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Analysis of data captured by barcode medication administration system using a PDA; aiming at reducing medication errors at point of care in Japanese Red Cross Kochi Hospital

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Abstract

Preventing medication errors by using a barcode administration system has become prevalent in patient safety. Analyses of data captured by bar code systems provide opportunities to understand the actual situation at the point of care. Our study aims at understanding issues of medication safety as well as investigating measures taken to prevent medication accidents, by analyzing data captured by a bar code system and a personal digital assistant (PDA),. The barcode administration system named Point-of-Act-System implemented in Japanese Red Cross Kochi Hospital was designed to capture every activity at the bedside. Complete activity data captured by the system, which included injections, treatment and other nursing activity, as well as injection warning data, were used for our analyses. We describe the data and analyze them statistically to find potentially times of risk and to ascertain the relation between busyness and error. The injection warning rate as a whole was 6.1% on average. The results showed there was a negative correlation between the number of injections given and the injection warning rate (-0.48, p<0.05). The warning rate was low during the hours when a large number of injections were administered. The data also showed that a variation in activities being performed has a negative effect on medication safety. A bar code administration system is quite an effective way not only to prevent medication error at point of care, but also to improve patient safety through analyses of data captured by such a system.

Keywords:

Point of Care System, Medication Errors, Administration and Organization, Handheld Computer, Patient Safety

Introduction

It is widely believed that patient safety is an important issue for health care systems. Many organizations and hospitals have been accumulating information on patient safety and medication errors to improve patient safety based on the data collected. These data is accumulated to provide information on threats to patient safety. Such data are quite useful in understanding the threats and actual situations related to medication errors in hospitals. However, most of this evidence is basically information on medical accidents and incidents, compiled from voluntary reports submitted by medical workers. This information is not detailed enough to enable the discovery of underlying general principles, because accidents and errors are part of the reality in a hospital setting. A complete picture of the situation in hospitals, including details of medical accidents and incidents, is essential to identifying general causes and frequencies of medical errors. However, it is extremely costly to obtain by observational research sufficient data to enable an understanding of all the activities conducted in a hospital, and furthermore, the accuracy of data collected by observation is sometimes defective. Information technologies such as electronic medical records and barcode administration systems at the point of care have the potential to provide new opportunities for us to understand the overall picture of medical activities by digital capturing data on daily medications and patient care in hospital settings. By using information systems for all patients in all wards, data captured by the systems become useful resources to understanding various phenomena in medical situations and investigating research questions. In terms of medication accidents, the point of care is a potentially risky area in medical activities [1-3]. Therefore, data captured at the point of care is quite effective in understanding medication accidents. One potential candidate system for this is a barcode administration system for safe injections and medication. Barcode medication administration systems prevent medication errors by authenticating the "5 Rights" of medication: right patient, right drug, right dose, right time, right route. Performed at the bedside, the system offers an excellent opportunity to gather data on medications [4-7]. In addition to their contribution to the authentication of the 5 Rights, data captured by barcode administration systems have the potential to provide sources of research to improve patient safety in terms of actual injections and medication data.

Our study aims to use and analyze complete data on medical activities captured at the point of care by the system to understand all the activities and issues related to medical safety, and to investigate preventive measures for medical accidents to manage healthcare situations. We focused on injections, which a major cause of medical accidents, and investigated the relation between mistakes and the context of medical activities including how busy staffs were, and shift work.

Materials and Methods

Settings and items to be addressed

Japanese Red Cross Kochi Hospital has 482 registered beds and approximately 290,000 out-patients and 9,355 in-patients per year. The hospital implemented a hospital information system called "Point of Act System," or POAS, in 2004. POAS is a real time bar-code capturing health information system designed to prevent medication errors by capturing the barcodes of patients, workers and drugs, and then authenticating the 5 Rights of each medical action [10-12]. Figure 1 shows a Personal Digital Assistant (PDA) for barcode capturing, nursing work management, and risk management for injections and intravenous drips (IV). When nurses scan the barcodes of drugs or IV bags for patients, the system checks the correctness of the injections and IVs against real-time accurate information in a computerized order entry system and electronic health record within 2 seconds.

At the same time, POAS captures complete data on each medical action including 6W1H information (When, Where What, Why, for What, to Whom and How) conducted in the hospital. The units of data recorded by the system are: Who—the implementer (the person who initiated the order, or the person who carried it out), to Whom—the patient, How—medical activities and changes in them, What—materials used (pharmaceuticals, medical materials and others), How much—amount of materials used and number of applications, for What—name of patient receiving medical services, When—date the order was placed, implemented and discontinued and the activities that were implemented, and Where—place of implementation (department, hospital, ward, etc.). The principal characteristics of data captured by this system are (1) complete data at a specific place including every action recorded in real time and accurately and (2) process data-based process management that enables POAS to ensure the correct process of medication and assures it captures complete data. The collection of complete data including 6W1H information is an innovative source in understanding actual situations directly without estimation or bias, and enables the investigation of solutions to prevent errors.

Data

Data captured at the sites of the injection process were used for our analyses of medication administration. In this study, data on injections means both injections and IVs. 6W1H information was captured at each point of the injection process: Order to give injection, Drug selection, Drug audit, Drug mixing, and Injection. Although the first objective of a bar code administration system is to ensure patient safety by verifying the 5 Rights of medication, another objective is to record the activities of nurses to support nurses' request of drugs and devices consumed, and enforce medication for patients.

At the point of care, nurses uses PDAs to scan the barcodes of ampoules or vials containing the medication to be injected or scan the barcodes of activities to enter information on their actions such as treatment, care, observations, counseling and emergency. This information is primary used for the documentation of nursing activities. However, this information can also be used not only for hospital management—by understanding the workloads of nurses and the actual costs of administering medications—but also for patient safety by understanding the prevailing situations when mistakes are made. In addition to these data entered by nurses, we also used warning data demonstrating mistakes that can be made in scanning the barcodes on drug vials. Warning data do not directly mean data on medication errors, because the system prevents error by alerting staff before a mistake is made. However, warning data are useful sources of information in analyzing the causes of medication errors, because a warning means a potential medication error without a barcode administration system. Therefore, high warning rates at specific times, places, situations and workers mean risky times, places, situations and workers in terms of patient safety. Basic types of warning are basically: a wrong or expired vial scanned by a nurse for a patient; wrong patient; and mixing error meaning incorrect mixing of drugs. Data collected from January 2005 to June 2008 were used for the analyses. The total numbers of activities represented by the data are 14,824,046 individual acts, and the number of injections and IVs administered were 604,847. The data covered almost 100% of the injections and 99% of the activities by nurses in the hospital according to internal research.

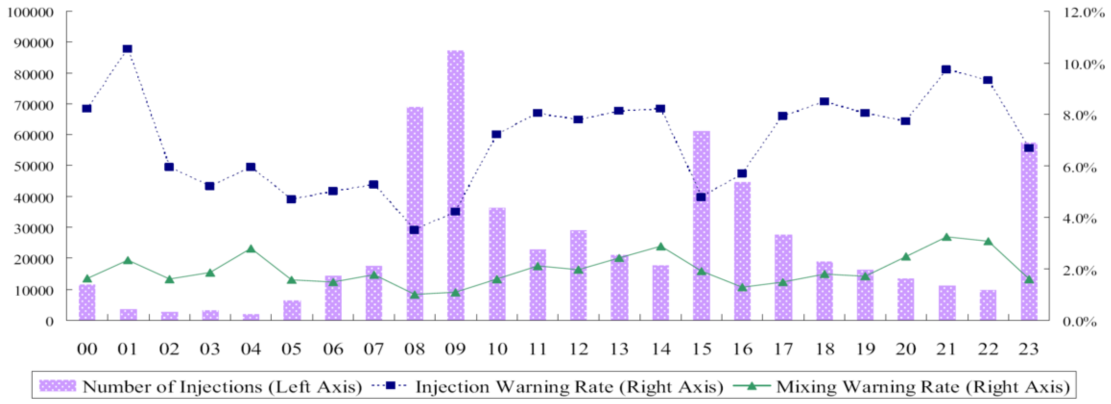

Figure 1 - Number of injections per hour and warning rate

Data Analysis

We accumulated data for each hour (for 24 hours a day) to identify times of high risk so as to understand the big picture of medical activities and medical errors in hospital wards. Warning rates were computed for each hour. These rates were treated as indicators to show risky times and situations.

We described these data, and analyzed them statistically to investigate correlations between situations and warning rates. Total number of injections per hour, total number of activities, total number of injections per PDA by hour, and total number of activities per PDA by hour were used as indicators for a nurse's workload at the time. The fraction out of total activities spent giving injections was used as an indicator for variation in hours. We calculated the proportion of the number of injections among total activities at that time. We employed Pearson Correlation Analysis to investigate relations and the significant level was 5%.

Results

Total number of activities was 14,824,046 including 69,276 injections (0.4%), 535,571 IV starts (3.6%), 483,770 IV finishes (3.3%), 1,979,804 care giving (13.3%), 10,437,250 observations (70.4%), 14,713 counseling (0.1%), 824,743 treatments (5.6%) and 478,919 emergencies (3.2%). The number for observations is extremely high. The total number of injections including IVs was 604,847, and the total warnings for injections were 37,046 (6.1%). The injection warning rate during early periods of implementation was around 9%, but has decreased to around 6 %.

Figure 1 shows the trend in warning rate and activities by the hour. The bar graph shows the number of injections by hour. There is a variability in the number of injections by hour, with three peeks for injections administrated: 9:00, 15:00 and 23:00**.** Most injections were administrated around these three peaks. The two line graphs show injection warning rates and mixing warning rates by the hour. Minimum and maximum of injection warning rates were 4.2% and 10.5%, while the minimum and maximum mixing warning rates were 1.0% and 3.2%. These figures vary quite a bit over the hours.

This graph shows the warning rate was lower when nurses where administrating a large number of injections. For example, the warning rates between 8:00 and 10:00 are lowest, although the numbers of injections are highest. The warning rates between 15:00 and 17:00 are also lower compared with the warning rates around the time.

In this hospital, the nurses work three shifts: Day shift (8:00-16:40), Evening shift (16:00-0:40), and Night shift (0:00-8:40). The warning rates per shift were 5.5% Day shift, 7.3% Evening shift, and 6.0% Night shift. Some researchers have reported that warning rates during nighttime are higher than during daytime [5]. However, there is no clear evidence to support the statement in our analyses. The trends in injection warnings and mixing warnings have basically the same tendency, although the tendency can be recognized more clearly in the injection warning rates. Especially during Day shifts, this tendency was demonstrated quite clearly.

We ran some statistical analyses to investigate the relation between warning rate and other variables. According to the results of a correlation analysis between variables, there was a negative correlation between the number of injections and injection warning rates. Figure 2 is a scatter plot of the number of injections per nurse and injection warning rate. The correlation coefficients between the number of injections and injection warning rates was -0.48 ($p<0.05$), and that between the number of injections per PDA and injection warning rates was -0.34 ($p<0.05$). Both results were statistically significant at the 95% level. This results show there is a tendency that more injections means safer injections at specific times as described above.

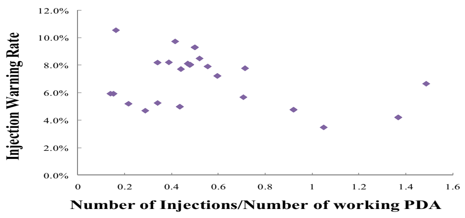

Figure 2 - Number of injections per nurse and warning rate

Variation in activities had a negative effect on the injection warning rate according to other correlation analyses. Figure 3 is scatter plot showing the relation between the injection fraction of total activities computed by the number of injections divided by the total number of activities and injection warning rates. The correlation coefficient between the treatment fraction of total activities and injection warning rates was 0.35 ($p<0.05$) and statistically significant. This indicator implied a high fraction of treatment, meaning nurses should administrate injections along with other treatments for patients and discourage nurses from concentrating on injections.

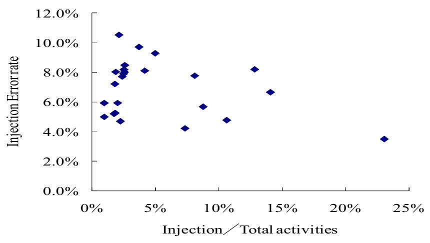

Figure 3 - Number of injections and warning rate

Discussion

There are some differences between our study and previously published literature. In past literature on patient safety, many studies had said workloads and busyness are the principal cause of medication errors, based on observatory studies of nursing practice [13-14]. These studies implied that it was acceptable that healthcare workers were so busy that they had to rush tasks, which caused a lack of due care and attention to be given to the administration of medications, and sometimes resulted in the certification processes being skipped. However, this study shows an opposite tendency in the medication errors rate. This study implies that people made mistakes not because they were doing too many things, but because they were doing too many different kinds of things. During a high frequency time for injections, nurses can concentrate on administrating injections to patients. Literature on human factor engineering indicate the same kinds of conclusions to ensure quality of activities [15-16]. It basically says that doing too many kinds of things is not a good way to ensure quality and reduce costs of activities, and that specialization is essential to redesigning workflow to improve management.

There is also another difference in our results compared with previously published literature. Injection warning rates in this study were relatively high compared to other studies on administration errors in injections [1-3, 13-14]. Many researchers have assumed injection error rates by observation of daily work, and their results gave a figure of around 4% for injection error rates as opposed to the 6.1% found in our study. Of course, there is a possibility that the difference in the injection warning rate came from environmental or other factors. However, the accuracy of data used in the analyses and detection of mixing errors could be regarded as the cause of the difference in results. Data captured by observational study has a bias in that people administrate more carefully when being observed. Therefore, the data captured by observational studies might be better than in reality. Other reason for the difference stem from the fact that other studies could not detect incorrect mixing of drugs. To identify incorrect mixing, drugs need to be managed not by a drug name ID but by a serialized ID [11]. A serialized ID on each product makes it possible to distinguish mixed and unmixed vials by recording the mixing for each drug and injection.

Clarification by time is an aspect of related factors for medication processes. Multivariate analyses with risk adjustment are needed to investigate more precisely reasons for medication errors. It is possible to accumulate data by place and people to identify a risky situation more precisely and in more depth, instead of clarifying by time. Figure 4 shows an example of another type of analysis, a scatter plot for the number of injections and injection warning rates per ward. The numbers of injections administered are totally different, but the injection warning rates are similar.

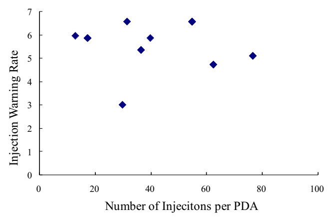

Figure 4 - Number of injections and warning rate per ward

We can identify one outlier whose warning rate is lower than for the other wards. To investigate the reason for this result, we need more in-depth analyses based on multiple variables and qualitative analyses.

One limitation to our research is in treating injections and other activities as the same workload activities, though actually there are quantitative and qualitative differences between these activities. It is necessary to assign weighs to each activity based on a time study or some methodology so as to capture more deeply and accurately the workloads of nurse for subsequent analysis. Another issue to be developed in this kind of analysis is privacy protection. In this analysis, data accumulated by hour and ward was utilized. The results did not contain personal data such as health care workers performance or data on patients. All patients and healthcare workers have unique identification numbers in this hospital. Therefore it is possible to analyze data using the identification numbers—including patient identification and worker including patient identification and worker identification. To utilize digital data from electronic health records and other hospital information systems, discussions on the utilization of data and privacy protection is essential for the development of methodologies for data utilization and protection, as well as for frameworks supporting and sometimes restricting the use of data.

Conclusion

This study showed general trends in medication mistakes in practice using data captured by the hospital information system "Point-of-Act System" in real time and accurately. The results suggested that a high variation in activities performed might have negative effects on patient safety, and that busyness could not be regarded as the main causes of errors. Our study also implied the possible effects of bar code administration systems. According to the results, the injection warning rate was about 6%, and these warnings prevented nurses from committing errors and accidents. The lack of accidents with respect to injections in the hospital provides the system's ability. In conclusion, the bar code administration system might be quite an effective way not only to prevent medication errors at point of care, but also to improve patient safety through the analyses of data captured by them, if a system were designed correctly. Further research is needed to make progress in digital data usage and the utilization of healthcare IT.

Acknowledgments

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References

[1] Keohane CA, Bane AD, Featherstone E, Hayes J, Woolf S, Hurley A, Bates DW, Gandhi TK, Poon EG. Quantifying Nursing Workflow in Medication Administration. The J. of Nursing Administration. 2008:38: 19-26.

[2] Shane R. Current status of administration of medicines, AJHP. 2009:65: 62-8.

[3] Sakowski J, Leonard T, Colburn S, Michaelsen B, Schiro T, Schneider J, Newman JM. Using a Bar-Coded Medication Administration System to Prevent Medication Errors. AJHP. 2005:62: 2619-2625.

[4] Taylor C, Lillis C, LeMone P. Fundamentals of Nursing: The Art and Science of Nursing Care. 4th edition. 2001 Philadelphia: Lippincott.

[5] Lisby M, Nielsen LP, Mainz J. Errors in the medication process: frequency, type, and potential clinical consequences. Int J. of Quality of Health Care. 2005:17: 15-22.

[6] Koppel R, Wetterneck T, Tells J, Karsh B. Workarounds to Barcode Medication Administration Systems: Their Occurrences, Causes, and Threats to Patient Safety. JAMIA 2008:15: 4408-423.

[7] Shane R. Current status of administration of medicines. AJHP. 2009:1:62-8.

[8] Mills PD, Neily J, Mims E, Burkhardt ME, Bagian J. Improving the bar-coded medication administration system at the Department of Veterans Affairs. AJHP 2006:63:1442-7.

[9] Cescon DW, Etchells E. Barcoded Medication Administration. A Last Line of Defense. JAMIA. 2008:299:2200-2202.

[10] Akiyama M. Migration of Japanese Health care enterprise from a financial to integrated management: strategy and architecture. Study of Health Tech. and Info. 2001:10: 715-718.

[11] Akiyama M. Risk Management and Measuring Productivity with POAS- Point of Act System. A medical information system as ERP (Enterprise Resource Planning) for Hospital Management. Methods of Information in Medicine. 2007:46: 686-93.

[12] Akiyama M, Kondo T. Risk Management and Measuring Productivity with POAS - Point of Act System. Study of Health Tech. and Info. 2007:129: 208-212.

[13] Fitzpatrick JJ, Stone PW, Walker PH. Annual Review of Nursing Research Vol 24: Focus on Patient Safety. 2006. Springer Publisher

[14] Tissot E, Cornette C, Demoly P, Jaquet M, Barale F, Capalleier G. Medication errors at the administration stage in an intensive care unit. Intensive Care Medicine. 1999:25: 353–359.

[15] Dean BS, Allan EL, Barber ND, Barker KN. Comparison of medication errors in an American and a British hospital. AJHP. 1995:52: 2543-49.

[16] Larrabee S, Brown M. Recognizing the institutional benefits of barcode point-of-care technology. Joint Commission J. of Quality and Safety. 2003:29:345-353.

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