partner and a strong nursing leader who was committed to facilitating the staff's voice in the change process. The presence of a strong pharmacy partner and nurse leader resulted in an effective medication safety team that quickly addressed and refined the interfaces between medication administration and the technology. Nursing Home Four's rapid and effective redesign of the medication administration and technology interfaces resulted in sustained improvement from their initial destabilization 3 months post-implementation to the last observation.

Reflecting on each nursing home in the study provides insight into how organizational factors, such as communication, leadership, and teamwork, did have an influence on their ability to create and sustain improvement. Although all nursing homes appeared to be similar on established measures of staff perceptions related to communication, leadership, and teamwork at baseline, they did vary on the presence, abilities, and tenure of their nurse leaders; the

receptivity of critical pharmacy partners; and other organizational decisions to support the integration of eMAR into medication administration. Although stable and strong nursing leadership did appear to contribute to the nursing home with significant improvement from baseline to the final observation, decisions made by other long-time nurse leaders actually delayed the positive impact of the technology. Nursing homes with top-down communication appeared to delay medication safety teams' ability and desire to engage in the quality improvement process. Finally, it was also noted that, as medication safety teams became more forthcoming on reporting opportunities for improvement, more observant of potential problems with medication safety practices, and more trusting of their nurse leaders, the medication safety teams became more effective in their problem solving.

The medication safety team's engagement and observations suggested that the team members were becoming more mindful of medication safety concerns and that the nursing homes were beginning to create a culture where team members felt "safe" to share concerns (Scott-Cawiezell, Vogelsmeier, McKenney, et al., 2006). Although the nursing homes still had many challenges related to moving from a culture of blame to a culture of safety, the medication safety team provided an opportunity for cultural movement to begin (Scott-Cawiezell et al., 2006; Vogelsmeier, Scott-Cawiezell, 2007).

Impacting Medication Safety Practices

In addition to understanding the interplay of communication, leadership, and teamwork upon the improvement of medication error, other benefits to the introduction of technology were noted. First, the introduction of technology to nursing home medication administration provided immediate streamlining to complex processes. For example, prior to the implementation of computerized order entry, there were multiple places that the nurse had to document a new order. In addition to the immediate streamlining of the ordering process, technology provided clear, legible, real-time information on medications due at any point in time. Streamlined computer order entry provided more readily accessible, up-to-date, and legible medication orders that resulted in fewer interruptions to clarify medication orders. Improvements to medication administration contributed to the observed changes in efficiency, as evidenced by the increase in the observed medications given per hour from 40 to 57 medications. In addition to fewer interruptions to clarify medication orders, the presence of the full EMR also provided readily available updates on resident condition changes or current vital signs. Readily available supplemental medical information also decreased the need for the medication administrator to stop the medication administration.

Another important feature of eMAR was the reporting function that could generate a large variety of reports that quantified such problems as missing medications to improve the nursing home/pharmacy interface. For example, Nursing Home One had many issues with timely delivery of medications. During the initial focus group interviews, staff reported that it often took 2 to 3 days for a new medication to be available at the nursing home. Although the nursing home did have some stock medications in the building, most staff were unaware of the availability of the in-house medications. Using the missing medication report and reports from staff, the nursing home was able to work with the pharmacy and the third-party delivery system and improve the timely delivery of medications (Scott-Cawiezell, Madsen, Pepper, et al., in review).

Another benefit of the study was the opportunity to scrutinize the staff's response to the various features of eMAR. These responses often resulted in staff working around various features of the technology of the redesigned medication administration processes, resulting in the overriding of safety alerts and shortcutting of documentation processes. By carefully monitoring workflow and discussing perceived blocks to workflow, the medication safety teams were able to identify both opportunities for further redesign of medication administration and/or

communication about the reason behind safety features embedded in the eMAR (Vogelsmeier, Halbesleben, Scott-Cawiezell, in press).

Conclusions

The challenge of managing medications among the frail elderly is complex. Technology can improve communication, support effective decision making, and integrate complex tasks. Regardless of how effectively the technology is designed, technology is frequently "laid upon" nursing home medication administration systems that are archaic and fragmented. The addition of technology can destabilize nursing home medication administration without careful attention to the interface that must be designed between these fragmented processes. Additionally, the implementation of technology will not solve chronic structure and process issues in isolation. However, the combination of focused quality improvement efforts and technology does appear to provide a means to enhance medication safety practices and ultimately reduce medication errors.

Significant Implications

There are several implications from the study. First, the implementation of technology and related process improvements did increase the efficiency of nursing home medication administration. The pace of medication administration moved from 40 medications per hour to 57 medications per hour by the end of the study. Second, organizational factors, such as communication, leadership, and teamwork, must be considered as nursing homes build their organizational capacity to create and sustain improvement. Nurse leaders are critical to sustained improvement and vary in their skills and abilities to lead large-scale change, suggesting that nurse leader development is essential for safe care.

Providing safe care requires leadership. Leadership is critical to providing an environment where opportunities to improve can be addressed and critical safety discussions can occur. Although our primary outcome measures do not reflect the impact of what appeared to be changing cultures, perhaps the biggest observed success of the study was related to how quality information provided a mechanism to bring together nursing home and pharmacy staff to solve problems in an open and blame-free environment after years of keeping medications underground for fear of punishment (Scott-Cawiezell, Madsen, Pepper, et al., in review). The provision of multiple forms of information, particularly the reports that could be generated from the EMR, raised medication error discussion from blaming individuals to solving systemic problems. The provision of information created a transparency to the nursing home medication administration that few had ever seen. The result, medication safety teams were solving problems and coming forth with opportunities for improvement, confident that they could create solutions and that people would not be punished. The most telling example of this was the last meeting at one of the study nursing homes. This nursing home had started the study suggesting to the research team that they had only one medication error in the previous 6 months. In reality, they had received only one report of a medication error in the previous 6 months. As data collection began, it quickly became evident that they were like many other healthcare settings. Known errors were the tip of the iceberg. On the last day the research team was onsite, the team reported 45 opportunities for improvement through the medication monitoring for the month. Although at first glance this may appear as a failure, the research team and medication safety team celebrated the arrival of an environment in which the slightest error or near miss created an opportunity to improve. Technology brought the information to this nursing home team and created a chance for the medication safety team to become informed and high performing.

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