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1 **Time trend of injection drug errors before and after implementation of bar-code**  
2 **verification system**

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3

4 **Abstract (155 words)**

5 BACKGROUND: Bar-code technology, used for verification of patients and their  
6 medication, could prevent medication errors in clinical practice.

7 OBJECTIVE: Retrospective analysis of electronically stored medical error reports was  
8 conducted in a university hospital.

9 METHODS: The number of reported medication errors of injected drugs, including  
10 wrong drug administration and to the wrong patient, was compared before and after  
11 implementation of the bar-code verification system for inpatient care.

12 RESULTS: A total of 2867 error reports associated with injection drugs were extracted.  
13 Wrong patient errors decreased significantly after implementation of the bar-code  
14 verification system (17.4 /year vs. 4.5 /year,  $p < 0.05$ ), although wrong drug errors did  
15 not decrease sufficiently (24.2 /year vs. 20.3 /year). The source of medication errors due  
16 to wrong drugs was drug preparation in hospital wards.

17 CONCLUSION: Bar-code medication administration is effective for prevention of  
18 wrong patient errors. However, ordinary bar-code verification systems are limited in

1 their ability to prevent incorrect drug preparation in hospital wards.

2

3 **Key words:**

4 Bar-code technology; Error report; Injection drug; Medical safety; Wrong patient

## 1 **1. Introduction**

2 Administration of injected medications to inpatients is one of the primary tasks of  
3 nurses and doctors, and is potentially associated with medical errors involving wrong  
4 drugs, wrong patients and wrong doses. According to a previous report, the rate of  
5 wrong drug administration and wrong patients was around 15% in all  
6 medication/infusion events.[1]. Healthcare information technology (IT) can play an  
7 important role in the prevention of medical errors caused by human factors [2]. The  
8 bar-code is a classic technological tool for identifying and managing products in  
9 logistics and retailing. Recently, the bar-code has become a useful tool for patient  
10 management, especially in terms of medical safety, through the use of bar-code  
11 medication administration (BCMA) at hospitals. For example, bar-coded wristbands can  
12 substitute for Identifier (ID) cards in an inpatient setting. To enhance medical safety, the  
13 bar-code verification system was applied to electronic medication-administration  
14 systems, in an attempt to reduce medical errors, including dispensing errors and  
15 administration errors [3]. However, limitations of BCMA were pointed out [4] and other  
16 new technology, such as radio-frequency identification, has been introducing in some  
17 specific area[5]. Therefore, preparing an environment for appropriate use of bar-code  
18 verification system is important for effective BCMA implementation [6].

1 Medication administration errors have five domains (right patient, right drug, right  
2 time, right dose, and right route), and appropriate application of the bar-code  
3 verification system to each domain is still under consideration [7]. The number of  
4 medication errors in clinical practice is one indicator of whether a new method or  
5 technology effectively contributes to medical safety. In the 2003 fiscal year, an incident  
6 reporting system was initiated in the hospital. Bar-coded wristbands and a drug-patient  
7 bar-code matching system were introduced in the 2008 fiscal-year. The aim of this study  
8 was to evaluate the rate of medical errors associated with medication administration  
9 before and after implementation of the bar-code verification system, and to find efficacy  
10 and limitation of BCMA in clinical practice settings.

11

## 12 **2. Methods**

### 13 *2.1. Design and Data source*

14 Retrospective analysis of electronically stored incident reports at the Hokkaido  
15 University Hospital was performed. Incident is defined as any deviation from usual  
16 medical care that causes an injury to the patient or poses a risk of harm at Hokkaido  
17 University Hospital. Incidents are voluntarily reported by every hospital staffs through  
18 intranet via easy-access ordering terminal. When reporting, staffs must choose a

1 pre-registered type of error (drug, fall, tube trouble, unpreventable complication, etc.). If  
2 they choose drug error, then they must choose a pre-registered type of drug error (wrong  
3 drug or patient, wrong speed, wrong route, etc.). Each report is verified by staffs in the  
4 division of hospital safety management and amended if necessary, therefore consistency  
5 of incident reports are assured. Staffs in the division of medical information planning  
6 manage the database of incident reports. Incident reports included type of error, error  
7 level, date, and interpretation of the cause of the error. This study included reports  
8 submitted from April 2003 to March 2012, each fiscal-year being defined from April to  
9 March of a particular year (e.g., the 2003 fiscal year was from April 2003 to March  
10 2004). The bar-code verification system between patients and injection drugs for  
11 inpatient care was implemented in April 2008. This study was approved by the  
12 Institutional Review Board of Hokkaido University Hospital.

### 13 *2.2. Injection drugs operation and Bar-Code verification system*

14 Inpatients at the hospital wear a bar-coded wristband during the hospital stay. Personal  
15 digital assistant (PDA) devices with bar-code readers are used for verification between  
16 bar-coded wristbands and order-printed labels with bar-codes on the drugs to be injected.  
17 Three different ways of injection drug preparation and administration pathway at  
18 pharmacy and hospital ward were performed at our hospital (Fig. 1). Total parenteral

1 nutrition drugs and anti-cancer drugs are premixed and packaged together in a common  
2 container in the hospital pharmacy, for transport to the hospital wards, if the orders are  
3 received one or more days before drug administration. These packages have a bar-coded  
4 label with drug and patient information (left flow in Fig. 1). Injection drugs other than  
5 total parenteral nutrition and anti-cancer drugs are transported to hospital wards without  
6 mixing, bar-coded labels being simultaneously transported, although unattached to the  
7 drugs. In the hospital wards, nurses mix the drugs and attach the bar-coded labels to the  
8 drugs, if the orders have been created one or more days before administration (center  
9 flow in Fig. 1). In the hospital pharmacy, pharmacists use a bar-code reader for  
10 verifying between an order-printed label and bar-codes on drug labels attached by  
11 pharmaceutical companies. Injection drugs ordered on the administration day are  
12 prepared from hospital ward storage and mixed in hospital wards by the ward staff.  
13 Bar-coded labels with drugs and patient information are printed in the ward and stuck to  
14 the drug bottles or put beside the drugs when vials or ampoules are too small. Verifying  
15 between a bar-coded label printed at the hospital and bar-codes on drug labels attached  
16 by pharmaceutical companies was not performed in hospital wards because of  
17 performance of PDA and workloads of nurses (right flow in Fig. 1). In these latter two  
18 ways, preparation and mixing of injection drugs are performed under a double check



1 process (two staff verification).

## 2 2.3. Analysis

3 The effect of implementation of the BCMA was evaluated by comparing the rate of  
4 annual error reports in each category of injection drugs before (2003 FY – 2007 FY) and  
5 after (2008 FY- 2011 FY) implementation of the BCMA. Efficacy of the BCMA for  
6 minimizing wrong patient errors was evaluated by the number of error reports per year  
7 using the Mann-Whitney U test. Statistical significance was defined as a two-tailed p  
8 value of <0.05 for all analyses. All statistical analysis was conducted by STATA version  
9 12.0 (STATA Corporation, College Station, TX, USA).

10

## 11 3. Results

12 A total of 2867 (Before BCMA: 1550, After BCMA: 1317) error reports associated  
13 with injection drugs were extracted from the incident reporting system. Time trends of  
14 the number of total incident reports, reports of injection drugs error, and inpatients  
15 showed an increased trend of total errors per patient, but injection drug errors were  
16 unchanged (Fig. 2). The percentage of errors of wrong patient and wrong drug to all  
17 error reports associated with drug injection were 13% (208/1550) before the BCMA  
18 (2003FY-2007FY) and 8% (99/1317) after the BCMA (2008FY-2011FY), respectively.

1 The changes in numbers of errors associated with injection drugs before and after  
2 implementation of the BCMA are shown in Table 1. The mean of wrong patient/drug  
3 errors per year (41.6/year) was reduced by 40% after the implementation of the BCMA  
4 (24.8/year). Time trends of errors with wrong patient and wrong drug were shown in Fig  
5 3-A/B. Wrong patient errors decreased significantly after implementation of the BCMA  
6 (17.4 /year vs. 4.5 /year,  $p<0.05$ ), although wrong drug errors did not decrease (24.2  
7 /year vs. 20.3 /year,  $p=0.33$ ) significantly. The demographics of wrong drug errors are  
8 shown in Table 2. Wrong drug errors were mainly caused by drug preparation in  
9 hospital wards. Typical case of wrong drug preparation was due to similar drug name,  
10 such as Veen D®/Veen F® or Amigrand®/Aminofluid®, during hospital ward  
11 preparation (Fig. 1). A typical case of bedside error occurs in the following situation: a  
12 nurse takes two or more injection drugs for a couple of patients to a multi patient room  
13 and performs bar-code verification at bedside all in one piece. When injection, a wrong  
14 drug is picked up and administered.

15

#### 16 **4. Discussion**

17 This study confirmed the effect of the bar-code verification system in reduction of the  
18 rate of errors associated with injection drug administration, and found injection drugs

1 prepared in hospital wards to be an unresolved source of errors, at least within the  
2 BCMA system.

3 Medication administration errors are fundamental problems of medical safety [8]. As  
4 evaluated using a hospital information system, bar-code technology is becoming a  
5 primary tool for the prevention of medical errors. Medication administration errors can  
6 be reduced by implementation of the BCMA [9]. The bar-code verification system has  
7 been shown to increase the safety of blood transfusion in terms of wrong patient  
8 administration errors [10]. However, since infusion drug administration is potentially  
9 associated with several types of errors, including wrong site, wrong procedure, wrong  
10 drug, and wrong patient [11], BCMA can reduce the administration errors but cannot  
11 eliminate them [3]. Moreover, errors due to wrong time of drug administration are a  
12 limitation of conventional bar-code technology [12]. However, modified application of  
13 bar-code technology can reduce the wrong time errors of drug administration in a  
14 certain circumstance [13]. This suggests that bar-code technology should be adapted for  
15 each hospital or department with regard to workflows and workloads [14]. As also  
16 shown in previous studies [7, 15], our study confirmed the fact that bar-code technology  
17 reduces injection drug administration errors, although drug preparation in hospital  
18 wards remains unresolved source of errors, especially preparation using hospital ward

1 storage (Fig. 1). This risk in hospital ward was classified in dispensing errors and  
2 similar names, packaging or labeling of drugs cause of it [16]. In addition to verification  
3 between bar-coded wristbands and order-printed labels, using bar-codes on drug labels  
4 attached by pharmaceutical companies may reduce the drug preparation errors in  
5 hospital wards.

6 Medication errors occur at several stages from prescription to administration, therefore  
7 strategy using IT to prevent medication errors is not only BCMA but computerized  
8 physician order entry, automated transcription, automated dispensing machines, or  
9 intravenous medication safety systems [17]. There have been many reports about IT to  
10 prevent medication errors, however, optimization of administration technologies for  
11 drug delivery system is still under discussion and requiring more theoretically driven  
12 researches [18]. On the other hand, IT systems can adversely affect clinical care by  
13 generating more work or new work for clinicians and nurses, causing workflow  
14 problems, or even generating new kinds of errors [19, 20]. Further, no matter how  
15 excellent a system is, a certain type of error due to inappropriate use of PDA is  
16 unpreventable without optimized application of the system in clinical practice. As future  
17 perspectives of technologies for medical safety, integration of technologies and standard  
18 procedures of clinical practice is important for application of technologies.

1

## 2 **5. Limitations**

3 A limitation of this study is that the data were taken retrospectively from stored  
4 incident reports. The presence of unreported errors in the incident reporting system has  
5 been pointed out as an important and unavoidable problem of the study [1, 21, 22]. On  
6 the other hand, comprehensive log archiving of bar-code verification system can be a  
7 complementary data source for error reports. This problem should be considered in  
8 future studies using error reports. Lack of qualitative evaluation regarding the  
9 preparation of injection drugs in hospital wards is another limitation of this study. Some  
10 studies using ethnographic methods described negative side effects and non-compliance  
11 of nurses for BCMA [23, 24]. These points of view are important to find the best  
12 practice for the preparation of injection drugs in hospital wards.

13

## 14 **6. Conclusion**

15 In conclusion, the bar-code verification system is effective for prevention of the wrong  
16 patient error during injection drug administration. However, drug preparation in hospital  
17 wards is an unresolved source of administration errors of injected drugs.

18

1 **Acknowledgement**

2 We thank Kaori Shibuya and Yoshiko Okuhara for their cooperation in this study.

3

4

## 1   **References**

- 2   1.       Milch CE, Salem DN, Pauker SG, Lundquist TG, Kumar S, Chen J. Voluntary  
3   electronic reporting of medical errors and adverse events. An analysis of 92,547 reports  
4   from 26 acute care hospitals. *J Gen Intern Med.* 2006; 21(2): 165-170.
- 5   2.       Bates DW, Gawande AA. Improving safety with information technology. *N Engl*  
6   *J Med.* 2003; 348(25): 2526-2534.
- 7   3.       Poon EG, Keohane CA, Yoon CS, Ditmore M, Bane A, Levtzion-Korach O, et al.  
8   Effect of bar-code technology on the safety of medication administration. *N Engl J Med.*  
9   2010; 362(18): 1698-1707.
- 10  4.       Henneman PL, Marquard JL, Fisher DL, Bleil J, Walsh B, Henneman JP, et al.  
11  Bar-code verification: reducing but not eliminating medication errors. *J Nurs Adm.* 2012;  
12  42(12): 562-566.
- 13  5.       Hohberger C, Davis R, Briggs L, Gutierrez A, Veeramani D. Applying  
14  radio-frequency identification (RFID) technology in transfusion medicine. *Biologicals.*  
15  2012; 40(3): 209-213.
- 16  6.       Early C, Riha C, Martin J, Lowdon KW, Harvey EM. Scanning for safety: an  
17  integrated approach to improved bar-code medication administration. *Comput Inform*  
18  *Nurs.* 2011; 29(3): 157-164, quiz 165-156.
- 19  7.       Young J, Slobodnik M, Sands L. Bar code technology and medication  
20  administration error. *J Patient Saf.* 2010; 6(2): 115-120.
- 21  8.       Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, et al.  
22  Incidence of adverse events and negligence in hospitalized patients. Results of the  
23  Harvard Medical Practice Study I. *N Engl J Med.* 1991; 324(6): 370-376.
- 24  9.       Paoletti RD, Suess TM, Lesko MG, Feroli AA, Kennel JA, Mahler JM, et al.  
25  Using bar-code technology and medication observation methodology for safer  
26  medication administration. *Am J Health Syst Pharm.* 2007; 64(5): 536-543.
- 27  10.      Sandler SG, Langeberg A, Dohnalek L. Bar code technology improves positive  
28  patient identification and transfusion safety. *Dev Biol (Basel).* 2005; 120(19-24).
- 29  11.      Seiden SC, Barach P. Wrong-side/wrong-site, wrong-procedure, and  
30  wrong-patient adverse events: Are they preventable? *Arch Surg.* 2006; 141(9): 931-939.
- 31  12.      Helmons PJ, Wargel LN, Daniels CE. Effect of bar-code-assisted medication  
32  administration on medication administration errors and accuracy in multiple patient care  
33  areas. *Am J Health Syst Pharm.* 2009; 66(13): 1202-1210.
- 34  13.      DeYoung JL, Vanderkooi ME, Barletta JF. Effect of bar-code-assisted  
35  medication administration on medication error rates in an adult medical intensive care

- 1 unit. *Am J Health Syst Pharm.* 2009; 66(12): 1110-1115.
- 2 14. Glover N. Challenges implementing bar-coded medication administration in the  
3 emergency room in comparison to medical surgical units. *Comput Inform Nurs.* 2013;  
4 31(3): 133-141.
- 5 15. Hassink JJ, Essenberg MD, Roukema JA, van den Bemt PM. Effect of  
6 bar-code-assisted medication administration on medication administration errors. *Am J*  
7 *Health Syst Pharm.* 2013; 70(7): 572-573.
- 8 16. Escobar-Rodriguez T, Monge-Lozano P, Romero-Alonso MM, Bolivar-Raya  
9 MA. Deploying information technology and continuous control monitoring systems in  
10 hospitals to prevent medication errors. *The HIM journal.* 2012; 41(1): 17-25.
- 11 17. Agrawal A. Medication errors: prevention using information technology systems.  
12 *British journal of clinical pharmacology.* 2009; 67(6): 681-686.
- 13 18. Wulff K, Cummings GG, Marck P, Yurtseven O. Medication administration  
14 technologies and patient safety: a mixed-method systematic review. *Journal of advanced*  
15 *nursing.* 2011; 67(10): 2080-2095.
- 16 19. Ash JS, Berg M, Coiera E. Some unintended consequences of information  
17 technology in health care: the nature of patient care information system-related errors. *J*  
18 *Am Med Inform Assoc.* 2004; 11(2): 104-112.
- 19 20. Samaranayake NR, Cheung ST, Chui WC, Cheung BM. Technology-related  
20 medication errors in a tertiary hospital: a 5-year analysis of reported medication incidents.  
21 *International journal of medical informatics.* 2012; 81(12): 828-833.
- 22 21. Blais R, Bruno D, Bartlett G, Tamblyn R. Can We Use Incident Reports to Detect  
23 Hospital Adverse Events? *Journal of Patient Safety.* 2008; 4(1): 9-12.
- 24 22. Stanhope N, Crowley-Murphy M, Vincent C, O'Connor AM, Taylor-Adams SE.  
25 An evaluation of adverse incident reporting. *J Eval Clin Pract.* 1999; 5(1): 5-12.
- 26 23. Patterson ES, Cook RI, Render ML. Improving patient safety by identifying side  
27 effects from introducing bar coding in medication administration. *J Am Med Inform*  
28 *Assoc.* 2002; 9(5): 540-553.
- 29 24. Patterson ES, Rogers ML, Chapman RJ, Render ML. Compliance with intended  
30 use of Bar Code Medication Administration in acute and long-term care: an observational  
31 study. *Hum Factors.* 2006; 48(1): 15-22.

32

33



1 **Tables**

2 Table 1. Mean error reports before and after implementation of the bar-code verification

3 system

	<b>Before bar-code (/year) (2003 FY–2007 FY)</b>	<b>After bar-code (/year) (2008 FY–2011 FY)</b>	<b>Ratio (After/Before)</b>
Wrong dose	50.0	89.8	180%
Wrong speed	76.0	53.5	70%
Skipped administration	46.4	48.8	105%
Wrong patient or drug	41.6	24.8	60%
Wrong preparation	39.6	32.5	82%
Wrong time	11.6	15.0	129%
Wrong route	10.0	13.3	133%
Other	34.8	51.8	149%

4

5

1 Table 2. Demographics of wrong drug errors

<b>Error type</b>	<b>Implementation of bar-code verification system</b>	
	<b>Before</b>	<b>After</b>
Wrong drug preparation in hospital wards	79	54
Wrong drug injection at bedside*	11	10
Time lag error <sup>†</sup>	7	3
Unclassified	24	14

2 \* Such as mistake target patient injection drugs with another patient injection drugs due  
3 to inappropriate use of PDA or inappropriate drug handling

4 <sup>†</sup> Caused by time lag between drug change order and order change transmission

1 **Figure captions**

2 Fig. 1

3 Three different ways of injection drug preparation and administration pathway at  
4 pharmacy and hospital ward were performed at Hokkaido University Hospital.  
5 Dispensing and preparation errors at hospital ward were only caused at hospital ward  
6 preparation pathway. Administration errors caused by inappropriate PDA use were  
7 caused in every pathway.

8

9 Fig. 2.

10 Cumulative time trend of the total number of inpatients and number of error reports. The  
11 number of total error reports increased gradually compared to the number of inpatients.

12

13 Fig. 3.

14 Fig. 3-A.

15 Time trend of wrong patient error showed a significant reduction (17.4 /year vs. 4.5 /year,  
16  $p < 0.05$ ) in the incidence of such errors after bar-code implementation.

17 Fig. 3-B.

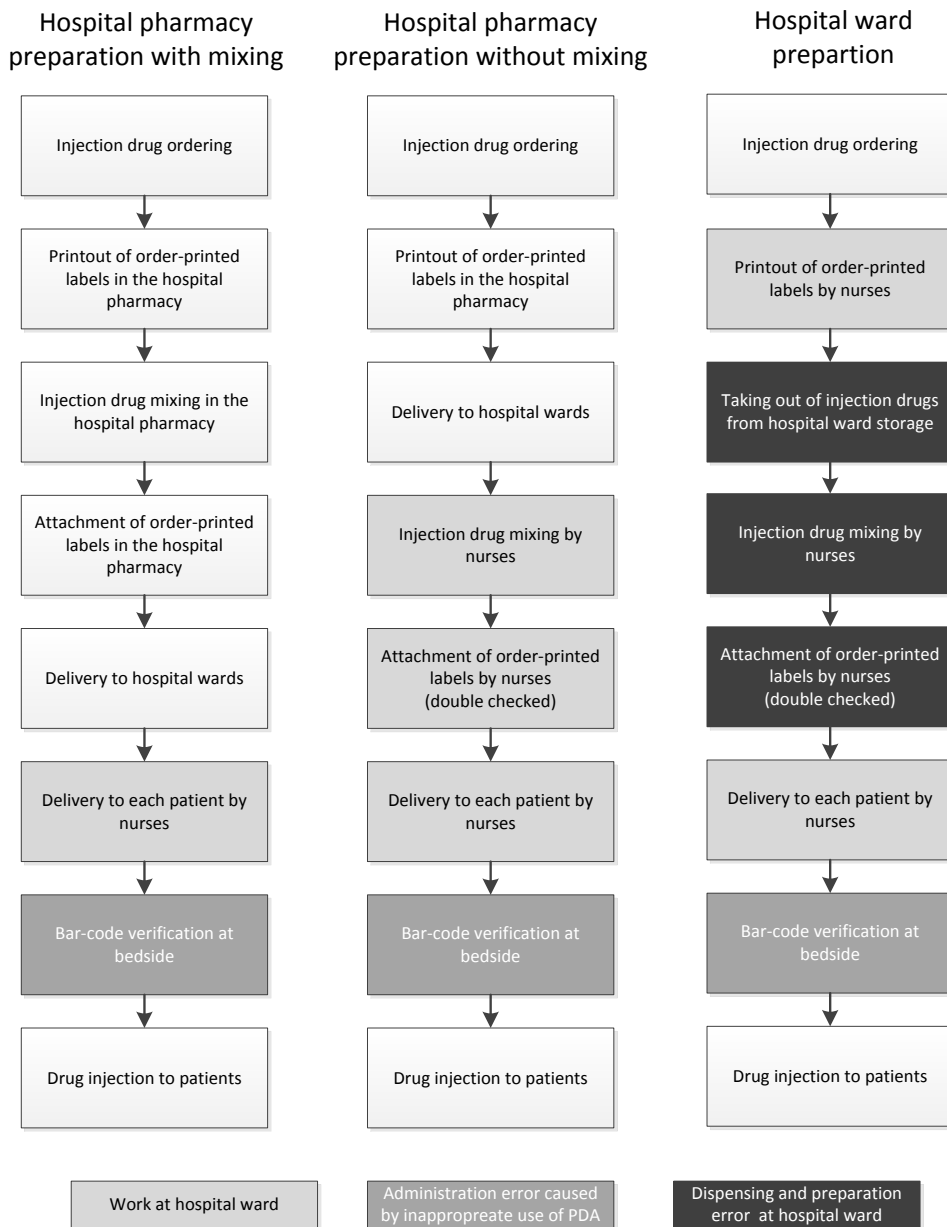
18 There was no significant reduction (24.2 /year vs. 20.3 /year,  $p = 0.33$ ) in the time trend of

1 wrong drug error after bar-code implementation.

2

1 **Figures**

2 Fig. 1.

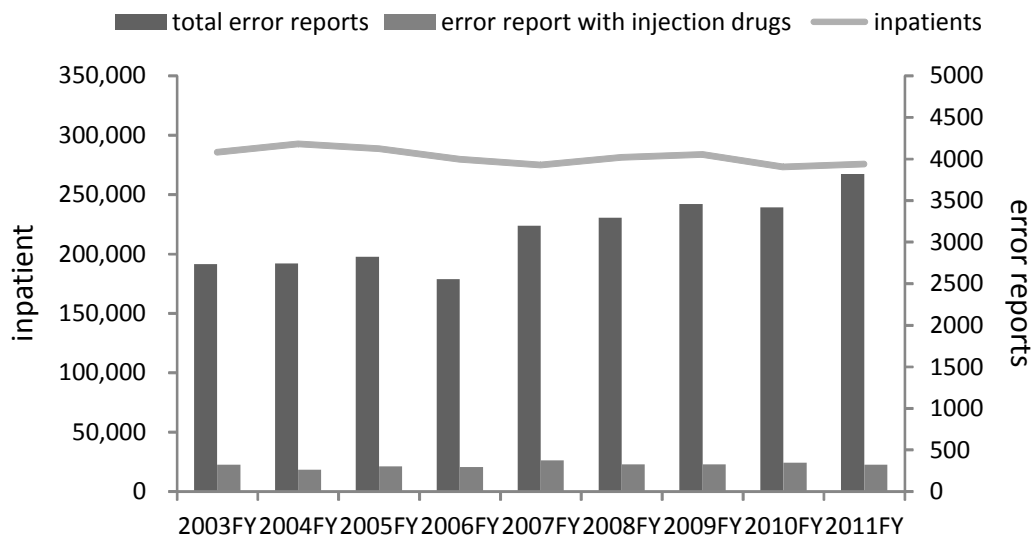


3

4

5

1 Fig. 2.

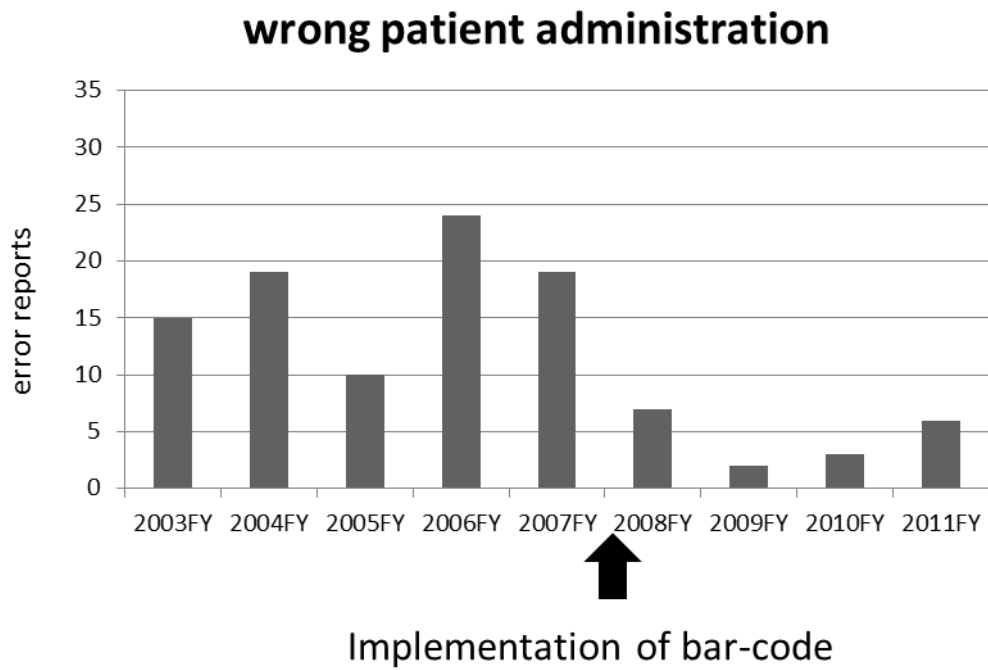


2  
3

1

2 Fig. 3.

3 Fig. 3-A.



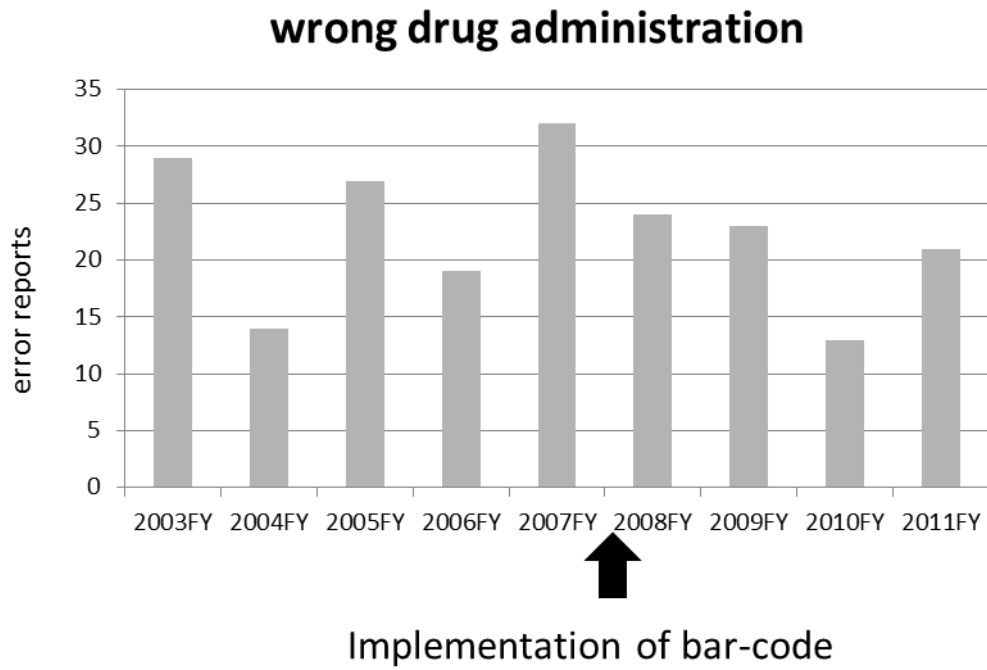
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1

2 Fig. 3-B.



3