Table 2 Clinical technological problems more marked in the developing world with implications and possible solutions

	Issue	Implications	Possible solutions
Blood products	► Hospital-based transfusion practices still widespread due to centralised blood collection and preparation being too expensive	► Decreased availability of blood products ► Dependence on family donors or higher-risk paid donors ► Substandard laboratory support for blood product refrigeration and virus/parasite screening[79] ► Increased risk of transmission of bloodborne infection to patient[80]	► Consistent quality local hospital-based rapid serological testing until centralisation becomes more affordable[81]
Infection control	► Poor hand-washing facilities ► Substandard sterilisation and disinfection practices	► Increased Healthcare-Acquired Infection with increased reliance upon antibiotics causing increased antibiotic resistance	► Targetted by WHO Global Patient Safety Challlenge: Clean Care is Safer Care ► Alcohol-based hand sanitisers or other novel disinfection products
	► Building designs to combat airborne infection spread are not available ► Ignorance of isolation methods in wards	► Increased spread of contagious diseases (eg, multidrug-resistant strains of tuberculosis)	► Modular or locally appropriate building designs
Anaesthetic equipment	► Inadequate staff training for specific machines ► Old anaesthetic machines and equipment, unreliable oxygen and power supplies ► Unreliable supply of medical-grade oxygen cylinders	► For example, only 6% of anaesthetists in Uganda have adequate facilities to provide safe anaesthesia for caesarean sections[82 83]	► Distance learning and interactive electronic tutorials ► Seminars and clinical teaching from external tutors ► Preoperative surgical checklists[56] ► Electric-powered oxygen extraction and concentration has been a success[84] ► Solar-powered oxygen generators
Resuscitation equipment	► Ongoing user education is deficient ► Users are sometimes low/non-literate ► Power source/batteries cause majority of failures[85]—even laryngoscope battery failure is a significant problem ► Planned Inspection and Preventive Maintenance programmes are often not strictly implemented		► Simple technologies with basic or graphical instructions made obvious on device
Cold chainmonitoring	► Ageing refrigeration equipment, interrupted power supply and poor maintenance[86]	► Major issues for vaccines, blood supplies and other temperature-sensitive medications at risk of spoilage	► New refrigeration technologies taking advantage of new photo-electric, insulation, cooling and energy storage technologies
Diagnostic testing	► Many patients are unable to return to clinic for results ► Many tests are inaccurate or expensive	► Incorrect or delayed diagnoses cause individual morbidity and epidemics	► Rapid, affordable, point of care immuno- and molecular diagnostics[87] (eg, for HIV, TB, malaria[88] and STIs)
Maternal and newborn care	► Delays around referral—centres are often a considerable distance—80% of African women live more than 5 km from even a primary health centre and have very poor transport options ► Unwillingness and inability to give birth in hospital/institution ► Preference for traditional birth attendants and decreased presence of skilled birth attendants at delivery (eg, only 40% in Africa)[89]	► Increased maternal and fetal complications ► Inadequate provision of timely caesarean section, control of labour pains, induction and ability to deal with complications ► Low-birthweight/sick neonates not readily identified	► Community-based transport options ► Mobile phone networks ► Readily available oxytocin and anti-shock garment for postpartum haemorrhage prevention and treatment
	► Inadequate fetal heart rate monitoring with often only a Pinard stethoscope available—requires skill[90]	► Worse detection of and response to perinatal distress/asphyxia	► Simplified, portable, rugged oximeters[91] and heart-rate monitors

healthcare providers to provide safe technology for fear of institutional negligence. Within the developing world, fewer reports of concern and adverse incidents lead to continuation of poor practices. Standards and regulations to ensure product quality and safety can be inadequate, as well as the mechanisms to enforce them. As a marker of inadequate access to quality care, a patient in a low-resource health setting is at a 2–20-fold higher risk of acquiring a facility or Healthcare-Acquired Infection (HAI) than a patient in a high-resource setting, where approximately 5–10% of hospital patients suffer HAIs.[70]

Solutions need to be inexpensive to implement and designed for low-resource settings (box 4). For example, many developing countries have significant problems providing skilled attendance for obstetric emergencies. WHO Regional Office for Africa recommmends groups of young volunteers from the primary healthcare level transporting appropriate patients to referral level care using motorcyles or adapted vans, fitted with radio transmitters.[74] Additionally, while it is sometimes culturally difficult, there is a limited evidence base for the provision of small and simple 'maternity waiting homes,'[75] situated close to the referral hospital. These homes are used by women in the final period of their pregnancy who are at risk of complications or by those who live far from the referral hospital.[76] Where infants are born at home, infection risks are higher; however, single-use delivery kits provide a sterile plastic delivery sheet, razor blade, cord ties and soap with pictorial instructions for low-literacy users. Tanzanian studies have shown this reduces umbilical cord infection from 3.9% to 0.3% and puerperal sepsis from 3.6% to 1.1%.[77] Another issue with home births by low-literacy traditional birth attendants is that detection of low-birthweight babies requiring treatment is more difficult. One novel solution has been the use of non-numeric tactile or colour-coded indicator weighing scales.[78] Table 2 outlines some of the other challenges facing the developing world with relevant implications and potential solutions where possible.

CONCLUSION

Although technology is pivotal for the advancement of healthcare, it can cause significant harm if not adequately designed, regulated and maintained. Although medical devices will have CE markings under the medical devices directive (93/42EEC) within Europe,[92] and FDA approval in the USA, this level of certification must be ensured internationally and enforced within the developing world, especially for higher-risk technologies. It is likely that this would be easier to achieve with worldwide agreement on the minimum standards. Although it has proven difficult to acquire agreement on even common nomenclature, the Global Harmonisation Task Force has embarked upon this ambitious but important strategy.[93 94] A recent example is the work performed by WHO and collaborators through the Global Pulse Oximetry Project to establish global standards for the use of pulse oximetry in anaesthesia.[91]

Even with robust regulation of minimal requirements for their design, however, healthcare technologies are vulnerable to misuse and can create error in ways that can only be identified through appropriate encouragement of non-punitive open reporting. By classifying and investigating these near misses and adverse events and recording them in national and international databases, it becomes possible to establish root causes. As described, data support the benefits of these systems with regards to safety of technology[26] and they must be encouraged in the developing world.

It is time to start work on internationally standardised practical methodologies and nomenclature for reporting systems and on gathering information from all available sources based on the ICPS, which is scheduled to be completed in the next 3 years. A common data field format and means of collection will allow the development of a universal international events database. This is possible with limited technology such as mobile phones that are linked to reporting centres provided with the software that elicits the information needed for populating the ICPS. This data collection will pave the way for the final step—the dissemination and implementation of the lessons learnt. The cost of implementing basic systems for safe technology must be weighed against the current very high costs of not doing so.

Vital for the provision of safe technology are maintenance programmes and consideration of intelligent redesign to reduce the risks that are contributed by the end user. Furthermore, there needs to be adequate training and education programmes for healthcare professionals. Common standards for accreditation and quality assurance schemes will also improve safety. In the developing world, it is essential that all these safety mechanisms and solutions be affordable, appropriate and, above all, able to be realised.

Funding The project was funded by WHO Patient Safety.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

REFERENCES

1. **Donahoe G,** King G. Estimates of medical device spending in the United States. *AdvaMed* 2009.
2. **Valentin A,** Capuzzo M, Guidet B, *et al*. Patient safety in intensive care: results from the multinational Sentinel Events Evaluation (SEE) study. *Intensive Care Med* 2006;**32**:1591–8.
3. **Webb RK,** Russell WJ, Klepper I, *et al*. The Australian Incident Monitoring Study. Equipment failure: an analysis of 2000 incident reports. *Anaesth Intensive Care* 1993;**21**:673–7.
4. **Thomas AN,** Galvin I. Patient safety incidents associated with equipment in critical care: a review of reports to the UK National Patient Safety Agency. *Anaesthesia* 2008;**63**:1193–7.
5. **Runciman B,** Merry A, Walton M. *Safety and ethics in healthcare: a guide to getting it right*. Aldershot: Ashgate, 2007.
6. **Hutchinson A,** Young TA, Cooper KL, *et al*. Trends in healthcare incident reporting and relationship to safety and quality data in acute hospitals: results from the National Reporting and Learning System. *Qual Saf Health Care* 2009;**18**:5–10.
7. **Vincent C,** Stanhope N, Crowley-Murphy M. Reasons for not reporting adverse incidents: an empirical study. *J Eval Clin Pract* 1999;**5**:13–21.
8. **Thomas AN,** Pilkington CE, Greer R. Critical incident reporting in UK intensive care units: a postal survey. *J Eval Clin Pract* 2003;**9**:59–68.
9. **Runciman WB,** Williamson JA, Deakin A, *et al*. An integrated framework for safety, quality and risk management: an information and incident management system based on a universal patient safety classification. *Qual Saf Health Care* 2006;**15** (Suppl 1):i82–90.
10. **Leveson NG,** Turner CS. An investigation of the therac-25 accidents. *Computer* 1993;**26**:18–41.
11. **Jick H,** Walker AM, Spriet-Pourra C. Postmarketing follow-up. *JAMA* 1979;**242**:2310–14.
12. **Cope JU,** Morrison AE, Samuels-Reid J. Adolescent use of insulin and patient-controlled analgesia pump technology: a 10-year Food and Drug Administration retrospective study of adverse events. *Pediatrics* 2008;**121**:e1133–8.
13. **Runciman WB.** Lessons from the Australian Patient Safety Foundation: setting up a national patient safety surveillance system—is this the right model? *Qual Saf Health Care* 2002;**11**:246–51.
14. **Samore MH,** Evans RS, Lassen A, *et al*. Surveillance of medical device-related hazards and adverse events in hospitalized patients. *JAMA* 2004;**291**:325–34.
15. **Jha AK,** Kuperman GJ, Teich JM, *et al*. Identifying adverse drug events: development of a computer-based monitor and comparison with chart review and stimulated voluntary report. *J Am Med Inform Assoc* 1998;**5**:305–14.
16. **Runciman WB.** Shared meanings: preferred terms and definitions for safety and quality concepts. *Med J Aust* 2006;**184**(10 Suppl):S41–3.
17. **Elder NC,** Pallerla H, Regan S. What do family physicians consider an error? A comparison of definitions and physician perception. *BMC Fam Pract* 2006;**7**:73.
18. **Runciman W,** Hibbert P, Thomson R, *et al*. Towards an International Classification for Patient Safety: key concepts and terms. *Int J Qual Health Care* 2009;**21**:18–26.
19. **Sherman H,** Castro G, Fletcher M, *et al*. Towards an International Classification for Patient Safety: the conceptual framework. *Int J Qual Health Care* 2009;**21**:2–8.
20. **Runciman B,** Merry A, Smith AM. Improving patients' safety by gathering information. Anonymous reporting has an important role. *BMJ* 2001;**323**:298.
21. **Gorzeman J.** Balancing Just Culture with regulatory standards. *Nurs Adm Q* 2008;**32**:308–11.
22. **Wachter RM,** Pronovost PJ. Balancing 'no blame' with accountability in patient safety. *N Engl J Med* 2009;**361**:1401–6.
23. **Bjorn B,** Anhoj J, Lilja B. Reporting of patient safety incidents: experience from five years with a national reporting system. *Ugeskr Laeger* 2009;**171**:1677–80.
24. **Kidanto HL,** Mogren I, van Roosmalen J, *et al*. Introduction of a qualitative perinatal audit at Muhimbili National Hospital, Dar es Salaam, Tanzania. *BMC Pregnancy Childbirth* 2009;**9**:45.
25. **Pattinson R,** Kerber K, Waiswa P, *et al*. Perinatal mortality audit: Counting, accountability, and overcoming challenges in scaling up in low- and middle-income countries. *Int J Gynaecol Obstet* 2009;**107**(Suppl 1):S113–22.
26. **Cohen H.** *Serious hazards of transfusion annual report*, 2008.
27. **Levtzion-Korach O,** Alcalai H, Orav EJ, *et al*. Evaluation of the contributions of an electronic web-based reporting system: enabling action. *J Patient Saf* 2009;**5**:9–15.
28. **Shah JS,** Maisel WH. Recalls and safety alerts affecting automated external defibrillators. *JAMA* 2006;**296**:655–60.
29. **Maisel WH.** Pacemaker and ICD generator reliability: meta-analysis of device registries. *JAMA* 2006;**295**:1929–34.
30. **NHS.** Reporting and learning system data summary of patient safety incident reports in the NHS, 2008 Nov 12.
31. **NHS.** National reporting and learning system quarterly data summary England, 2008 Aug 16.
32. **MHRA.** MHRA Device Bulletin Adverse Incident Reports 2007. In: Health DO, ed, 2008 Mar.
33. **Hefflin BJ,** Gross TP, Schroeder TJ. Estimates of medical device—associated adverse events from emergency departments. *Am J Prev Med* 2004;**27**:246–53.
34. **Thomas AN,** McGrath BA. Patient safety incidents associated with airway devices in critical care: a review of reports to the UK National Patient Safety Agency. *Anaesthesia* 2009;**64**:358–65.
35. **Webb RK,** van der Walt JH, Runciman WB, *et al*. The Australian Incident Monitoring Study. Which monitor? An analysis of 2000 incident reports. *Anaesth Intensive Care* 1993;**21**:529–42.
36. **Runciman WB.** Commentary on equipment recommendations. *Eur J Anaesthesiol Suppl* 1993;**7**:16–18.
37. **Greenfield D,** Braithwaite J. Health sector accreditation research: a systematic review. *Int J Qual Health Care* 2008;**20**:172–83.

38. **Whittaker S,** Green-Thompson RW, McCusker I, *et al*. Status of a health care quality review programme in South Africa. *Int J Qual Health Care* 2000;**12**:247–50.
39. **Ammar W,** Wakim IR, Hajj I. Accreditation of hospitals in Lebanon: a challenging experience. *East Mediterr Health J* 2007;**13**:138–49.
40. **Bateman C.** COHASA—nibbling at the health care elephant. *S Afr Med J* 2006;**96**:93–4.
41. **Ghananewsagency.** 100,000 patients die due to medical errors in the US each year, 2009.
42. **ISO.** Medical devices: Symbols to be used with medical device labels, labelling and information to be supplied—Part 1: General requirements, 2007 14.15223–1:2007.
43. **Nightingale MJ,** Leimbach R. An evaluation of proposed changes to International Standards for blood bags and transfusion sets to improve their compatibility. *Transfus Med* 2008;**18**:281–6.
44. **Aoyagi T.** ISO 15189 medical laboratory accreditation. *Rinsho Byori* 2004;**52**:860–5.
45. **Dain SL.** Anesthesia standards for facilities and equipment. *Can J Anaesth* 2001;**48**:41–7.
46. **Brennan TA,** Leape LL, Laird NM, *et al*. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med* 1991;**324**:370–6.
47. **Reason JT.** *Human error*. Cambridge: Cambridge University Press, 1990.
48. **Baker R,** Hurwitz B. Intentionally harmful violations and patient safety: the example of Harold Shipman. *J R Soc Med* 2009;**102**:223–7.
49. **Marks V,** Richmond C. Beverly Allitt: the nurse who killed babies. *J R Soc Med* 2008;**101**:110–15.
50. **Vincent C,** Taylor-Adams S, Stanhope N. Framework for analysing risk and safety in clinical medicine. *BMJ* 1998;**316**:1154–7.
51. **Kohn LT,** Corrigan J, Donaldson MS. To err is human: building a safer health system. Washington, D.C.; [Great Britain]: National Academy Press, 2000.
52. **Johnson TR,** Tang X, Graham MJ, *et al*. Attitudes toward medical device use errors and the prevention of adverse events. *Jt Comm J Qual Patient Saf* 2007;**33**:689–94.
53. **Joice P,** Hanna GB, Cuschieri A. Errors enacted during endoscopic surgery—a human reliability analysis. *Appl Ergon* 1998;**29**:409–14.
54. **Spath PL.** Using failure mode and effects analysis to improve patient safety. *AORN J* 2003;**78**:16–37; quiz 41–4.
55. **Shebl NA,** Franklin BD, Barber N. Is failure mode and effect analysis reliable? *J Patient Saf* 2009;**5**:86–94.
56. **Vincent CD.** *Patient safety*. Edinburgh: Elsevier Churchill Livingstone, 2006.
57. **Schulmeister L.** Preventing vincristine administration errors: Does evidence support minibag infusions? *Clin J Oncol Nurs* 2006;**10**:271–3.
58. **Haynes AB,** Weiser TG, Berry WR, *et al*. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 2009;**360**:491–9.
59. **Smith A,** Kinross J, Bailey M, *et al*. Re-stocking the resuscitation trolley: how good is compliance with checking procedures? *Clin Risk* 2008;**14**:4–7.
60. **West J,** Halls S, Coleman R, *et al*. Resus:station: breathing life back into resuscitation. *Improving Patient Safety conference proceedings*; July 2008. Ergonomics Society.
61. **Graham MJ,** Kubose TK, Jordan D, *et al*. Heuristic evaluation of infusion pumps: implications for patient safety in Intensive Care Units. *Int J Med Inform* 2004;**73**:771–9.
62. **Turner CL,** Casbard AC, Murphy MF. Barcode technology: its role in increasing the safety of blood transfusion. *Transfusion* 2003;**43**:1200–9.
63. **Roark DC.** Bar codes and drug administration. *Am J Nurs* 2004;**104**:63–6.
64. **Patterson ES,** Cook RI, Render ML. Improving patient safety by identifying side effects from introducing bar coding in medication administration. *J Am Med Inform Assoc* 2002;**9**:540–53.
65. **Koppel R,** Wetterneck T, Telles JL, *et al*. Workarounds to barcode medication administration systems: their occurrences, causes, and threats to patient safety. *J Am Med Inform Assoc* 2008;**15**:408–23.
66. **Jensen LS,** Merry AF, Webster CS, *et al*. Evidence-based strategies for preventing drug administration errors during anaesthesia. *Anaesthesia* 2004;**59**:493–504.
67. **Beecher HK,** Todd DP. A study of the deaths associated with anesthesia and surgery: based on a study of 599, 548 anesthesias in ten institutions 1948–1952, inclusive. *Ann Surg* 1954;**140**:2–35.
68. **Cooper JB,** Newbower RS, Long CD, *et al*. Preventable anesthesia mishaps: a study of human factors. *Anesthesiology* 1978;**49**:399–406.
69. **Wyatt J.** Appropriate medical technology for perinatal care in low-resource countries. *Ann Trop Paediatr* 2008;**28**:243–51.
70. **Morris K.** Global control of health-care associated infections. *Lancet* 2008;**372**:1941–2.
71. **Sharma S.** Safe and newer injection technologies. *J Indian Med Assoc* 2005;**103**:215–16, 18, 21.
72. **Lloyd JS,** Milstien JB. Auto-disable syringes for immunization: issues in technology transfer. *Bull World Health Organ* 1999;**77**:1001–7.
73. **Battersby A,** Feilden R, Nelson C. Sterilizable syringes: excessive risk or cost-effective option? *Bull World Health Organ* 1999;**77**:812–19.
74. **Krasovec K.** Auxiliary technologies related to transport and communication for obstetric emergencies. *Int J Gynaecol Obstet* 2004;**85**(Suppl 1):S14–23.
75. **Figa-Talamanca I.** Maternal mortality and the problem of accessibility to obstetric care; the strategy of maternity waiting homes. *Soc Sci Med* 1996;**42**:1381–90.
76. **Stanton C,** Blanc AK, Croft T, *et al*. Skilled care at birth in the developing world: progress to date and strategies for expanding coverage. *J Biosoc Sci* 2007;**39**:109–20.
77. **Winani S,** Wood S, Coffey P, *et al*. Use of a clean delivery kit and factors associated with cord infection and puerperal sepsis in Mwanza, Tanzania. *J Midwifery Womens Health* 2007;**52**:37–43.
78. **Darmstadt GL,** Kumar V, Shearer JC, *et al*. Validation of accuracy and community acceptance of the BIRTHweigh III scale for categorizing newborn weight in rural India. *J Perinatol* 2007;**27**:602–8.
79. **Nightingale S.** Blood safety summary. In: Services USDoHaH, ed, 2001 Apr.
80. **Dhingra N,** Hafner V. Safety of blood transfusion at the international level. The role of WHO. *Transfus Clin Biol* 2006;**13**:200–2.
81. **Field SP,** Allain JP. Transfusion in sub-Saharan Africa: does a Western model fit? *J Clin Pathol* 2007;**60**:1073–5.
82. **Hodges SC,** Mijumbi C, Okello M, *et al*. Anaesthesia services in developing countries: defining the problems. *Anaesthesia* 2007;**62**:4–11.
83. **Froese A.** Anesthesia and the role of short-term service delivery in developing countries. *Can J Anaesth* 2007;**54**:940–6.
84. **Matai S,** Peel D, Wandi F, *et al*. Implementing an oxygen programme in hospitals in Papua New Guinea. *Ann Trop Paediatr* 2008;**28**:71–8.
85. **White RD.** Maintenance of defibrillators in a state of readiness. *Ann Emerg Med* 1993;**22**:302–6.
86. **Locke G.** Various HTM and Health & Safety Reports. In: Programme CFA, ed.
87. **Yager P,** Domingo GJ, Gerdes J. Point-of-care diagnostics for global health. *Annu Rev Biomed Eng* 2008;**10**:107–44.
88. **Moody A.** Rapid diagnostic tests for malaria parasites. *Clin Microbiol Rev* 2002;**15**:66–78.
89. **Carrera JM.** Maternal mortality in Africa. *J Perinat Med* 2007;**35**:266–77.
90. **Mahomed K,** Nyoni R, Mulambo T, *et al*. Randomised controlled trial of intrapartum fetal heart rate monitoring. *BMJ* 1994;**308**:497–500.
91. **WHO.** *Background document for first international consultation meeting of global Pulse oximetry project*. Geneva, Switzerland: WHO, 2008. http://www.who.int/patientsafety/events/08/1st_pulse_oximetry_meeting_background_doc.pdf.
92. **Bentley D.** CE marking—what does it really mean? *J Tissue Viability* 1999;**9**:11–15.
93. **McAllister P,** Jeswiet J. Medical device regulation for manufacturers. *Proc Inst Mech Eng H* 2003;**217**:459–67.
94. **Gagliardi J.** The global harmonization task force: what you need to know. *Biomed Instrum Technol* 2009;**43**:403–5.

Analysis on data captured by the barcode medication administration system with PDA for reducing medical error at point of care in Japanese Red Cross Kochi Hospital.

Masanori Akiyama[1,2], Atsushi Koshio[1,2], Nobuyuki Kaihotsu[3]

[1] Todai Policy Alternatives Research Institute, The Univerisity of Tokyo, Tokyo, JAPAN
[2] Sloan School of Management, Masachusettus Institute of Techonology, MA, USA
[3] Japanese Red Cross Kochi Hospital
{makiyama, koshio}@pp.u-tokyo.ac.jp

Abstract. Our study aim to understand complete picture and issues on medical safety and investigate preventive measures for medical errors by analyzing data captured by bar code system and entered by Personal Digital Assistance. Barcode administration system named Point-of-Act-System was designed to capture every activity at the bed sides. Complete activity data including injection, treatment and other nurses' activity and warning data showing mistakes on injections were used for our analyses. We described the data and analyze statistically by accumulating data by hour to find potentially risky time and understand relationship between business and errors. The warning rate as a whole was 6.1% in average. The result showed there was a negative correlation between number of injections and injection warning rate (-0.48, $p<0.05$). Warning rate was relatively low in the hours that numbers of administrating injections are high. Bar code administration system is quite effective way not only to prevent medical error at point of care but also improve patient safety with analyses of data captured by them.

Keywords: Barcode administration system, Point-of-Act-System, Point of Care, Patient Safety, Warning data

1 Introduction

It is widely believed that patient safety is an important issue for health care systems. Many organizations and hospitals have been trying to gather information and evidences on patient safety for the purpose to improve patient safety based on the data collected. These data is accumulated to provide information on threats for patent safety including bottle neck of administration and high risk areas. Such data are quite useful in understanding the threats and actual situations related to medication errors in hospitals. However, most of evidence is basically information on medical accidents and incidents, compiled from voluntary reports submitted by medical workers and the workers need to write reports to inform the situation to them. 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 situations in hospitals, including details of medical accidents and incidents, is essential to identifying general causes and frequency 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 technology such as electrical medical record and barcode administration system at 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 patient care through daily medications 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 potentially risky area in medical activities [1-3]. 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. 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 complete picture and issues related to medical safety, and to investigate preventive measures for medication accidents. We focused on injections, which are one of the major causes of medical accidents and, investigated the relation between errors and the contexts of medication activities including how busy staffs were, and shift works.

2 Methods

2-1. Settings and items to be addressed

Japanese Red Cross Kochi Hospital located on southern part of Japan 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 with real time information [4-6]. At the same time, POAS captures complete data of each medical action including 6W1H information (When, Where What, Why, for what, to whom and How) and stores the data to access in an instance. The system was designed to use data secondly for improve quality and productivity of health care. The basic requirement for successful measurement and data capturing, they must be integrated with the routine provision of care and whenever possible should be done using IS and this system satisfied this requirement The principal characteristics of data captured by this system are (1) complete data including every action in real time and accurately and (2) process management that enables POAS to ensure right process of medication and assure capturing complete data. Complete data capture through routinely use of hospital information system including 6W1H information is an innovative source to understand real situations directly without estimations and investigate solutions to prevent errors.

2-2. Data

Data captured at the sites of injection process was used for our analyses of medication administration, especially nursing care. Data on injections means both injections and IVs. 6W1H information was captured at each point of the injection process; Order to give injection, Drug picking, Drug audit, Drug mixing and Injection. Although the first objective of a bar code administration system is to ensure patient safety by verifying medication rightness including the 5 Rights of medication, another objective is to capture activities of nurses enforcing medications for patients. At the point of care or activity, nurses uses PDAs to scan the barcode of ambles or vials containing the medication to be injected or other activities including treatment, care, observation, counseling and emergency to enter information on their actions. This information is primary used for the documentation of nursing activities. However, this information can also be used not only for hospital management through understanding the workloads of nurses and the actual costs of administering medications but also for patient safety by understanding the prevailing situations when warnings 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 bottles of drugs. Warning data do not directly mean data on errors. However, warning data is useful sources to analyze causes of medical errors, because warned activities have potential possibility of medical errors without barcode administration system. Therefore, high warning rates in some specific times, places, situations and workers mean risky times, places, situations and workers for patient safety. Types of warning are basically wrong bottle, wrong patient and mixing error meaning incorrect mixing of drugs. All data from January 2005 to June 2008 was used for the analyses. Total numbers of activities are 14,824,046 and number of injections are 604,847. That covered almost 100 % injections and 99% of activities by nurses.

2-3. Data Analysis

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

We described these data and analyzed statistically to investigate correlations between situations and warning rates. Total number of injections per hour, total number of activities, total number of injection per PDA by hour and total number of activities per PDA by hour were used as indicators for workload at the time. Fraction of injections among total activities and fraction of treatments among total activities were used as indicators for variation of hours. We employed Pearson Correlation Analysis to investigate relationships and significant level was 5%.

3 Results

3-1. Description

Total number of activities data 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 cares (13.3%), 10,437,250 observations (70.4%), 14,713 counseling (0.1%), 824,743 treatments (5.6%) and 478,919 emergency (3.2%). Total injections combining injections and IV drops were 604,847 and total warning on injections is 37,046 (6.1%). Figure 1 shows trend of injection warning rate at point of care. After a half year of implantation, the warning rates were relatively higher. The injection warning rate has been gradually decreasing.

Figure 1. Trend of Injection warning rate from March 2003 to June 2008

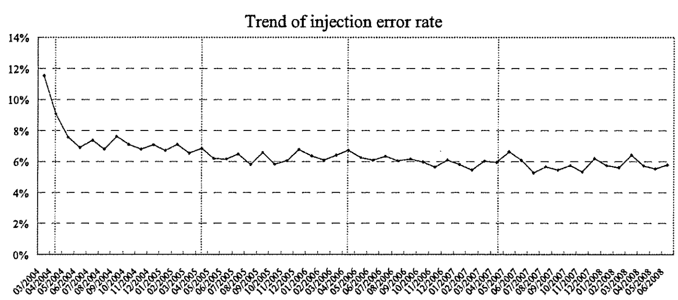


Figure 2 shows number of total entered data by nurse hour by hour. This data imply the workload at the time, though every activities were treated as same workload and actually the workloads are depend on the activities. Number of activities are higher on around 6AM and 10 AM.

Figure 2. Number of Total Entered Data by hour

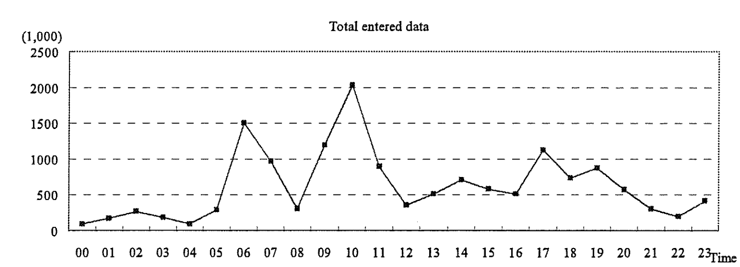
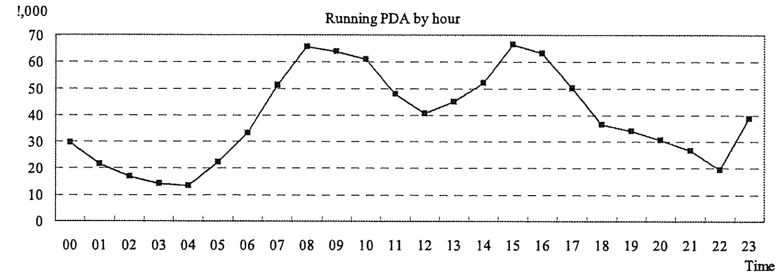


Figure 3 shows number of running PDA by hour. In Japanese Red Cross Hospital, Patients to nurse ratio during day time twice as high as during night time. The data implys actual working people at the time.

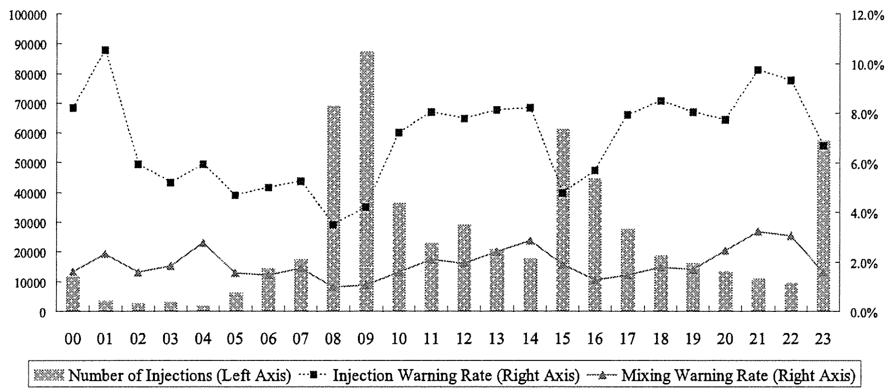
Figure 3. Number of running PDA by hour



3-2. Data Analysis

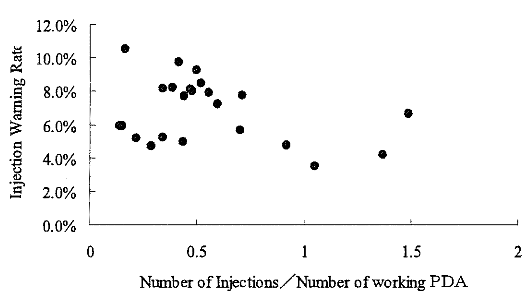
Figure 4 shows trend of warning rate and activities by hour. Bar graph shows number of injection by hour. There was variability in number of injections by hour. There are three points that nurses administrate injections in volume. Those were 9AM, 3PM and 11PM. Two line graphs show injection warning rates and mixing warning rates by hour. Mixing warning means drugs for injection are not mixed correctly. Minimum and maximum of the injection warning rates were 4.2% and 10.5%. Minimum and maximum of mixing warning rates were 1.0% and 3.2%. This graph shows the warning rate was relatively lower when nurses administrated many injections. In this hospital, there are three working shifts for nurses. These are Day shift (8:00-16:40), Evening Shift (16:00-0:40) and Night shift (0:00-8:40). The warning rates for each shift were 5.5% (Day shift), 7.3% (Evening shift) and 6.0% (Night shift). The tendency of injection warnings and mixing warnings have somewhere same tendency. Especially during day shift, this tendency was demonstrated quite clearly.

Figure 4. Number of Injections and Warning rate by hour



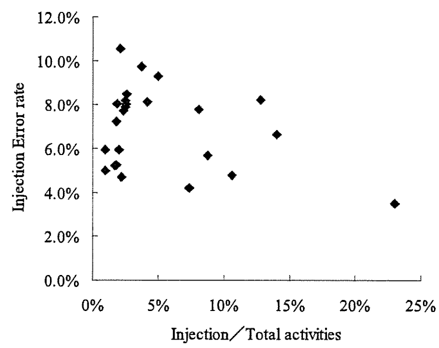
According to the results of correlation analysis, there was a negative correlation between number of injections and injection warning rates. The correlation coefficients between number of injections and injection warning rates was -0.48 ($p<0.05$) and between number of injections per PDA and injection warning rates was -0.34 ($p<0.05$) (Figure. 5). Both results are significant and implied negative relationships between error rate and business.

Figure 5. Scatter plot on Number of Injections and Warning rate by hour



Variation of activities had negative effects to warning rate. Figure 6 is scatter plot to show relationship between fraction of injections among total activities and injection warning rates. We chose proportion of injections among total number of activates at the time as an indicator for variation activities. In our assumption, nurse concentrating on administering injections tend to operate more safely. This figure implies negative correlation between the two indicators. The correlation coefficient between fraction of treatments among total activities and injection warning rates was 0.35 ($p<0.05$). High fraction of treatment means nurses should administrate injections with other kinds of treatments for patients and discourage nurses against concentrating on injections.

Figure 6. Scatter plot on proportion of injections among total number of activities adn Injection error rate



4 Discussion

In the literatures on patient safety, many studies had mentioned workloads and busyness are the principal cause of medical errors [7.8]. It was acceptable for workers that rushing and fatigue would cause lack of attentions to medications. However, this study demonstrated opposite tendency of medical errors. This study implied that people would make mistakes because of not doing too many things but too many kinds of things. Literatures on human factor engineering indicated same kinds of conclusions to ensure quality of activities [9.10].

Warning rates in this study was relatively high compare to other literatures on administration errors of injections [1-3, 7, 8]. This difference came from accuracy of data and detections of mixing errors. In this study, data was collected through routinely work by hospital information system. People tend to be careful when they are observed by other. Therefore, we indicate that the data captured by PDA is more bias free data compared to conservative data. And other study also could not detect wrong bottle errors caused by mixing error, because forgetting mixing drugs sometimes difficult to be found by human eyes. Single item management of drugs with serialized ID is essential for preventing and finding mixing errors [5]. Distinction of bottles and other drugs with single item level is an only method to distinguish mixed and unmixed bottle systematically.

It is possible to accumulate the data by wards and nurses to realize risky place and working style. In this study, we tried to investigate relationship between number of injections and injection warning rate by each ward. This analysis doesn't show clear relationship between two indicators, because each ward provides health care service to different patients. When we focus on the difference of error rate by ward, we need to consider some risk adjustment method to compare fairly. This policy can be applied in comparing results among multi hospitals. Accumulating by nurses submitted new issues on privacy of workers. The system anonymized data of each nurse and their attribution, but researchers could sometimes identify nurse through patterns of work and other aspects. Researcher should be cautious to publish results.

Beside, the other issue is weighting of each activity. We treated injections and other activities as same workload activities, though actually there are quantitative and qualitative differences among activities. It is necessary to decide weighs of each activity to analyze more deeply and accurately with time study or other research methods.

5 Conclusion

This study showed general tendency of possible medical errors in practice with data captured in real time and accurately. The result suggested that high variation of activities might have negative effects for patient safety, though busyness is not one of the main causes of errors. Our study also demonstrated the effectiveness of bar code administration system. According to the result, injection warning rate was about 6% and these warning had been prevented nurses against errors and accidents with the system. In conclusion, bar code administration system is quite effective way not only to prevent medical error at point of care but also improve patient safety with analyses of data captured by them.

References

1. Carol A. Keohane, Anne D. Bane, Erica Featherstone, Judy Hayes, Seth Woolf, Ann Hurley, David W. Bates, Tejal K. Gandhi, Eric G. Poon, Quantifying Nursing Workflow in Medication Administration. The Journal of Nursing Administration. 38 (2008), 19-26
2. Rita Shane, Current status of administration of medicines, Am J Health-Syst Pharm. 65 (2009), 62-8
3. Julie Sakowski, Thomas Leonard, Susan Colburn, Beverly Michaelsen, Timothy Schiro, James Schneider, Jeffrey M. Newman, Using a Bar-Coded Medication Administration System to Prevent Medication Errors. Am J Health-Syst Pharm 62 (2005), 2619-2625
4. Masanori Akiyama, Migration of Japanese Health care enterprise from a financial to integrated management: strategy and architecture, Stud Health Technol Inform, 10 (2001), 715-718
5. Masanori Akiyama, Risk Management and Measuring Productivity with POAS-Point of Act System. A medical information system as ERP (Enterprise Resource Planning) for Hospital Management, Methods Inf Med 46 (2007), 686-93.
6. Masanori Akiyama, Tatsuya Kondo, Risk Management and Measuring Productivity with POAS - Point of Act System, Stud Health Technol Inform, 129 (2007), 208-212
7. Joyce J. Fitzpatrick, Patricia W. Stone, Patricia Hinton Walker. Annual Review of Nursing Research Vol 24: Focus on Patient Safety

8. 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 Med, 25 (1999), 353- 359.
9. Dean BS, Allan EL, Barber ND, Barker KN. Comparison of medication errors in an American and a British hospital., Am J Health Syst Pharm , 52 (1995), 2543- 2549.
10. Larrabee S, Brown M. Recognizing the institutional benefits of barcode point-of-care technology, Joint Comm J Qual Saf, 29 (2003),:345-353.00) 295—301.
11. David W. Bates, Elizabeth Pappius, Gilad J. Kuperman, Dean Sittig, Helen Burstin, David Fairchild, Troyen A. Brennan, Jonathan M. Teich. Using information systems to measure and improve quality. International Journal of Medical Informatics 1999; 53: 115- 124.

Capturing and Analyzing Injection Processes with Point of Act System for improving quality and productivity of health service administration

Atsushi Koshio[1,2], Masanori Akiyama[1,2]

[1] Todai Policy Alternatives Research Institute, The Univerisity of Tokyo, Tokyo, JAPAN
[2] Sloan School of Management, Masachusettus Institute of Techonology, MA, USA
{koshio, makiyama}@pp.u-tokyo.ac.jp

Abstract. The objective of this paper is to show process data captured with barcode administration system and the results of data analyses and visualizations for improving quality of care and productivity. Hospital Information System named Point-of-Act System that was designed to capture every process of all medical acts was employed to capture data of medical processes. Data of injection process was analyzed based on operative timeliness. The result shows nursing workload didn't be allocated equally through the day and some parts of injections hadn't been administrated at the right time. Improving operative timeliness can contribute to improve quality of care and productivity. This kind of process information has a possibility to provide new research opportunity to analyze outcome with context information including process information.

Keywords: Hospital Information System, Process Management, Electrical Data Capturing, Data Analysis, Visualization

1 Introduction

Utilizing data captured and stored by hospital information systems is quite important issue to make hospital IT systems more effective for improving health care quality and productivity. After the report of medication errors and health care quality by Institute of Medicine, these data have been regarded as significant sources for managing hospital environments [1-2]. The data can be constructed as indicators evaluating health care process and outcome. The movements such as "e-indicators" have been trying to analyze and publish these data for the purpose of health outcome management with bench marking and public disclosure [3-11]. Outcome information has a possibility to affect patient's decision and make health care system more patients centered. In addition to this outcome information, process information is also important to understand reality of health care service provision. Process indicators provide context of outcome indicators and show practices to improve quality and productivity [12-15].

Data captured through daily use of hospital information systems are containing data of medication processes. Utilizing process data for understanding daily medication process is an useful way to plan resource allocation in hospitals to improve operation and management of service delivery. Process information has an ability to provide why differences of outcome are coming from. And this activities capturing process information and managing medical process also have a possibility to make health care industry more transparent and accountable through publishing the information. Transparency is one of the prioritized areas to be solved to construct better health care systems [16-18].

The objective of this paper is to show process data captured with barcode administration system and the results of analyses and visualizations for achieving the targets described above. This study will emphasize benefits of hospital information system named Point of Act System based on process management and real time data capturing and capturing every activity in the hospitals. In this study, we focus injections and utilize injection process data to analyze medical activities and visualize process in the hospital.

2 Methods

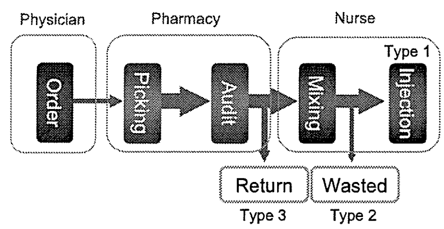
2-1. Things that need to be addressed

Point of Act System (POAS) is a real time bar-code capturing health information system in International Medical Center of Japan (IMCJ) in Tokyo, Japan [19-22]. POAS has a function to prevent medical errors by certifying correctness of medical activities with capturing bar cords on patients, worker and drugs. It ensure not only the correctness of patients, drug, dose but also route and time based on real time information. At the same time, POAS captures implementation records at each process of medical activities including 6W1H information (When, Where What, Why, for what, to whom and How) of the activities. The basic requirement for successful measurement and data capturing, they must be integrated with the routine provision of care and whenever possible should be done using IS and this system satisfied this requirement [6].

There are basic characteristics of POAS captured data. The data is including every activity in the hospital that means it concludes complete data of the administration. This implies the research based on not sampling data but all data of the medications. The second characteristic is process management of administration. The first target of process management is restraining skipping processes that would sometimes be causes of medication errors. The system record the data at each point of action of processes described by figure 1 showing injection process as an example.

By capturing the data routinely at each process of activities, the data provides information on returned and wasted injections as well as normal injections without entering additional information at end points.

Figure 1. Data capturing points of Injection processes



2-2. Data and Analysis Methods

Injection process was chose as a target of this study to analyze process data and visualize processes of medical activities. As a standard injection process physicians order for patients and pharmacists pick up and audit the order. These drugs deliver to nurse stations and nurses mix and inject them to patients. 6W1H information have been captured at each point of action; Order, Picking, Audit, Mixing and Injection. In addition to these data, data on order is including "scheduled order time" that shows the scheduled time to inject to patients. These data were liked by serialized ID on each drug and order. Data from July to September 2007 that is including 306768 drugs taken in all injections during the term at every ward in IMCJ was used to analyze. The data was merged from different partial information system such as physician order entry system, pharmacy system and risk management system. Data from other term was also referred if necessary. Basic descriptive analyses and some visualization techniques are applied for analyzing injection process. Especially we described frequency of injection processes minutes by minutes to analyze business of the hospital and time differences including scheduled time and actual administration time to assess time precision of the administration processes to scheduled plan.

3 Results

Figure 2 shows the distribution of scheduled injection order time by physicians. Enormous portion of orders were scheduled on 6AM, 10AM and 6PM. Figure 3 shows actual number of activities including mixing of drugs for injections and injections of drugs by minutes. As the peak of order by physicians was 6AM, the time of peak of actual injections is around 6AM. The orders scheduled 6AM were injected from around 4AM to 7AM, because the number of orders surpassed capacity of nurses at the time. Nurses adjusted to variation of number of orders by time by injecting earlier than scheduled time.

Figure 2. Distribution of scheduled time

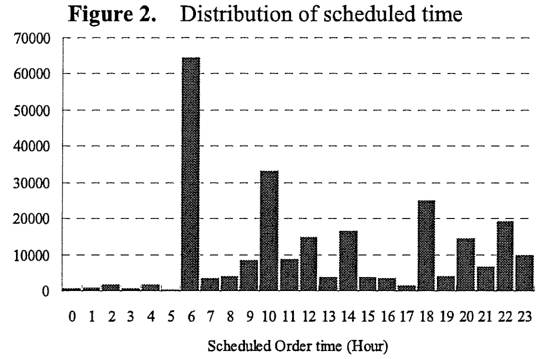


Figure 3. Distribution of scheduled time of injections

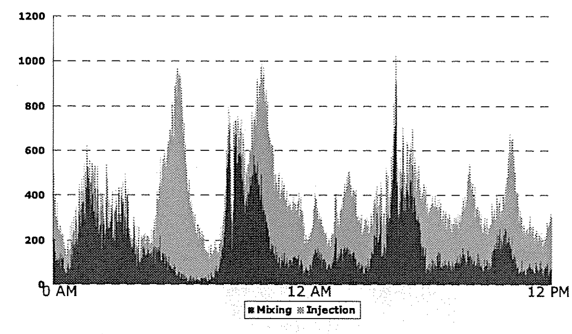
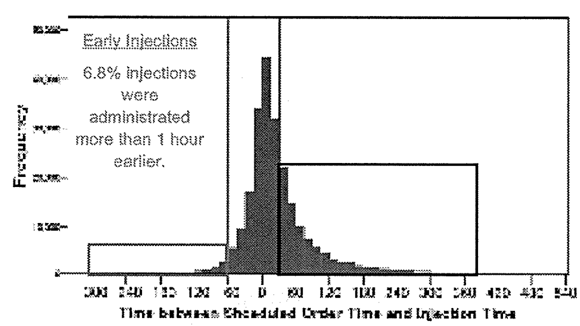


Figure 4. Distribution of difference between scheduled time and actual time of injections



As described above, nurses adjusted to high frequency of scheduled order by injecting earlier or later. Figure 4 shows Distribution of time difference between scheduled order time and injection time. Time between scheduled order time and injection were calculated by the formula and a minute unit.

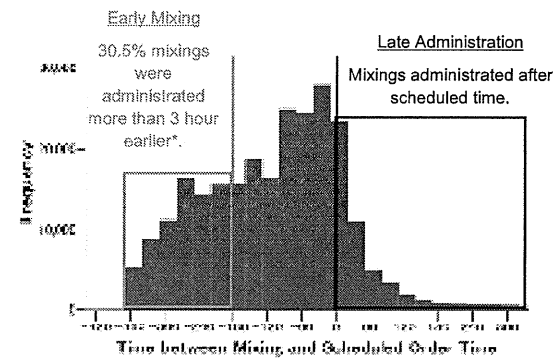
(Time between scheduled order time and injection) = (Scheduled Order Time) – (Injection Time)

Positive numbers shows early administration of injections, negative number shows lately administration of injections and 0 means right on time. It might be regarded as positive to close to 0 from the point of view of right time administration. Mean of the time is 10.63 minutes. The most frequent category is from 0 to -15 and the second most frequent category is from 15 to 0. Most of injections are around 0. 6.8 % of injections were regarded as early administration that was defined by one hour early administration[33].

Figure 5 shows time between mixing and scheduled order time. Time between mixing and scheduled order time was calculated by the formula and a minute unit.

(Time between mixing and scheduled order time)= (Mixing time) – (Scheduled Order time)

Figure 5. Distribution of difference between drug mixings and injections



For example, 180 minutes means mixing before 3 hour. Mean of the time is 108.5 minutes. The highest frequency is from 0 to 30 minutes. According the guideline for safe medication in the hospital, drug mixing shouldn't be implemented 3 hours before injection. However, 30.5 % of injections were regarded as early mixing and this information hadn't informed by the nurses.

4 Discussion

We captured data by POAS that was designed by the concept of process analysis and management. This concept provided the system a structure to capture the data. According to the survey of system use, the system covered more than 99.9% mixing drugs and injections. Process management prohibits workers from skipping each activity on the process and that contribute to ensure the correctness of medical activities through the process.

Secondly these process data suggests the importance of process indicator related to outcome indicators. Outcome data and process indicator have been used as measurement indicators of performance. The advantage of outcome indicators is that it explain the achievements of targets itself. Outcome measurement will reflect all aspect of the processes of care and not simply those that are measurable or not [24-28]. However, as Mant said, difference in outcome might sometimes be due to case mix, how the data were collected, chance, quality of care or other factors such as nutrition, life style. Outcome indicators can be improved if efforts are made to standardize data collection and case mix adjustment systems are developed and validated [7]. Process data can be redeeming indicators to understand meanings of outcome indicators. Process data is providing context information to understand the setting for the case [29-36].

This is the example of research linking process data to some outcome indicators. In this example, we set wasted rate of drugs. If physicians change their order after nurse's mixing drugs, these drugs must be wasted. It is of course necessary to inject right drugs based on up data decisions of physicians, but drug wasting would cause inefficacy of hospital management.

Figure 6. Time difference between drug mixings and injections and drug wasted rate

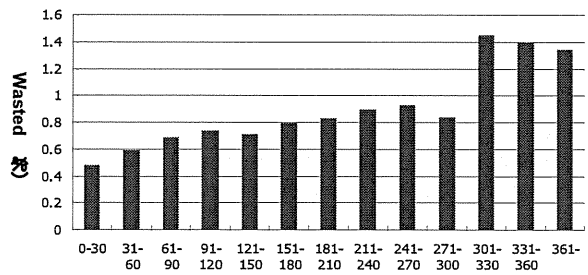
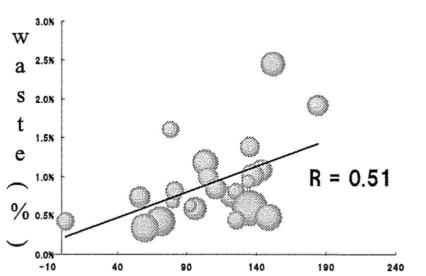


Figure 6 shows the result of analysis that beforehand mixings for laborsaving whose intervals are relatively longer have tend to be wasted by order changes. Analysis on data in unit of wards also shows wards whose intervals between mixing and injection are longer tend to waste more.

Just measuring drug wasted rate is not enough to analyze the cause of high drug wasted rate. By linking process information to outcome information and capturing process routinely, the data make us possible to investigate the reason of some outcomes.

Figure 7. Relationship between intervals and drug wasted rate



5 Conclusion

In this study, we show clearly that data captured by hospital information system provide us new research opportunities to improve quality of care and productivities. Many hospitals have been introducing hospital information system to improve operational efficiency. Secondly use of data captured by HIS hasn't become widely yet, though it has a possibility to improve quality and safety of care as well as productivity. The important thing to spread utilization of bust amount of data is providing evidences that secondly use of data can improve them.

Concern on performance measurement has been increasing rapidly and many organization including government and hospital associations and researches have been trying to set indictors for performance measurement [2]. As discussion of process and outcome indicators, both indicators have useful meanings for patients to chose hospitals and acquire healthcare information. This study will help to understand the benefits of process data and contribute to measure quality of care and improve hospital management on health care quality and safety.

References

1. Institute of Medicine. To error is human. National Academies Press, Washington, DC; 1999.
2. Institute of Medicine: Crossing the quality chasm: A New Health System for the 21st Century. National Academies Press, Washington, DC; 2001.
3. Jinnet Briggs Fowles, Elizabeth A. Kind, Shadi Awwad, Jonathan P. Weiner and Kitty S. Chan. Performance Measures Using Electronic Health Records: Five Case Studies. The Commonwealth Fund, 2008.
4. David. Baker, Stephen Persell, Jason Thompson, Neilesh Soman, Karen Bugner, David Liss, Karen Kmetik. Automated Review of Electorical Health Records to Assess Quality of Care for Outpatients with Heart Failure. Annal of Internal Medicine. Feb. 2007.
5. M Weiner, T E Stump, C M Callahan, J N Lewis and C J McDonald. Pursing integration of performance measures into electronic medical records: beta-adrenergic receptor antagonist medications. Qual. Saf. Health Care 2005; 14; 99-106.
6. David W. Bates, Elizabeth Pappius, Gilad J. Kuperman, Dean Sittig, Helen Burstin, David Fairchild, Troyen A. Brennan, Jonathan M. Teich. Using information systems to measure and improve quality. International Journal of Medical Informatics 1999; 53: 115- 124.
7. Davies HT, Marshall MN. Public disclosure of performance data. Lancet. 1999;353:1639-1640.
8. Epstein A. Rolling down the runway: the challenges ahead for quality report cards. JAMA. 1998; 279:1691-1696.
9. Kassirer JP. The use and abuse of practice profiles. N Engl J Med. 1994;330:634-635.
10. Lansky D. Overview: performance measures. Comm J Qual Improv. 1996;22:439-442.
11. Ådahl, Kerstin (2006) Validation of Transparency in e-Health – Turning Information Visible Through Design. The IRIS29 Conference 2006. Keynote paper.
12. Nelson R & Ball M J. Consumer Informatics – Applications and Strategies in Cyber Health Care Springer-Verlag New York, Inc. 2004.
13. Rindebäck C. & Gustavsson R. (2005) Why Trust is Hard – Challenges in e-Mediated Services LNAI, Springer Verlag
14. Smith R. Transparency: a modern essential. BMJ. 2004;328.7448.0-f
15. Sylvan Lee Weinberg. Transparency in Medicine: Fact, Fiction, or Mission Impossible?
16. Jonathan Mant "Process versus outcome indicators in the assessment of quality of health care" International Journal of Quality in Health care 2001, 13:6. 475-480.
17. Marshall MN, Shekelle PG, Leatherman S, Brook RH. The Publication of Performance Data in Health Care. London, England: Nuffield Trust. 2000.
18. Becker, J., Kugeler, M., Rosemann, M. (eds.): Process Management: A Guide for the Design of Business Processes, 2nd edn. Springer, Berlin. 2007
19. Masanori Akiyama, Tatsuya Kondo. Risk Management and Measuring Productivity with POAS - Point of Act System. Medinfo 2007:208-212.

20.Masanori Akiyama. Migration of the Japanese Healthcare Enterprise from a Financial to Integrated Management: Strategy and Architecture. Medinfo 2001: 715-718
21.Masanori Akiyama. Risk Management and Measuring Productivity with POAS- Point of Act System. Methods inf Med 2007; 46; 686-693.
22.Akiyama M. A Medical Information System as ERP (Enterprise Resource Planning) for the Hospital Management Medinfo. 2004: 11: 1502.
23.C. Westphal and T. Blaxton. The process of discovery begins by getting an overall picture of the available data Data Mining Solutions – Methods and Tools for Solving Real-World Problems, John Wiley & Sons, New York, 1998.
24.Charles E. Noon, Charles T. Hankins. Spatial Data Visualization in Healthcare: Supporting a Facility Location Decision via GIS-based Market Analysis. Proceedings of the 34th Hawaii International Conference on System Sciences - 2001
25.E. Ammenwerth, F. Ehlers, R. Eichst¨adter, R. Haux, B. Kruppa, P. Parzer, et al., Analysis and modeling of the treatment process characterizing the cooperation within multiprofessional treatment teams, in: A. Hasman, B. Blobel, J.Dudeck, R. Engelbrecht, G. Gell, H.U. Prokosch (Eds.), Proceedings of the MIE 2000, IOS Press, Amsterdam, 2000, pp.57—61.
26.Archon Fung, Mary Graham, David Weil, and Elena Fagotto. Transparency Policies: Two Possible Futures. TAUBMAN CENTER POLICY BRIEFS May 2007
27.Harry McNaughton, PhD; Kathryn McPherson, PhD; William Taylor, FRACP; Mark Weatherall, FRACP. Relationship Between Process and Outcome in Stroke Care
28.Mant J, Hicks N. Detecting differences in quality of care: the sensitivity of measures of process and outcome in treating acute myocardial infarction. BMJ. 1995;311:793–796.
29.Mant J, Hicks NR, Fletcher J. Correcting outcome data for case mix in stroke medicine: study should have had more patients or longer time scale. BMJ.1996;313:1006
30.Davies HT, Lampel J. Trust in performance indicators. Qual Health Care. 1998;7:159-162.
31.Thomson R, Lally J. Clinical indicators. Qual Health Care. 1998;7:122.
32.Pascal Staccini, Michel Joubert, Jean-Francois Quaranta, Dominique Fieschi, Marius Fieschi. Modelling health care processes for eliciting user requirements: a way to link a quality paradigm and clinical information system design. International Journal of Medical Informatics 64 (2001) 129–142
33.Julie Sakowski; Thomas Leonard; Susan Colburn; Beverly Michaelsen; Timothy Schiro; James Schneider; Jeffrey M. Newman Using a Bar-Coded Medication Administration System to Prevent Medication Errors. American Journal of Health-System Pharmacy 2005;62(24):2619-2625
34.E. Ammenwerth, F. Ehlers, R. Eichst¨adter, R. Haux, B. Kruppa, P. Parzer, et al., Analysis and modeling of the treatment process characterizing the cooperation within multiprofessional treatment teams, in: A. Hasman, B. Blobel, J.Dudeck, R. Engelbrecht, G. Gell, H.U. Prokosch (Eds.), Proceedings of the MIE 2000, IOS Press, Amsterdam, 2000, pp.57-61.
35.Lenz, R., Reichert, M.: IT Support for Healthcare Processes. In: van der Aalst, W.M.P.,Benatallah, B., Casati, F., Curbera, F. (eds.) BPM 2005. LNCS, vol. 3649, pp. 354–363 Springer, Heidelberg (2005)
36.P.E. Plsek, Systematic design of healthcare processes, Qual. Health Care 6 (1997) 40—48.
37.P. Kueng, P. Kawalek, Goal-based business process models: creation and evaluation, Business Process Manage. J. 3 (1997) 17—38.
38P. Dadam, M. Reichert, Towards a new dimension in clinical information processing, Stud. Health Technol. Inform. 77 (2000) 295—301.