Health Information Technology in the Nursing Home

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Abstract

Purpose: The overarching aim of this project was to begin to fill gaps in knowledge regarding the use of computerized provider order entry with clinical decision support in the nursing home setting.

Scope: Given the complexity of the drug-use process and the multitude of potential failure points, computerized order-entry with clinical decision support may be a promising tool for improving the drug use process in the long-term care setting.

Methods: The setting for this study was an academically-affiliated long-term care facility with an electronic medical record system including integrated computerized provider order entry. We assessed the effectiveness of computer-based clinical decision support in the nursing home setting for improving the quality of medication ordering and the costs directly related to the development and installation of computer-based clinical decision support. We also assessed the nursing home setting with respect to readiness to incorporate computerized provider order-entry with computer-based clinical decision support.

Results: A clinical decision support system in the long-term care setting can lead to improved medication safety, but implementation costs are substantial and only modest cost savings can be expected.

Key Words: medication safety, long-term care, nursing home, patient safety

Final Report

Purpose

The specific aims for our study were:

Aim 1. To assess the effectiveness of computer-based clinical decision support in the nursing home setting for improving the quality of medication ordering.

Aim 2. To determine costs directly related to the development and installation of computer-based clinical decision support and the impact of computer-based clinical decision support in the nursing home setting on drug, laboratory, and personnel costs.

Aim 3. To assess the impact of computer-based clinical decision support in the nursing home setting on provider productivity with reference to physicians, pharmacy staff, and nurses.

Aim 4. To assess the nursing home culture and organizational structure with respect to readiness to incorporate computerized provider order-entry with computer-based clinical decision support.

Scope

Our project addressed specific areas that are of particular interest to AHRQ with special relevance to the delivery of high quality care to a priority population – the frail elderly patient population residing in nursing homes. The project provided a framework and foundation to assess the economic implications of health information technology in the nursing home environment that will be of interest to key stakeholders including physicians, pharmacists, nurses, payers, policymakers, the nursing home industry, and pharmaceutical vendors to long-term care institutions. The dearth of evidence about the value of information technology in the care of nursing home residents and uncertainties about return on investment continue to delay the adoption of this technology for use in the nursing home setting. The overarching aim of this project was to begin to fill this gap in knowledge with solid evidence using rigorous study designs to assess the value of computerized provider order entry with clinical decision support in the nursing home setting. The existence of that gap served as the impetus for the work described in this report.

There is substantial evidence that the use of information technology can improve the quality of medication ordering and monitoring. This is particularly true for computer-based clinical decision support systems.[1,2] Clinical decision support systems are clinical consultation systems that offer real-time information for clinicians. These systems aid patient management through analyses of patient-specific information in comparison with an expert knowledge base and offer the potential to improve the quality of care by influencing medical decisions at the time and

place decisions are made.[3] As Classen has written, "Drug use represents the most common intervention in medicine and has the potential for costly and deadly consequences.[4] Given the shear complexity of the drug-use process and the multitude of potential failure points, computerized order-entry with clinical decision support is one of the most promising tools for decreasing medication errors, preventing adverse drug events, and improving drug use.[5,6]

Raschke and colleagues have written, "computer systems with online physician order-entry would enable decision-support systems to provide potentially critical information to the physician close to the moment of decision making. Improvements in information systems and increasing utilization of this powerful tool by physicians should have an enormous beneficial impact on the quality of medical care."[7] Based on a systematic review of controlled clinical trials assessing the effect of computer-based clinical decision support systems on physician performance and patient outcomes, Hunt and colleagues concluded these systems do enhance performance for drug dosing.[8] Of note, our own work has demonstrated that in the nursing home setting, computerized provider order-entry with accompanying computer-based clinical decision support systems did not reduce the rate of preventable adverse drug events.[9]

An expert panel in information technology was convened to consider the current state of the national health information infrastructure and to develop a model of an ideal infrastructure for the future.[10] The project utilized a modified Delphi approach; panel members estimated the current state of the national health information infrastructure and the expected state in five years if the situation continues on its current trajectory. Nursing homes were identified among the most important stakeholders in a national health information infrastructure along with physician offices, hospitals, home health agencies, laboratories, and pharmacies. However, among these stakeholders, health information infrastructure was felt to be least developed in the nursing home setting, and the expert panel felt that nursing homes would likely make the least progress in developing health information technology infrastructure over the coming five years. The expert panel members attributed deficiencies in the adoption of information technology in the nursing home setting to the existence of few financial incentives to develop such an infrastructure.

Methods

Aim 1: To Assess the Effectiveness of Computer-Based Clinical Decision Support in the Nursing Home Setting for Improving the Quality of Medication Ordering

The setting for this study was an academically-affiliated long-term care facility in Canada with an electronic medical record system including integrated computerized provider order entry (CPOE). The facility's CPOE software was fully linked to information in the electronic medical record and was capable of being programmed to present alerts in real-time during medication orders. Ten community-based physicians provided care to long-stay residents. The facility had wireless capabilities and physicians could also access the system and place medication orders from their off-site offices and homes. Physicians usually ordered medications personally through the CPOE system.

The clinical decision support system (CDSS) for adjusting dose and frequency of medication orders for long-term residents with renal insufficiency was developed by a team of physicians,

pharmacists, and informatics professionals. Sixty-two drugs were selected for inclusion based on published guidelines and lists from hospital-based dosing alert systems. Decisions on dosing recommendations were based on dose adjustment suggestions in geriatric and psychotropic drug dosing handbooks and the Micromedex® online knowledge base. We included oral drugs commonly prescribed in the long-term care setting that are primarily eliminated by the kidney and have known nephrotoxic effects or for which drug efficacy may be modified due to renal insufficiency.

Four types of alerts were developed: 1) alerts recommending maximum total daily dose of the medication; 2) alerts recommending maximum frequency of administration; 3) alerts recommending that the medication be avoided; and 4) alerts notifying prescribers that no creatinine clearance could be calculated for this resident because of missing serum creatinine test results or weight. Calculation of creatinine clearance used the Cockcroft-Gault equation based on age, weight, sex, and serum creatinine. Recommendations in the alerts were directly related to specific levels of renal impairment for each drug. A total of 94 alerts were developed for the 62 drugs. Alerts were triggered when a physician used the CPOE system to initiate an order for one of the specific medications included in the CDSS for a resident with renal impairment. After initiating the order, the prescriber could have chosen to continue with the order, modify the dose or frequency, or cancel the order. Alerts were not provided during renewals. The underlying software system could not present alerts from which prescribers could directly submit drug orders so the alerts were solely informational.

The 22 long-stay units of the facility were randomly assigned for prescribing physicians to receive or not receive the alerts. Randomization was done within blocks by unit type with blocks defined as 1) Alzheimer's disease, 2) stroke and cognition problems, 3) complex medical conditions, 4) behavioral and mental health problems, and 5) functional support. In the control units, current creatinine clearance was displayed during the drug orders with no further recommendations, as had been previously generated in all units of the facility. During the 12 months of the trial, we captured in an audit file each alert that was displayed to a physician when starting to order a drug for a resident of an intervention unit as well as the hidden alerts triggered by initiation of drug orders for residents in the control units. We also output data files containing full details on all electronic drug orders that were actually submitted and all serum creatinine tests with dates and results. Our analysis included all alerts for drug orders that were directly input into the CPOE system by physicians.

Each alert appearing in an audit trail was categorized as a dose, frequency, avoid, or missing information alert. Alerts were linked to drug orders by resident and date and we determined whether the final drug order's dose or frequency was within the recommended maximum for that drug, based on the resident's calculated creatinine clearance. For each alert to avoid a medication, we reviewed the drug orders for the resident and considered the response to the alert appropriate if the medication was not ordered on the day of the alert. For missing information alerts, we determined whether the alert resulted from a lack of serum creatinine test results or resident weight. Weighing of residents and entry of that information into the electronic medical record was a component of the facility's nursing function, so we focused only on alerts related to missing serum creatinine. These alerts were linked to serum creatinine test results and the physician's actions were considered appropriate if a test was scheduled for the resident within the day following the alert.

The unit of randomization and analysis was the resident care unit. As in most long-term care facilities, residents were distributed across units by the type of support they needed, rather than

by specific medical conditions. Therefore, there were likely to be differences among units in terms of the specific drugs ordered during the 12-month period of the trial. We responded to this by tracking the alerts that identified the initiation of every order of a drug included in the CDSS when it was being prescribed for a resident with renal impairment in any unit. This allowed us to compare the proportions of alerts that led to an appropriate final drug order as well as the overall rate of prescribing of drugs that should be avoided among residents with renal impairment between the intervention and control units.

We calculated the rates of alerts triggered based on the total resident days in intervention and control units. For each category of alerts, we compared the proportions of final drug orders that were appropriate between intervention and control units by calculating the relative risk and 95% confidence intervals. The rates of prescribing of drugs that should be avoided for residents with renal impairment were calculated as the number of these drugs that were actually ordered divided by the resident days in the intervention and control units. These rates were compared using the rate ratio and 95% confidence interval.

Aim 2: To Determine Costs Directly Related to the Development and Installation of Computer Based Clinical Decision Support and the Impact of Computer-Based Clinical Decision Support in the Nursing Home Setting on Drug, Laboratory, and Personnel Costs

Many of the assessments of successful CDSS are based on locally developed systems designed to support CDSS.[11] The success of these experiments in improving the safety of medication use has inspired many healthcare systems to consider adding such tools to their commercially purchased CPOE systems. However, the impact on staff time and the potential costs of developing CDSS in this situation have not been clear.[12]

As described above (Aim 1), we developed and implemented a CDSS to provide prescribers with recommended maximum doses of 62 drugs for patients with renal insufficiency in the long-term care setting. As we developed and implemented this CDSS, we performed a study estimating the time and costs involved. The CDSS was developed by a team that included physicians, pharmacists, informatics professionals, project coordinators, and a health services researcher. The physicians and pharmacists selected drugs for inclusion by reviewing published guidelines and lists from previous hospital-based renal dosing alert systems with updates for newer medications and/or recent evidence. The focus was on drugs primarily eliminated by the kidney with known potential nephrotoxic effects. We limited the review to oral drugs commonly prescribed in the long-term care setting. The resulting list was then compared to frequency of use of these therapies within the facility and the potential severity of the adverse effects. Final selection was based on team consensus and included 62 medications.

Type and wording of alerts was determined by the team with subsequent review by the facility's Pharmacy and Therapeutics Committee. Four types of alerts were developed for various levels of creatinine clearance for residents with impaired renal function: 1) alerts recommending maximum total daily dose; 2) alerts recommending maximum frequency of administration; 3) alerts recommending that the medication be avoided; and 4) alerts notifying prescribers that no creatinine clearance could be calculated for this resident (due to missing creatinine test results or weight.) Ultimately, 94 alerts were developed within these categories.

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Based on these decisions, the project coordinators prepared a "blueprint" for each alert that included scenario, alert message, mnemonics for all drugs and range of creatinine clearance that would trigger that alert. To identify mnemonics for all strengths of each included drug, pharmacists reviewed the facility's formulary and medication usage history. The facility's pharmacists had previously developed an underlying calculation of creatinine clearance using the Cockcroft-Gault equation based on age, weight, sex and serum creatinine and this calculation had already been programmed within the CPOE system. Pre-testing proceeded with the selection of four prototypical drugs which were programmed and fully tested off-line with a cycle of test and revision of programming until all problems were eliminated. The remaining alerts were then programmed and tested off-line. A message was sent to prescribers to inform them of the new CDSS messages before the alerts were transferred to the live system. The facility had a history of including alerts within their CPOE system so training requirements were minimal and few user problems were encountered.

Because the alerts were added to an existing CPOE system within an electronic medical record that included laboratory test results and nursing notes, no additional hardware or software were required. Costs for developing and implementing the system resulted entirely from personnel time. Six categories of personnel were required: physician, pharmacist, informatics project manager, project coordinator, health services researcher, and specialized computer programmer. The programmer was external to the facility and was paid hourly as a consultant; estimates of the time and costs of programming were based on tracking of submitted bills. Time tracking for the remaining personnel is based on weekly reports that required participants to specifically categorize the time spent on the project. For analyses, we collapsed categories into: project management, preparation of the contents of the CDSS, preparation of blueprints and instructions for the programmer, programming, and testing and implementing. We included data collection through two weeks following the "go-live" date and did not include personnel time for on-going maintenance and upgrades.

Our goal was to produce cost estimates that would be of use to clinicians considering development of CDSS within their own facilities. Therefore, we did not collect facility-specific costs for this project, such as actual wages of the participants, fringe benefits or overhead costs. Rather, we based estimates on the reported hours for each individual combined with US national average hourly wages for their personnel category, obtained from the Bureau of Labor Statistics, National Compensation Survey. Costs for the specialized computer programmer were the exception to this approach; they are based on the actual billed hours converted from Canadian to US currency. We produced summary tables by personnel categories as well as activity categories.

Several aspects of the project were likely to produce large costs, including the need to develop the contents of the CDSS and the use of a specialized and expensive computer programmer. To support estimates of the reduction in costs that might be attained with variations in these factors, we developed a series of alternative scenarios: (1) availability of a pre-existing and updated database with recommended dosing for drugs according to level of renal impairment assessed by creatinine clearance and appropriate for frail elderly patients; (2) availability of an off-the-shelf renal dosing program compatible with the CPOE system; and (3) use of a CPOE system that is programmable by a less specialized programmer. We estimated the reductions in hours for each category of personnel that would result from each of these scenarios and we estimated alternative total and activity category costs using these reduced estimates.

Aim 3: To Assess the Impact of Computer-Based Clinical Decision Support in the Nursing Home Setting on Provider and Staff Productivity

In order to provide a framework to assess the impact of clinical decision support (CDS) in the nursing home setting on provider and staff productivity concerning an effect of CDS on drug ordering, we determined the time required for the full medication administration process in the long-term care (LTC) setting. The work described here relates specifically to nursing. Similar efforts are being undertaken relating to pharmacists. Efforts to assess the impact of the renal CDSS on physicians have determined that the impact is minimal. Few alerts show during ordering sessions to meaningfully impact on productivity.

We used time-motion methods to record the amount of time nursing staff took to complete the medication administration process, from arranging the medication cart to completion of medication administration duties. To determine whether resident or nurse characteristics influenced time required to complete these tasks, we observed medication rounds across four unit types and observed regular and temporary nurses.

We used time-motion methods to directly observe nurses during the medication administration process and to quantify the time required to complete each of seven steps in the process (defined below). In time-motion studies, an observer follows a subject and continually records the nature and duration of every activity with a timing data collection tool.

Both registered nurses (RNs) and registered practical nurses (RPNs) were observed during the study. Regular nurses were defined as those regularly assigned to the observed unit. Temporary nurses were defined as those not regularly assigned to the observed unit and for whom this was their first experience on the unit; this included nurses who regularly worked on other units but were temporarily reassigned to the unit on the day of observation and nurses who were part of a pool of float nurses who had no regular unit assignment. All residents who were scheduled to receive medication during the observed medication administration processes were included.

All observations were timed using a PalmOne (PalmOne, Inc., Milpitas, CA) personal digital assistant with timer software developed by Stevens Creek Software, LLC. The observer continuously timed each observation and tapped codes that corresponded to the nurse's actions.

A total of 126 regularly scheduled medication administration time periods by regular nurses, evenly distributed across morning, noon, and evening time periods, were observed. Morning medication time periods took place between approximately 7:30 am and 9:30 am, noon medication time periods between 12:00 pm and 12:30 pm and evening medication time periods between 4:00 pm and 5:30 pm. An additional 15 regularly scheduled medication administration time periods delivered by temporary nurses were observed. These were also stratified by time of day (morning (n=5), noon (n=6), and evening (n=4)).

The research team developed a seven-step time-motion protocol based on discussion with facility staff and observations on units where the study was conducted. For the purpose of this study, the medication administration process was defined as the time that the nurse spent with the medication cart at regularly scheduled intervals. This definition did not encompass all medication-related activities (such as documentation in the medical record and discussions with pharmacy staff and other health care professionals on the floor or over the phone) that occurred outside of those regularly scheduled intervals. Prior to study initiation, the time-motion protocol was pilot-tested on six medication administration processes. The protocol steps were refined

based on these findings. The steps in the medication administration process were: 1) organize medication cart and obtain supplies, 2) locate and identify resident, 3) prepare medications (i.e. checking medication administration record, dispensing, and altering dosage form (usually by crushing), 4) prepare resident to receive medication, 5) provide medication to resident, 6) observe resident following receipt of medication to assess for any immediate adverse event, and 7) travel back to medication cart.

Interruptions were recorded and were defined as any demand that caused the nurse to deviate from medication administration activities. This included phone calls, questions from other staff, and resident emergencies.

One investigator conducted all of the observations. Prior to each observation, the observer made appointments with nurses and explained the purpose of the study. Each resident's medication administration record was obtained to provide a count of the total prescribed medications at each time of day. Nurses were instructed to carry out the medication administration process as usual. The observer did not interact with either nurses or residents.

The average time required for the total medication administration process and for each pre-defined step in the process was calculated. To determine whether time varied by specific factors, analyses were stratified by unit type, by time of administration (morning, noon and evening), and by nurse type (regular and temporary). Standardization was used to obtain a 20-bed unit estimate of the average time required for the total medication administration process. To do this, the observed average time per resident estimate was multiplied by twenty. Standardization to 20-beds was necessary to facilitate comparison between units and to improve generalizability of findings. We chose a 20-bed standard because this is the average unit size in long-term care facilities.

The percentage of time engaged in the medication administration process during a day shift was calculated by dividing the standardized average total recorded time for the morning and noon time periods by the total amount of time nurses spent on the units (7 hours when time for lunch and breaks are excluded). The day shift is from 7 am to 3 pm and includes the regularly scheduled morning and noon medication administration process time periods. These calculations do not include time spent on medication activities outside of the predefined medication administration process such as pro re nata (PRN or "as needed") medications or scheduled afternoon time periods.

Aim 4: To Assess the Nursing Home Culture and organizational Structure with Respect to Readiness to Incorporate Computerized Provider Order-Entry with Computer-Based Clinical Decision Support

We developed a framework for considering the costs and benefits of CPOE with clinical decision support in the long-term care setting, together with a systematic assessment of all stakeholders involved, to identify barriers to adoption. We sought to describe the key stakeholders and their relationships. Potential costs and benefits were determined with a summary of factors that could impact their magnitude. We also performed an assessment of potential barriers and the misalignment of benefits versus costs, which could result in disincentives to the adoption of these systems in the long-term care setting.

Results

Aim 1: To Assess the Effectiveness of Computer-Based Clinical Decision Support in the Nursing Home Setting for Improving the Quality of Medication Ordering

During the 12 months of the trial, more than 800 residents were present on the participating units. The average age of residents in the intervention and control units was nearly matched but the intervention units had a slightly higher percentage of women. In total, there were 107,856 resident-days in the intervention units and 106,111 days in the control units.

The rates of alerts were nearly equal in the intervention and control units. Physicians prescribing medications for residents in the intervention units received 274 alerts for a rate of 2.5 per 1000 resident days. In the control units, 257 alerts were generated during physician medication orders and output to the audit trail for a rate of 2.4 per 1000 resident days.

The proportions of final drug orders for which doses were appropriate were similar between the intervention and control units (relative risk 0.95, 95% confidence interval 0.83, 1.1). For each of the remaining alert categories, a significantly higher proportion of drug orders was appropriate in the intervention units. The relative risks for appropriate drug orders were 2.4 for the alert category recommending maximum frequency (1.4, 4.4), 2.6 for the category recommending that a drug be avoided (1.4, 5.0), and 1.8 for alerts about missing serum creatinine (1.1, 3.4). Across all categories of alerts, drug orders were appropriate significantly more often – relative risk 1.2 (1.0, 1.4).

In a further analysis of drugs that should have been avoided, we found that these drugs were prescribed less often in the intervention units, 3.5 per 1000 resident-days compared to 5.2 per 1000 resident days in the control units. The rate ratio was 0.68 and this was of borderline statistical significance (95% confidence interval 0.45, 1.0).

Among the drugs triggering alerts, the most common were levofloxacin, nitrofurantoin, cephalexin, metformin, gabapentin, and glyburide.

By tracking personnel time and expenditures, we estimated the cost of developing the clinical decision support system as $48,668.57 (see Aim 2 below). Drug costs saved over a 12 month period were estimated at $2,137.

Table 1. Rates of appropriate drug orders by alert type

Alert type	Intervention Units Alerts No.	Intervention Units Appropriate Orders No.	Intervention Units Appropriate Orders %	Control Units Alerts No.	Control Units Appropriate Orders No.	Control Units Appropriate Orders %	RR	95% CI
Dose	114	86	75.4	134	107	79.9	0.95	0.83, 1.1
Frequency	49	30	61.2	35	9	25.7	2.4	1.4, 4.4
Avoid	64	26	40.6	65	10	15.4	2.6	1.4, 5.0
Missing information	47	30	63.8	23	8	34.8	1.8	1.1, 3.4
Total	274	172	62.8	257	134	52.1	1.2	1.0, 1.4

Aim 2: To Determine Costs Directly Related to the Development and Installation of Computer Based Clinical Decision Support and the Impact of Computer-Based Clinical Decision Support in the Nursing Home Setting on Drug, Laboratory, and Personnel Costs

The total estimate of costs for personnel involved in the production of the renal dosing CDSS was $48,178.11. The total time spent on the project across all personnel types was 924.5 hours with physicians providing nearly half of that time. The three participating physicians spent the majority of their project time (390 hours) preparing the content of the CDSS. The two pharmacists contributed 179.75 hours. Seventy-nine percent of their time was split between participating in the preparation of the content of the CDSS and performing extensive testing of each alert. The informatics project manager contributed nearly 122 hours. Her activities included managing interactions between the project and the Information Management department, selecting and overseeing the activities of the specialized computer programmer, and coordinating and supporting the process of testing and implementing the alerts. She also participated in all project meetings throughout the development process. Over the course of the project, several project coordinators participated. They attended all project meetings, maintained and distributed agendas and meeting minutes and handled communication flow among the various participants. They also prepared the alert blueprints under the direction of the health services researcher who also designed the audit trail system to allow on-going evaluation of the impact of the alerts. The project required a computer programmer with extensive expertise in programming within the Meditech electronic medical record system. The total programming time was 110.5 hours.

The table presents the estimated costs for personnel time across the collapsed categories of project activities. Fifty-six percent of the costs were associated with preparation of the contents of the CDSS. This reflects the extensive time required from physicians and pharmacists. Because the alerts were designed to guide dosing decisions, the process of selecting the drugs and deciding on the combinations of renal impairment and dose recommendations was painstakingly thorough, including reviews of geriatric dosing guidelines and the dosing recommendations used in hospital-based CDSS. The personnel time for physicians also includes meetings with the facility's Pharmacy and Therapeutics and Medical Advisory Committees.

Eighteen percent of the project's costs were for programming. The other project activities accounted for the remaining 26% of project costs.

The first alternative scenario was constructed to estimate the reduction in costs that would be attained if a standard database existed with recommended drug dosing for frail elderly patients with renal impairment based on the best evidence. We estimate a substantial reduction in the costs for developing the content of the CDSS of 50% and an accompanying 33% reduction in project management time. Estimated reductions are limited by the need for a facility's physicians to carefully review and weigh a database's recommendations before enacting them within the CDSS. Nevertheless, the total estimated cost is lowered by approximately 30% to $34,200.71.

The second alternative scenario further reduces costs to $23,694.51 by positing the existence of a CDSS renal dosing product compatible with the CPOE system. We estimate the same reductions in costs for developing the content of the system and managing the project as for the first scenario. Additional reductions include half of informatics project management time, and three-quarters of the time required for programming and preparing instructions for the

programmer. If the CDSS product was truly "plug and play", there could be further reductions in programming and informatics management time.

The third scenario produced a more modest reduction to $43,268.44 by assuming a CPOE system that did not require specialized programming skills. Estimates for this scenario do not reduce the hours involved in any of the activities but reduce the hourly cost for programming by using the average hourly wage for computer programmers in the United States in 2005 of $30.89.

In a subsequent analysis, we estimated that drug costs saved over a 12-month period were only $2,137.

Table 2. Costs of activities

Activity Category	Hours	Cost ($)	% of total cost
Project management	80.25	2,220.17	5
Preparing contents of the CDSS	482.25	27,455.61	56
Informatics project management	121.7	4,987.27	10
Preparing blueprints and instructions for programmer	50.8	1,869.95	4
Programming	110.5	8,813.48	18
Testing and implementing	79.0	3,322.09	7
Total	**924.5**	**48,668.57**	

Aim 3: To Assess the Impact of Computer-Based Clinical Decision Support in the Nursing Home Setting on Provider and Staff Productivity

In total, 141 medication administration processes were observed over an 11-month period. The full medication administration process, from organizing the medication cart to completion, was lengthy but varied with unit type and time of day.

On physical support, behavioral care, and dementia care units, nurses were responsible for providing medications to approximately 20 residents, but the average number of medications administered ranged from 81.4 (SD = 51.4) on behavioral care units to 115.3 (SD = 70.0) on physical support units. On a per resident basis, time for the full medication administration process was 3.1 minutes (SD = 1.1) on physical support, 4.2 minutes (SD = 1.0) on behavioral care, and 3.5 minutes (SD = 1.1) on dementia care units.

Continuing care units are designed for residents with the heaviest physical care needs and are staffed differently than the other long-term care units. On these units, nurses were responsible for providing medications to an average of six residents and administered an average of 39.3 medications (SD = 15.9). For the total medication administration process, the observed time was 9.6 minutes per resident (SD = 3.2).

Across all units, the lengthiest medication administration process was recorded in the morning when residents received the greatest number of medications (physical support: 214.4 medications (SD = 15.4); behavioral care: 145.1 medications (SD = 16.5); dementia care: 208.9 medications (SD = 21.4); continuing care: 60.2 medications (SD = 8.9)). Likewise, residents received the fewest medications during the noon time period (physical support: 52.3 medications (SD = 9.6); behavioral care: 32.0 medications (SD = 3.4); dementia care: 35.7 medications (SD = 7.6); continuing care: 20.9 medications (SD = 5.5)).

Once standardized to 20 beds, differences across units become more apparent. The estimated mean total time for physical support units was 62.0 minutes per 20 residents (SD = 4.9), for

behavioral care was 84.0 minutes per 20 residents (SD = 4.5), and for dementia care was 70.0 minutes per 20 residents (SD = 4.9).

As consistent with the number of medications administered, the lengthiest medication administration process was the morning time period (physical support: 78.0 minutes per 20 residents (SD = 2.7), behavioral care: 104.0 minutes per 20 residents (SD = 3.1), and dementia care: 86.0 minutes per 20 residents (SD = 4.9)) and the shortest was the noon time period (physical support: 46.0 minutes per 20 residents (SD = 4.0), behavioral care: 68.0 minutes per 20 residents (SD = 3.6), and dementia care: 50.0 minutes per 20 residents (SD = 2.7)).

Based on standardized estimates, the proportion of a 7-hour day shift spent on medication administration was estimated as 29.5% (interquartile range: 23.3% - 33.2%) on physical support units, 40.9% (interquartile range: 35.4% - 47.1%) on behavioral care units, and 32.3% (interquartile range: 26.3% - 34.7%) on dementia care units.

Interruptions accounted for 11.5% of the total observed time. At least one interruption was recorded in 79% of medication rounds but the distribution was skewed. An average of 4.8 (SD = 6.6) with a median of 3.0 interruptions were counted per medication administration process. On average, interruptions accounted for 8.2 minutes (SD = 11.2) but this varied by unit type (physical support: 13.8 minutes (SD = 18.3); behavioral care: 10.6 minutes (SD = 10.7); dementia care: 11.4 minutes (SD = 8.8); and continuing care: 3.7 minutes (SD = 5.7)).

The findings of this analysis will be useful in determining the impact on nursing productivity relating to any increases or reductions in medication doses resulting from the clinical decision support system.
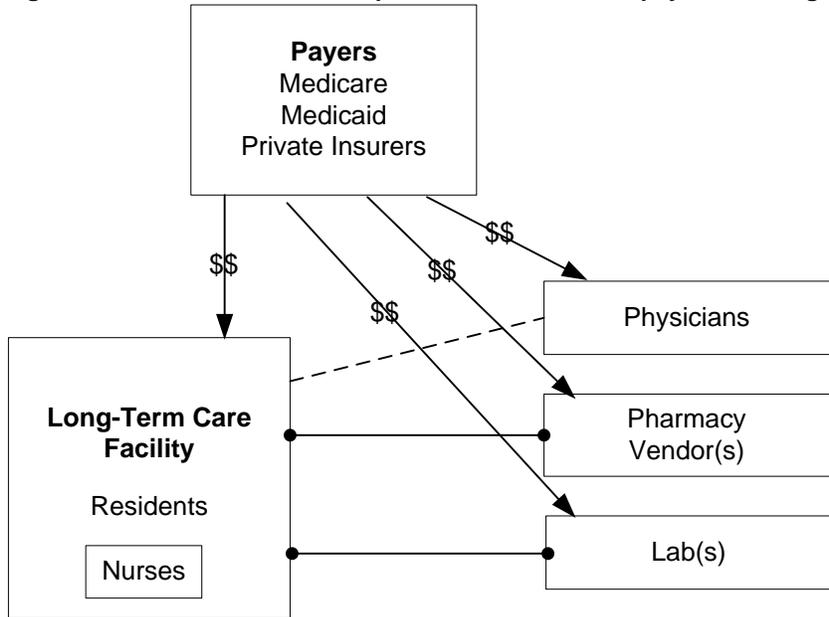
Aim 4: To Assess the Nursing Home Culture and organizational Structure with Respect to Readiness to Incorporate Computerized Provider Order-Entry with Computer-Based Clinical Decision Support

Our analysis of the costs and benefits relating to implementation of CPOE with clinical decision support in the long-term care setting indicated that the costs of implementing and maintaining these systems will be incurred by multiple stakeholders, but that the costs incurred by each may not be aligned with the benefits. Recognition of the costs and benefits borne by the various participants and the substantial time lag in the realization of benefits suggests that incentives may be necessary to enhance adoption of these systems. For instance, under a fee-for-service mechanism, payers could offset costs to the nursing home for implementing the system through direct subsidies or other forms of incentive payments.

Successful adoption of health information technology depends on physician, nurse practitioner, and nurse receptivity to utilizing these systems. Incentives, either non-monetary or monetary, may need to be in place to ensure this use. Insurers, such as Blue Cross and Blue Shield, are starting to make bonus payments to physicians for implementation of health information technology and electronic communications; such initiatives can play an important role in adoption and use of health information technology in the long-term care setting. If physicians are required to navigate across multiple different systems promulgated by vendors or payers without standardization, their willingness to participate will be lower. Local and regional health initiatives, such as the Massachusetts eHealth Collaborative, the Indiana Heath Information Exchange, and the California Regional Health Information Organization, may help foster coordination and collaboration among diverse healthcare stakeholders and lead to the adoption of standardized systems.

Our analysis provides a framework for considering the potential benefits and costs for stakeholder groups involved in health information technology integration and operations with a particular focus on CPOE with clinical decision support, but an accurate determination of the magnitude of the costs and savings is essential to completely understand the individual stakeholder impacts. Future studies of these technologies in the long-term care setting are required to provide the information necessary to assess the true costs and benefits of widespread implementation and use of these systems.

Figure 1. Stakeholder relationship under fee-for-service payment arrangement

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                    │      Payers         │
                    │     Medicare        │
                    │     Medicaid        │
                    │   Private Insurers  │
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                          $$    $$   $$   $$

   ┌──────────────────┐                  ┌──────────────────┐
   │ Long-Term Care   │                  │    Physicians    │
   │    Facility      │                  └──────────────────┘
   │                  │                  ┌──────────────────┐
   │   Residents      │──────────────────│    Pharmacy      │
   │  ┌──────────┐    │                  │    Vendor(s)     │
   │  │  Nurses  │    │──────────────────└──────────────────┘
   │  └──────────┘    │                  ┌──────────────────┐
   └──────────────────┘                  │      Lab(s)      │
                                         └──────────────────┘
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Dashed line indicates individual relationships between physicians and residents.
Solid line indicates contractual relationships

Table 3. Costs and benefits of CPOE with CDS in the LTC setting

Type	Description
Acquisition Costs	Initial purchase or licensing of systems
Acquisition Costs	Hardware and other infrastructure requirements
Acquisition Costs	Hiring additional staff (e.g., information technology related)
Acquisition Costs	Implementation of systems
Acquisition Costs	Integration of CPOE with CDS systems with vendors' electronic networks
Acquisition Costs	Initial training of staff
Acquisition Costs	Lost productivity while becoming familiar with the system
Annual Costs	Maintenance of systems/Annual license fees
Annual Costs	Upgrade and monitor of systems
Annual Costs	Update of clinical and pharmaceutical information on CDS
Annual Costs	On-going staff training
Annual Costs	Increased laboratory costs due to more tests
Annual Costs	Increase in physician time
Benefits	Efficiency gains in nursing homes
Benefits	Efficiency gains in laboratories and pharmacies
Benefits	Reduction in costs related to storage of paper records
Benefits	Reduction in prescription drug costs
Benefits	Reduction in adverse drug events
Benefits	Reduction in medical costs associated with adverse drug events
Benefits	Improvements in health-related quality of life

References

1. Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety. A systematic review. *Arch Intern Med* 2003;163:1409-1416.

2. Johnston ME, Langton KB, Haynes B, Mathieu A. Effects of computer-based clinical decision support systems on clinician performance and patient outcome. *Ann Intern Med* 1994;120:135-142.

3. Classen DC. Clinical decision support systems to improve clinical practice and quality of care. *JAMA* 1998;280:1360-1361.

4. Classen DC, Pestotnik SL, Evans RS, Lloyd JF, Burke JP. Adverse drug events in hospitalized patients: excess length of stay, extra costs, and attributable mortality. *JAMA* 1997;277:301-306.

5. Bates DW, Leape LL, Cullen DJ, Laird N, Peterson LA, Teich JM, et al. Effect of computerized physician order entry and a team intervention on serious medication errors. *JAMA* 1998;280:1311-1316.

6. Schiff GD, Rucker TD. Computerized prescribing: building the electronic infrastructure for better medication usage. *JAMA* 1998;279:1024-1029.

7. Raschke RA, Gollihare B, Wunderlich TA, et al. A computer alert system to prevent injury from adverse drug events. *JAMA* 1998;280:1317-1320.

8. Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. *JAMA* 1998;280:1339-1346.

9. Gurwitz JH, Field TS, Rochon P, Judge J, Harrold LR, Bell CM, Lee M, White K, LaPrino J, Erramuspe-Mainard J, DeFlorio M, Gavendo L, Baril JL, Reed G, Bates DW. Effect of computerized provider order entry with clinical decision support on adverse drug events in the long-term care setting. *J Am Geriatr Soc* 2008;56:2225-2233.

10. Poon EG, Jha AK, Cristino M, et al. Assessing the level of healthcare information technology adoption in the United States: a snapshot. *BMC Medical Informatics and Decision Making* 2006, 6:1. Published 05 Janurary 2006.

11. Kaushal R, Shojania KG, Bates DW. Effects of computerized physician order entry and clinical decision support systems on medication safety: A systematic review. *Arch Intern Med* 2003;163:1409-1416.

12. Kuperman GJ, Gibson RF. Computer physician order entry: benefits, costs, and issues. *Ann Intern Med.* 2003;139:31-39.

List of Publications and Products

1. Field TS, Rochon P, Lee M, Gavendo L, Baril JL, Gurwitz JH. Computerized clinical decision support during medication ordering for long-term care residents with renal insufficiency. *J Am Med Inform Assoc* (in revision)

2. Field TS, Rochon P, Lee M, Gavendo L, Subramanian S, Hoover S, Baril J, Gurwitz J. Costs associated with developing and implementing a computerized clinical decision support system for medication dosing for patients with renal insufficiency in the long-term care setting. *J Am Med Inform Assoc* 2008;15:466-72.

3. Thomson MS, Gruneir A, Lee M, Baril J, Field TS, Gurwitz JH, Rochon PA. Nursing time devoted to medication administration in long-term care: Clinical, safety, and resource implications. *J Am Geriatr Soc* (in press).

4. Subramanian S, Hoover S, Gilman B, Field TS, Mutter R, Gurwitz JH. Computerized physician order entry with clinical decision support in long-term care facilities: Costs and benefits to stakeholders. *J Am Geriatr Soc* 2007;55:1451-7.

5. Subramanian S, Hoover S, Field TS, Baril J, Donovan J, Kanaan A, Rochon P, Gurwitz JH. Cost savings from implementation of computerized clinical decision support for medication dosing for long-term care residents with renal insufficiency. (in preparation)

6. Wolfstadt JI, Gurwitz J, Field TS, Lee M, Kalkar S, Wu W, Rochon PA. The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: a systematic review. *J Gen Intern Med* 2008; 23:451-458.