# Impact of a Barcode Medication Administration System on Patient Safety

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**OBJECTIVES:** To determine the impact of barcode medication administration (BCMA) on the incidence of medication administration errors among patients in an onco-hematology day hospital and to identify the characteristics of medication errors in that setting.

**SAMPLE & SETTING:** 715 patients treated in the onco-hematology day unit at the Príncipe de Asturias University Hospital in Madrid, Spain.

**METHODS & VARIABLES:** A between-groups, pre-/postintervention study was conducted. Administration errors observed in patients with solid tumors (intervention group) were compared with those in patients with hematologic cancer (control group) before and after the introduction of BCMA. Error incidence, type, and severity were assessed, as was length of stay for treatment.

**RESULTS:** Use of a BCMA system reduced the incidence and severity of errors in medication administration in the onco-hematology day hospital.

**IMPLICATIONS FOR NURSING:** BCMA is a useful technology to check the five rights of medication administration in the onco-hematology day hospital and could help nurses increase the time spent on direct patient care activities.

**KEYWORDS** outpatient care; medication errors; barcode medication administration

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The process of medication administration is the last stage during which a barrier can be erected to prevent an error from reaching the patient. The study and implementation of strategies for error prevention are considered to be priorities by health organizations. Studies of medication administration errors (MAEs) report an incidence of about 7%–20%, and 8% when wrong-time errors, or errors related to the medication administration schedule, are excluded (Berdot et al., 2012; Keers, Williams, Cooke, & Ashcroft, 2013).

The type of medication is important when evaluating the characteristics of errors; health strategies and policies are focused on medications defined as high risk (Saedder, Brock, Nielsen, Bonnerup, & Lisby, 2014). Antineoplastic agents are considered to be high-risk medications because of their narrow therapeutic range and high toxicity (ASHP Council on Professional Affairs, 2002). In a study analyzing the causes of death because of medication errors, antineoplastic medications were found to be the most common agents involved (McCarthy, Tuiskula, Driscoll, & Davis, 2017). The incidence of MAEs in chemotherapy administration ranges from 0.04% (Ford, Killebrew, Fugitt, Jacobsen, & Prystas, 2006) to 18.8% (Walsh et al., 2009). The incidence of MAEs in the outpatient setting range from 0.68% (León Villar, Aranda García, Tobaruela Soto, & Iranzo Fernández, 2008) to 7.1% (Walsh et al., 2009) in the adult population. The outpatient oncology setting is considered to be a priority when reinforcing patient safety (Goldspiel, DeChristoforo, & Hoffman, 2015; León Villar et al., 2008).

Barcode medication administration (BCMA) is recommended for the prevention of MAEs (Lefkowitz, Cheiken, & Barnhart, 1991; Neuenschwander et al., 2003) because it allows nurses to verify the five rights of medication administration (i.e., patient, drug, time, route, and dose). Observational studies on BCMA technology reported a decrease in the incidence of MAEs,

ranging from 23% (Helmons, Wargel, & Daniels, 2009) to 56% (DeYoung, Vanderkooi, & Barletta, 2009). When wrong-time errors were excluded, the percentage of errors ranged from 41% (Poon et al., 2010) to 81% (Bonkowski et al., 2013). Little evidence exists regarding the impact of this intervention on the severity of errors (Hassink, Jansen, & Helmons, 2012). An important aspect to consider is the effect that BCMA devices have on the time nurses need to administer medication; to date, no study has observed any variations in time (Franklin, O'Grady, Donyai, Jacklin, & Barber, 2007; Tsai, Sun, & Taur, 2010).

In addition, little evidence exists related to the frequency and type of MAEs in oncology, particularly in the outpatient setting (Strudwick et al., 2017); assessment of the use of information and communication technology in this area to improve patient safety is also limited. In the case of BCMA systems, the advantages achieved in other populations and clinical units have been applied to the oncology setting (Bubalo et al., 2014). The diversity of criteria used to define medication errors and error types, the disparity of the methods used to detect them, and the variety of settings justify the need for this study (Hassink et al.,

**TABLE 1. Types of Medication Administration Errors in the Onco-Hematology Day Hospital**

| New Classification | Observations and Changes Made |
|---|---|
| Wrong medication: Dispensation/administration of a medication different than the prescribed | The subcategory "wrong prescription" was not included. No definition of transcription is provided. |
| Omission of a dose or medication: Not administering a prescribed dose (patients refusing medication were excluded) | The current authors only considered medication or dose omissions. |
| Wrong dose (higher, lower, extra) | No observations |
| Wrong date | The current authors renamed the category "wrong time of administration" to "wrong date." |
| Wrong pharmacy dose | No observations |
| Wrong preparation/handling/packaging/labeling | No observations |
| Wrong administration technique | No observations |
| Wrong route | No observations |
| Wrong infusion rate | No changes were made in this category. The infusion rate was checked for each drug with the drug sheet and the hospital's protocols. The current authors considered a rate of 20% plus or minus of the advised infusion rate to be correct. |
| Wrong patient | No observations |
| Insufficient drug monitoring: Absence of clinical review | The "absence of analytical controls" subcategory was excluded. |
| Deteriorated medication (including expired drug, incorrect preservation) | No observations |
| Wrong order of administration of antineoplastic treatment | New category proposed by the current study's research group |
| Other types (not included in the rest of the categories) | No observations |

**Note.** The Ruiz-Jarabo 2000 work group classifies 18 types of error. The categories "wrong storage," "wrong length of administration," "not applicable," and "patients' noncompliance" were not considered. The rest of the categories were included.
**Note.** Based on information from Grupo Ruiz-Jarabo 2000 (2008).

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2012). The aim of this study was to assess the impact of BCMA on the incidence of MAEs, types of errors, patient risk, and time spent administering medication to onco-hematology patients in the day hospital.

## Methods

An MAE (Keers et al., 2013) was defined as nonconcordance between the medication administration performed and any of the following options: doctor's prescription, official administration instructions according to the protocol of the center, or the administration instructions from the manufacturer. Also taken into account were nonconcordance errors between the doctor's prescription and the dispensation or transcription of the medication by the pharmacy department.

In this study, the current authors used the adapted version of the classification of type of medication errors as defined by the Ruiz-Jarabo 2000 work group (Grupo Ruiz-Jarabo 2000, 2008) (see Table 1). Of the 14 types of error proposed, 7 could be influenced by the BCMA system: wrong medication, dose or medication omission, incorrect dose, wrong date of treatment, wrong route of administration, wrong patient, and wrong order of medication administration. The potential severity of each error was assessed on a scale from 1 (no severity) to 5 (catastrophic). The degree of severity resulting from the errors was assessed according to the index of the National Coordinating Council for Medication Error Reporting and Prevention. The length of stay for treatment was also measured.

### Setting and Sample

A pre-/postintervention study was conducted in the onco-hematology day unit of the Príncipe de Asturias University Hospital from January 2011 to May 2012. Twenty patients were admitted to the day hospital. BCMA and computerized physician order entry (CPOE) were implemented for the intervention group, made up of patients with solid tumors.

MAEs observed in patients with solid tumors (intervention group, N = 627) were compared with those observed in patients with hematologic cancer (control group, N = 88). About 30,000 medication administrations are performed annually in this ward. Sixty-three patients were excluded from the study for various reasons: (a) adverse drug reaction leading to the interruption of therapy administration (intervention, n = 7; control, n = 1); (b) incomplete observer records of the drug's administration because of lack of time (intervention, n = 17; control, n = 8); and (c) technical issues during BCMA implementation in the intervention group (n = 30).

Training was given to an interprofessional team of professionals from the quality, pharmacy, information, and technology departments, as well as from the biomedical research foundation and the day unit. Nurses received two training sessions on the management of the BCMA system, which was then implemented in phases. Systematic assessment of the implementation was performed throughout the process.

This study was approved by the Príncipe de Asturias University Hospital's ethics committee in clinical research. Informed consent was obtained from the nurses who were involved in the study because of their medication preparation and administration duties. Patients were assigned correlative numbers, and the anonymized patient data were included in a database.

### Data Collection Procedure

The observation technique described by Barker, Flynn, and Pepper (2002) and by Dean and Barber (2001) was used to detect MAEs. To avoid nurses modifying their actions because they were being observed during the BCMA process, they were told that the observer was there to monitor the performance of the medication distribution system. Observations were carried out during the Monday to Friday nursing shift (from 8 am to 7:30 pm) starting one month before the introduction of the BCMA system and ending one month afterward. According to the power analysis conducted, a sample size of 1,994 observations (997 in the preimplementation period and 997 in the postimplementation period) would be required to detect a difference in the MAE rate of 4.2% with 80% power and 95% confidence interval (CI). The preintervention phase was conducted 10 months before implementation of the BCMA system, and postintervention observations took place 6 months after BCMA implementation.

Study observers were selected and trained during a workshop; the group of observers consisted of four pharmacy students, six pharmacists, and one nurse. To prepare for the observation, the observers studied the standard operating procedures and the applicable drug administration procedures of the setting. Observers were trained to detect and classify errors. For this reason, a written observational protocol was established. Each observer carried out pilot observations that were supervised by one of the researchers for one week to become familiar with the BCMA system. Pilot observations were discussed with the research

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team, and pilot data were discarded. In practice, the observer accompanied the nurse who administered the medication using the BCMA system and observed the administration of each dose of medication to the patient. The observer was instructed to record each of the nurse's actions while administering medication to patients. These observation records were then compared with the prescribed medication and with available medication protocols in the ward to identify MAEs. If the observer became aware of a potentially

**TABLE 2. Characteristics of Medication Administration Before and After Implementing the BCMA System**

| | Solid Tumor (Intervention) | | | | | | Hematology (Control) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before BCMA | | | After BCMA | | | Before BCMA | | | After BCMA | | |
| **Characteristic** | **n** | **N** | **%** | **n** | **N** | **%** | **n** | **N** | **%** | **n** | **N** | **%** |
| **Medication administration** | | | | | | | | | | | | |
| Total number of OEs | 1,281 | 2,912 | 44 | 1,272 | 2,912 | 44 | 141 | 2,912 | 5 | 218 | 2,912 | 7 |
| Supportive drug OEs | 842 | 2,912 | 29 | 767 | 2,912 | 26 | 89 | 2,912 | 3 | 139 | 2,912 | 5 |
| Antineoplastic OEs | 439 | 2,912 | 15 | 505 | 2,912 | 17 | 52 | 2,912 | 2 | 79 | 2,912 | 3 |
| **Medication prescription** | | | | | | | | | | | | |
| Manual | 199 | 304 | 65 | – | – | – | 40 | 40 | 100 | 48 | 48 | 100 |
| Electronic | 105 | 304 | 35 | 323 | 323 | 100 | – | – | – | – | – | – |
| **Number of OEs by route** | | | | | | | | | | | | |
| IV | 1,157 | 1,281 | 90 | 1,205 | 1,272 | 95 | – | – | – | – | – | – |
| IV minibag (< 100 ml) | 785 | 1,281 | 61 | 750 | 1,272 | 59 | – | – | – | – | – | – |
| IV large volume (> 100 ml) | 366 | 1,281 | 29 | 455 | 1,272 | 36 | – | – | – | – | – | – |
| IV bolus dose | 6 | 1,281 | 1 | – | – | – | – | – | – | – | – | – |
| Oral | 110 | 1,281 | 9 | 52 | 1,272 | 4 | – | – | – | – | – | – |
| Subcutaneous | 14 | 1,281 | 1 | 13 | 1,272 | 1 | – | – | – | – | – | – |
| Intrathecal | – | – | – | – | – | – | – | – | – | – | – | – |
| Intramuscular | – | – | – | 2 | 1,272 | < 1 | – | – | – | – | – | – |
| **Patients**[a] | | | | | | | | | | | | |
| Overall | 304 | 715 | 43 | 323 | 715 | 45 | 40 | 715 | 6 | 48 | 715 | 7 |
| Women | 167 | 304 | 55 | 196 | 323 | 61 | 23 | 40 | 58 | 24 | 48 | 50 |

| | Solid Tumor (Intervention) | | | | | | Hematology (Control) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before BCMA | | | After BCMA | | | Before BCMA | | | After BCMA | | |
| **Characteristic** | **n** | **N** | **%** | **n** | **N** | **%** | **n** | **N** | **%** | **n** | **N** | **%** |
| **Age (years)**[b] | | | | | | | | | | | | |
| Younger than 25 | – | 298 | – | – | 320 | – | 1 | 38 | 3 | 3 | 45 | 7 |
| 25–34 | 6 | 298 | 2 | 3 | 320 | < 1 | 1 | 38 | 3 | – | 45 | – |
| 35–44 | 23 | 298 | 8 | 52 | 320 | 16 | 1 | 38 | 3 | 1 | 45 | 2 |
| 45–54 | 66 | 298 | 22 | 51 | 320 | 16 | 8 | 38 | 21 | 3 | 45 | 7 |
| 55–64 | 109 | 298 | 37 | 93 | 320 | 29 | 9 | 38 | 24 | 18 | 45 | 40 |
| 65 or older | 94 | 298 | 32 | 121 | 320 | 38 | 18 | 38 | 47 | 20 | 45 | 44 |

[a] The median number of patients per day was 20.2 for the intervention group and 2.8 for the control group.
[b] For the intervention group, the median age was 59.16 years (SD = 10.61, range = 32–84) before BCMA and 59.51 years (SD = 12.52, range = 30–87) after BCMA. For the control group, the median age was 60.87 years (SD = 13.29, range = 19–79) before BCMA and 62.16 years (SD = 15.25, range = 18–87) after BCMA.
BCMA—barcode medication administration; OE—opportunity for error (the sum of observed administrations and omitted medications)
**Note.** Because of rounding, percentages may not total 100.

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serious error, the observer was instructed to intervene for ethical reasons. These data were included in the study if the serious error reached the patient.

Calibrated chronometers were used to measure patients' total length of stay in the onco-hematology day unit and the time to administer each medication. In both study periods, nursing staff included four nurses with similar working conditions (number of patients attended to and medications administered). These four nurses attended to the two patient study groups (intervention and control) in the same setting. A maximum of three nurses were present during each round of medication administration, and one nurse was present from 4–7:30 pm.

To assess the degree of severity resulting from errors, a panel of experts, which consisted of a doctor specializing in oncology, a pharmacist, and a nurse, was engaged. The actual degree of severity of the MAEs was assessed with data obtained from medical records. Information taken from the administration instructions of the manufacturer and from UpToDate were used to assess the potential severity of MAEs. When no evidence was available, the authors relied on the consensus criteria of the panel of experts.

### Data Analysis

Information from the observations of the medication administration process was entered into a computerized database by one person. Absolute and relative frequencies of the MAEs were calculated and compared to determine the number of errors observed before and after implementation of the BCMA system. The chi-square test or the Fisher's exact test (as appropriate), odds ratio (OR), and relative error reduction were used for this purpose. These analyses were performed in the intervention and control groups. When appropriate, 95% CIs were calculated for further accuracy. For the comparison of quantitative variables before and after the intervention, the paired Student's t test was used when the variable followed a normal distribution, whereas the Mann–Whitney U test or the Wilcoxon signed-rank test was used when it did not. In all cases, a p value of less than 0.05 was considered to be statistically significant. The power of the study reached 91%. Data analysis was performed using IBM SPSS Statistics, version 20.0; EpiData, version 4.1; and GraphPad Prism, version 7.0.

## Results

A total of 2,912 medication administrations were observed (including omissions) in 715 patients (627 in the intervention group and 88 in the control group). The number of observations of medication administrations in the intervention group was similar before and after the intervention (1,281 versus 1,272, respectively). The number of observations was smaller in the control group because of the reduced number of patients who attended per day (141 before the intervention versus 218 after the intervention). Patients received a large number of different medications, including antineoplastic agents, drugs for comorbid illness, and medications for supportive care and for complications related to antineoplastic therapy. These were all observed and included in the study. Medications have been separated into two main groups: antineoplastic agents and supportive drugs. In all study groups, supportive drugs stood out as the most frequently used medications compared to antineoplastic agents. Concerning the route of administration, most medications were administered via IV. Table 2 shows the overall characteristics of the medications observed and the characteristics of the patients to whom they were administered.

### Frequency and Type of Errors

The most relevant result from this study is that, when attention is paid exclusively to the type of errors that could be influenced by the intervention, the BCMA system reduced the incidence of these errors by 85% (see Table 3). Research shows that the most frequently reported antineoplastic MAE is wrong dose, followed by dose omission (Ford et al., 2006; Gandhi et al., 2005; León Villar et al., 2008; Rinke, Shore, Morlock, Hicks, & Miller, 2007; Serrano-Fabiá, Albert-Marí, Almenar-Cubells, & Jiménez-Torres, 2010). However, the most frequent error in the intervention group during both periods was the rate of infusion. Among other possible causes, the current authors observed that infusion pumps were not systematically used for either supportive drugs or photosensitive antineoplastic medications. This type of error, although not sensitive to the intervention, set off a series of actions for improvement in the current authors' hospital. Few studies have assessed this error (Dhamija, Kapoor, & Juneja, 2014; Franklin et al., 2007). The second most frequent error in this study was the order of administration; the current authors found one study that also reports this error as frequent (Ulas et al., 2015). The third most frequent error during both study periods in the current study was the wrong technique of administration; nearly all the errors of this type were associated with the administration of paclitaxel.

The incidence of MAEs during the study was 39% (number of MAEs out of number of opportunities for error; this refers to both study groups and all types of

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MAEs), and about 6% of medications accumulated more than one error. The incidence of MAEs sensitive to the BCMA system (or not able to be influenced by the BCMA system) in the intervention group was 16%. Following the intervention, a significant relative reduction of about 2% occurred. In the control group, a significant increase was noted in the incidence of MAEs, from 18% before the intervention to 39% after the intervention.

With the implementation of the BCMA system, the authors observed a significant relative reduction in the following types of error in the intervention group: wrong medication, administration omission, wrong dose, and wrong order of administration. An increase in frequency of errors relating to technique of administration and rate of infusion was noted (see Table 4). However, these are not influenced by the BCMA system.

### Severity

The severity of MAEs was assessed in the intervention group, with a focus on those sensitive to BCMA implementation, and from two perspectives: the potential severity of the error and the actual consequences for the patient. Regarding potential severity of errors, all categories experienced a reduction in the number of errors, except in the mild category, and showed statistically significant differences in moderate potential

**TABLE 3. MAEs and Types of Errors Influenced by BCMA System in Patients With Solid Tumors (Intervention Group)**

| | Before BCMA | | | After BCMA | | | Relative Change in ROE | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | n | N | % | n | N | % | % | 95% CI | OR | 95% CI | p |
| **Intervention group** | | | | | | | | | | | |
| MAEs | 595 | 1,281 | 46 | 459 | 1,272 | 36 | −22 | [−23.4, −21.2] | 1.54 | [1.31, 1.8] | < 0.001 |
| Excluding infusion rate errors | 259 | 1,281 | 20 | 126 | 1,272 | 10 | −51 | [−54, −48.1] | 2.3 | [1.83, 2.9] | < 0.001 |
| **Control group** | | | | | | | | | | | |
| MAEs | 91 | 141 | 65 | 152 | 218 | 70 | 8 | [4.6, 12.7] | 0.79 | [0.5, 1.24] | 0.3 |
| Excluding infusion rate errors | 41 | 141 | 29 | 77 | 218 | 35 | 21 | [12.7, 33.3] | 0.75 | [0.47, 1.18] | 0.22 |
| Errors influenced by BCMA | 25 | 141 | 18 | 86 | 218 | 39 | 223 | [178.6, 184.7] | 0.33 | [0.2, 0.55] | 0.0012 |
| **Type of error influenced by BCMA** | | | | | | | | | | | |
| Errors influenced by BCMA | 206 | 1,281 | 16 | 31 | 1,272 | 2 | −85 | [−88.6, −81.3] | 0.13 | [0.09, 0.19] | < 0.001 |
| Pharmacy transcription errors[a] | 19 | 1,281 | 2 | 1 | 1,272 | < 1 | −93 | [−99.7, −81.3] | 0.05 | [0.01, 0.39] | < 0.001 |
| Wrong medication[a] | 6 | 1,281 | 1 | 2 | 1,272 | < 1 | −60 | [−88.2, −45.1] | 0.33 | [0.07, 1.66] | 0.159 |
| Medication administration omission[a] | 14 | 1,281 | 1 | 1 | 1,272 | < 1 | −91 | [−99.6, −76.3] | 0.07 | [0.01, 0.54] | 0.008 |
| Wrong dose (higher) | 7 | 1,281 | 1 | – | – | – | −100 | – | – | – | 0.008 |
| Wrong dose (lower) | 8 | 1,281 | 1 | – | – | – | −100 | – | – | – | 0.004 |
| Extra dose | – | – | – | – | – | – | – | – | – | – | – |
| Wrong date[a] | 2 | 1,281 | < 1 | – | – | – | −100 | – | – | – | 0.16 |
| Wrong route[a] | 8 | 1,281 | 1 | 6 | 1,272 | 1 | −17 | [−37, −16.4] | 0.75 | [0.26, 2.18] | 0.6 |
| Wrong patient[a] | – | – | – | – | – | – | – | – | – | – | – |
| Wrong order[a] | 142 | 1,281 | 11 | 21 | 1,272 | 2 | −86 | [−89.2, −80.6] | 0.13 | [0.08, 0.21] | < 0.001 |

[a] n refers to number of MAEs, whereas N is number of opportunities for error.
BCMA—barcode medication administration; CI—confidence interval; MAE—medication administration error; OR—odds ratio; ROE—rate of error

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severity (see Table 5). The no-severity category (55%) was the most frequent in the period before BCMA implementation, whereas the mild category (61%) was the most frequent in the period after BCMA implementation. No errors were rated in the highest severity category after BCMA implementation.

Regarding the actual consequences for patients, only four errors (2%) caused mild harm to the patient in the period before BCMA implementation. Most errors were classified into the "reached the patient but caused no harm" category, which was the only one to increase after the intervention. A nonsignificant reduction of errors was observed in both categories in which errors had an impact on patients, with no cases observed after the intervention.

### Length of Stay for Treatment Administration

When analyzing the impact of the intervention on average length of stay for treatment, no statistically significant differences were found. In the intervention group, the average length of stay was 166 minutes before the intervention and 160 minutes after the intervention. In the control group, the average length of stay was 167 minutes before the intervention and 155 minutes after the intervention.

## Discussion

The implementation of a BCMA system for patients with solid tumors was associated with an 85% relative reduction of MAEs. No statistically significant differences were observed in the control group. The current authors estimated that 3,200 potential MAEs per year could be prevented in the studied setting. As Bubalo et al. (2014) stated, these results are relevant because of the lack of studies focusing on these types of treatments. In their review of the impact of BCMA systems, Leung et al. (2015) emphasized the limited knowledge of these systems within the outpatient treatment

**TABLE 4. MAEs in Patients With Solid Tumors Before and After BCMA**

| | Before BCMA | | After BCMA | | Relative Change in ROE | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Type of error[a] | n | % | n | % | % | 95% CI | OR | 95% CI | p |
| Wrong medication | 32 | 5 | 3 | 1 | –89 | [–96.4, –74.8] | 8.64 | [2.63, 28.4] | < 0.001 |
| Pharmacy dispensation | 7 | 1 | – | – | –100 | – | – | – | 0.02 |
| Pharmacy transcription | 19 | 3 | 1 | < 1 | –94 | [–99.7, –75.7] | 15.1 | [2.01, 113.28] | < 0.001 |
| Administration | 6 | 1 | 2 | < 1 | –60 | [–85.7, –28.4] | 2.75 | [0.55, 13.68] | < 0.47 |
| Omission | 15 | 3 | 2 | < 1 | –84 | [–96.4, –62.1] | 6.91 | [1.34, 25.97] | 0.006 |
| Pharmacy transcription | 1 | < 1 | 1 | < 1 | 100 | [29.03, 50] | – | – | 1 |
| Pharmacy dispensation | – | – | – | – | – | – | – | – | – |
| Administration | 14 | 2 | 1 | < 1 | –91 | [–99.5, –69.3] | 11.04 | [1.45, 84.24] | 0.003 |
| Wrong dose | 15 | 3 | – | – | –100 | – | – | – | < 0.001 |
| Higher | 7 | 1 | – | – | –100 | – | – | – | 0.02 |
| Lower | 8 | 1 | – | – | –100 | – | – | – | 0.012 |
| Extra | – | – | – | – | – | – | – | – | – |
| Wrong date | 2 | < 1 | – | – | –100 | – | – | – | 0.5 |
| Wrong pharmaceutical form | – | – | – | – | – | – | – | – | – |
| Wrong preparation/handling/ packaging/labeling | 8 | 1 | 4 | 1 | –39 | [–60.34, –15.9] | – | – | 0.56 |
| Wrong administration technique | 53 | 9 | 91 | 20 | 123 | [10.7, 141.4] | 0.4 | [0.27, 0.57] | 0.001 |
| Wrong route | 8 | 1 | 6 | 1 | – | [–17.24, 7.22] | – | – | 0.95 |
| Wrong infusion rate | 317 | 53 | 332 | 72 | 36 | [33.2, 38.3] | 0.44 | [0.34, 0.57] | < 0.001 |
| Wrong patient | – | – | – | – | – | – | – | – | – |
| Wrong drug monitoring | 2 | < 1 | – | – | –100 | – | – | – | 0.5 |
| Deteriorated medication | 1 | < 1 | – | – | –100 | – | – | – | – |
| Wrong order | 142 | 24 | 21 | 5 | –81 | [–86.1, –74.9] | 6.54 | [4.06, 10.53] | < 0.001 |

[a] Number of errors out of total number of MAEs (N = 595 MAEs before BCMA; N = 459 MAES after BCMA)
BCMA—barcode medication administration; CI—confidence interval; MAE—medication administration error; OE—opportunity for error; OR—odds ratio; ROE—rate of error

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setting. Only one study (Seibert, Maddox, Flynn, & Williams, 2014) uses a methodology similar to the present study. It too measured the impact of BCMA in a day hospital; although the data on incidence of MAEs are not comparable, Seibert et al. (2014) did not observe a significant reduction of errors after BCMA implementation. The authors stated that a manual double-checking procedure was performed before the BCMA system was implemented, which may justify their findings (Seibert et al., 2014).

Most medications were administered via IV, which limits potential comparisons with similar studies. Only Helmons et al. (2009) clearly specified the routes of administration, and in their study, the oral route was the most frequently used.

In the current study, observations were mainly performed by pharmacists; in other studies, observations were carried out by pharmacists (Bonkowski et al., 2013; Franklin et al., 2007), nurses (Paoletti et al., 2007; Poon et al., 2010; Skibinski, White, Lin, Dong, & Wu, 2007), or a combination of both (Cochran & Haynatzki, 2013; DeYoung et al., 2009; Seibert et al., 2014). Future research should take into account the profile and training of observers; an interprofessional group of observers could improve the quality of the data obtained.

No current gold standard has been established with regard to the duration of the observation period. In the current study, the observation period extended to more than one month, with uninterrupted observations for 11 hours per day. In other studies, the observation period varied from four hours (Serrano-Fabiá et al., 2010) to seven months (Seibert et al., 2014).

Although the use of control groups is highly recommended to avoid potential random errors (Hassink et al., 2012), only one study has been conducted comparing an intervention group with a control group, as the current study does; however, the context is not the same (Paoletti et al., 2007). Paoletti et al. (2007) observed an increase in the number of errors in the control group after the intervention. In addition, in a systematic review of 42 pre-/postintervention studies on patient safety, the authors found that none included a control group to assess the effectiveness

**TABLE 5. Severity of MAEs in Patients with Solid Tumors Influenced by BCMA**

| | Before BCMA (N = 206)[a] | | After BCMA (N = 31)[a] | | |
|---|---|---|---|---|---|
| **Variable** | **n** | **%** | **n** | **%** | **p** |
| **Severity description** | | | | | |
| A. Potential | – | – | – | – | – |
| B. Did not reach the patient | 19 | 9 | 3 | 10 | 0.8 |
| C. Reached the patient but caused no harm | 144 | 70 | 28 | 90 | 0.77 |
| D. Reached the patient and required monitoring | 2 | 1 | – | – | 0.54 |
| E. May have contributed to or resulted in temporary harm to the patient and required intervention | 2 | 1 | – | – | 0.54 |
| F. May have contributed to or resulted in temporary harm to the patient and required initial or prolonged hospitalization | – | – | – | – | – |
| G. May have contributed to or resulted in permanent harm to the patient | – | – | – | – | – |
| H. Required intervention necessary to sustain the patient's life | – | – | – | – | – |
| I. May have contributed to or resulted in death of the patient | – | – | – | – | – |
| Not evaluated | 39 | 19 | – | – | – |
| **Severity of potential description** | | | | | |
| No severity | 113 | 55 | 12 | 39 | 0.33 |
| Mild | 48 | 23 | 19 | 61 | 0.003 |
| Moderate | 29 | 14 | – | – | 0.038 |
| Severe | 16 | 8 | – | – | 0.12 |
| Life-threatening | – | – | – | – | – |

[a] N refers to total number of MAEs influenced by BCMA
BCMA—barcode medication administration; MAE—medication administration error

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of the interventions (Acheampong, Anto, & Koffuor, 2014).

### Incidence of Medication Administration Errors

Results from the current study show a reduction of 85% in the incidence of medication errors—a finding that is in line with prior evidence, where a reduction of as much as 80% of the errors is reported after implementation of a BCMA system (Bonkowski et al., 2013; Leung et al., 2015). However, the literature regarding the impact of BCMA systems shows contradictory results.

The incidence of all MAEs in this study was higher than that observed in other studies with similar methodology (Bonkowski et al., 2013; Cochran & Haynatzki, 2013; Franklin et al., 2007; Hardmeier, Tsourounis, Moore, Abbott, & Guglielmo, 2014; Helmons et al., 2009; Morriss, Abramowitz, Carmen, & Wallis, 2009; Paoletti et al., 2007; Poon et al., 2010; Seibert et al., 2014; Skibinski et al., 2007) where the incidence of MAEs ranged from 7%–25% in the period before BCMA implementation and from 2%–21% in the period after. When selecting errors sensitive to the BCMA system in the intervention group, the incidence was 16%. These differences can be explained by the peculiarities of the study setting, the complex management of the medications used, and the study design. Among study variables, those related to the type of error were decisive to compare different studies' results. The frequency of administration error (related to time) was assessed in many studies and had a high incidence in comparison to other errors; the current authors could not consider it because each patient in this study received only one dose of medication per treatment. The current study provides unprecedented evidence of the high error rate in the incorrect medication infusion rate, which is a relevant finding because this type of MAE was not sensitive to BCMA implementation. Future research should be aimed at the reduction of incorrect medication infusion rates, given the potential adverse effect on patients' safety. A validated classification system for types of medication errors would be necessary to compare results.

### Types of Error in Medication Administration

The current authors' findings on types of error are noteworthy, given the current lack of research and error assessment in the field of medication administration. These results provide information on MAEs in oncology treatments that are specific to the outpatient setting. The types of error most frequently analyzed in similar studies are wrong medication, wrong dose, wrong route of administration, wrong time, and dose omission. Wrong order of administration is a unique type of error associated with antineoplastic treatments, which was included for the first time in the current study.

Regarding the impact of BCMA on errors sensitive to these systems, results from other studies are not at all homogeneous. In some studies, administration omission errors decreased the most after implementing the BCMA system (Franklin et al., 2007; Helmons et al., 2009). In other studies, the errors that decreased most were administration route (Poon et al., 2010; Skibinski et al., 2007), time to administer the medication (DeYoung et al., 2009; Morriss, Abramowitz, Nelson, et al., 2009; Poon et al., 2010), and wrong dose (Bonkowski et al., 2013, 2014; Seibert et al., 2014).

This study confirms that some errors are not preventable with BCMA and CPOE, which is why verification on the part of professionals is irreplaceable. In line with previous reports (Seibert et al., 2014), the current authors were able to observe an increase in wrong route of administration errors. The BCMA system would require further technological development to reduce the number of errors associated with infusion pumps.

### Severity of Errors

Results from the current study suggest that a BCMA system is effective in reducing severe MAEs. Few studies have addressed the impact of BCMA systems on the severity of MAEs (Franklin et al., 2007; Morriss, Abramowitz, Nelson, et al., 2009; Poon et al., 2010), and no study has assessed the influence of this in antineoplastic administrations. Regarding potential severity, the number of severe errors decreased. This finding is consistent with results from previous studies, where most medication errors had little effect on

#### KNOWLEDGE TRANSLATION

- Barcode medication administration (BCMA) is effective in reducing the incidence and severity of medication administration errors in outpatients with cancer.
- BCMA reduces the types of error relating to the five rights and those relating to wrong order of administration, which is a chemotherapy-specific medication error.
- BCMA implementation does not increase the length of stay for treatment of patients with cancer.

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patient health (Bates, 1999; Franklin et al., 2007; Poon et al., 2010; Taxis, Dean, & Barber, 2002).

As in the current study, most authors classified the consequences of MAEs as benign (Bonkowski et al., 2013; Morriss, Abramowitz, Nelson, et al., 2009; Walsh et al., 2009), possibly because of the low incidence of errors classified as severe (Bates, 1999; Bates, Boyle, Vander Vliet, Schneider, & Leape, 1995; Sakowski, Newman, & Dozier, 2008). No MAEs were classified in the most severe categories after intervention. As medical records were reviewed to retrospectively assess the severity of MAEs, additional variability and a certain degree of subjectivity may have influenced the classification of MAEs in the current study.

### Length of Stay of Patients

The results show that the implementation of a BCMA system does not increase the length of stay of patients. This supports and reinforces the results from other researchers who either report no changes (Helmons et al., 2009; Poon et al., 2006) or report a decrease in the length of stay (Dasgupta et al., 2011; Dwibedi et al., 2011; Franklin et al., 2007; Huang & Lee, 2011; Tsai et al., 2010).

### Limitations

Several limitations have been identified in this study. For instance, the results show the experience of using BCMA systems in an onco-hematology day hospital and cannot be generalized to other settings; however, they do provide information that adds to the few studies that explore the impact of BCMA on MAEs in the context of an onco-hematology day hospital. In addition, regardless of intervention, extension of the CPOE and additional changes necessary for implementing the BCMA system could have affected the incidence of observed MAEs, leading to improved patient safety. However, both technologies must be implemented at the same time (Hagland, 2004). Also, changes because of the long interval between pre-/postintervention data collection cannot be excluded, but the lack of change in the control group does not seem to support this hypothesis. This issue should be addressed in future studies (Strudwick et al., 2017). Another limitation is that the selected control group differed from the intervention group in terms of prescription, number of patients per day, and pathology. Nurses, too, may have modified their actions because they knew they were being observed, as in the Hawthorne effect. Although the observers received specific training for the project, the impact of education and experience cannot be ruled out because inter-rater reliability measures were not obtained. This could be improved in future studies. Similarly, assessment of the actual severity of MAEs was based on expert opinion. This adds a degree of subjectivity, which contrasts with the proper methods for gathering and interpreting data from medical records. Great difficulty is inherent in attempting to determine the effect of MAEs on patients' quality of life.

## Implications for Nursing

The results of this study have relevant implications for nursing practice. The BCMA system is a useful technology to check the five rights of medication administration in an onco-hematology day hospital. Although some specific errors related to chemotherapy could be directly addressed by implementation of a BCMA system, others are nonspecific and may also be prevented. Further research is required to investigate other types of errors (e.g., infusion rate) and their impact. This will help to raise awareness of the relevance of such errors. The results from this study suggest that a BCMA system can improve the safety and quality of the chemotherapy administration process. The need for an interprofessional team should be highlighted, with special attention paid to the oncology nurses who play an important role in the success of the implementation and maintenance of a BCMA system. A consolidated culture of patient safety may influence the implementation and maintenance of a BCMA system. In addition, the use of new technologies, such as BCMA, could help nurses increase the time they spend on other direct patient care activities. Oncology nurses are at the forefront of chemotherapy error-prevention activities and play a key role in implementing safety measures.

## Conclusion

The main contribution of this study is to present the first available evidence that the incidence of MAEs in patients in an onco-hematology day hospital can be reduced with the implementation of a BCMA system. The authors also show that a BCMA system reduces the potential and actual severity of errors. A BCMA system was effective in reducing the following errors: order of administration, pharmacy department medication transcription, dose omissions, and dose errors. In addition, BCMA technology needs to be improved to minimize frequently detected errors and to assess high potential errors, such as the infusion rate and

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the technique of administration. This technological development can lead to an improvement in patient safety.

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## REFERENCES

Acheampong, F., Anto, B.P., & Koffuor, G.A. (2014). Medication safety strategies in hospitals—A systematic review. *International Journal of Risk and Safety in Medicine, 26,* 117–131. https://doi.org/10.3233/JRS-140623

ASHP Council on Professional Affairs. (2002). ASHP guidelines on preventing medication errors with antineoplastic agents. *American Journal of Health-System Pharmacy, 59,* 1648–1668.

Barker, K.N., Flynn, E.A., & Pepper, G.A. (2002). Observation method of detecting medication errors. *American Journal of Health-System Pharmacy, 59,* 2314–2316.

Bates, D.W. (1999). Frequency, consequences and prevention of adverse drug events. *Journal of Quality in Clinical Practice, 19,* 13–17. https://doi.org/10.1046/j.1440-1762.1999.00285.x

Bates, D.W., Boyle, D.L., Vander Vliet, M.B., Schneider, J., & Leape, L. (1995). Relationship between medication errors and adverse drug events. *Journal of General Internal Medicine, 10,* 199–205.

Berdot, S., Sabatier, B., Gillaizeau, F., Caruba, T., Prognon, P., & Durieux, P. (2012). Evaluation of drug administration errors in a teaching hospital. *BMC Health Services Research, 12,* 60. https://doi.org/10.1186/1472-6963-12-60

Bonkowski, J., Carnes, C., Melucci, J., Mirtallo, J., Prier, B., Reichert, E., . . . Weber, R. (2013). Effect of barcode-assisted medication administration on emergency department medication errors. *Academic Emergency Medicine, 20,* 801–806. https://doi.org/10.1111/acem.12189

Bonkowski, J., Weber, R.J., Melucci, J., Pesavento, T., Henry, M., & Moffatt-Bruce, S. (2014). Improving medication administration safety in solid organ transplant patients through barcode-assisted medication administration. *American Journal of Medical Quality, 29,* 236–241. https://doi.org/10.1177/1062860613492374

Bubalo, J., Warden, B.A., Wiegel, J.J., Nishida, T., Handel, E., Svoboda, L.M., . . . Edillo, P.N. (2014). Does applying technology throughout the medication use process improve patient safety with antineoplastics? *Journal of Oncology Pharmacy Practice, 20,* 445–460. https://doi.org/10.1177/1078155213514469

Cochran, G.L., & Haynatzki, G. (2013). Comparison of medication safety effectiveness among nine critical access hospitals. *American Journal of Health-System Pharmacy, 70,* 2218–2224. https://doi.org/10.2146/ajhp130067

Dasgupta, A., Sansgiry, S.S., Jacob, S.M., Frost, C.P., Dwibedi, N., & Tipton, J. (2011). Descriptive analysis of workflow variables associated with barcode-based approach to medication administration. *Journal of Nursing Care Quality, 26,* 377–384.

Dean, B., & Barber, N. (2001). Validity and reliability of observational methods for studying medication administration errors. *American Journal of Health-System Pharmacy, 58,* 54–59.

DeYoung, J.L., Vanderkooi, M.E., & Barletta, J.F. (2009). Effect of bar-code-assisted medication administration on medication error rates in an adult medical intensive care unit. *American Journal of Health-System Pharmacy, 66,* 1110–1115. https://doi.org/10.2146/ajhp080355

Dhamija, M., Kapoor, G., & Juneja, A. (2014). Infusional chemotherapy and medication errors in a tertiary care pediatric cancer unit in a resource-limited setting. *Journal of Pediatric Hematology/Oncology, 36,* e412–e415. https://doi.org/10.1097/MPH.0000000000000044

Dwibedi, N., Sansgiry, S.S., Frost, C.P., Dasgupta, A., Jacob, S.M., Tipton, J.A., & Shippy, A.A. (2011). Effect of bar-code-assisted medication administration on nurses' activities in an intensive care unit: A time-motion study. *American Journal of Health-System Pharmacy, 68,* 1026–1031. https://doi.org/10.2146/ajhp100382

Ford, C.D., Killebrew, J., Fugitt, P., Jacobsen, J., & Prystas, E.M. (2006). Study of medication errors on a community hospital oncology ward. *Journal of Oncology Practice, 2,* 149–154. https://doi.org/10.1200/JOP.2006.2.4.149

Franklin, B.D., O'Grady, K., Donyai, P., Jacklin, A., & Barber, N. (2007). The impact of a closed-loop electronic prescribing and administration system on prescribing errors, administration

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errors and staff time: A before-and-after study. *BMJ Quality and Safety, 16,* 279–284. https://doi.org/10.1136/qshc.2006.019497

Gandhi, T.K., Bartel, S.B., Shulman, L.N., Verrier, D., Burdick, E., Cleary, A., . . . Bates, D.W. (2005). Medication safety in the ambulatory chemotherapy setting. *Cancer, 104,* 2477–2483. https://doi.org/10.1002/cncr.21442

Goldspiel, B.R., DeChristoforo, R., & Hoffman, J.M. (2015). Preventing chemotherapy errors: Updating guidelines to meet new challenges. *American Journal of Health-System Pharmacy, 72,* 668–669. https://doi.org/10.2146/sp150004

Grupo Ruiz-Jarabo 2000. (2008). *Clasificación de los errores de medicación (versión 2)*. Retrieved from http://www.ismp-espana.org/ficheros/Clasificaci%C3%B3n%20actualizada%202008.pdf

Hagland, M. (2004). Safe ways. Hospitals looking to improve patient safety are turning to CPOE, bar coding and e-prescribing. *Healthcare Informatics, 21,* 20–25.

Hardmeier, A., Tsourounis, C., Moore, M., Abbott, W.E., & Guglielmo, B.J. (2014). Pediatric medication administration errors and workflow following implementation of a bar code medication administration system. *Journal for Healthcare Quality, 36,* 54–63. https://doi.org/10.1111/jhq.12071

Hassink, J.J., Jansen, M., & Helmons, P. (2012). Effects of bar code-assisted medication administration (BCMA) on frequency, type and severity of medication administration errors: A review of the literature. *European Journal of Hospital Pharmacy, 19,* 489–494. https://doi.org/10.1136/ejhpharm-2012-000058

Helmons, P.J., Wargel, L.N., & Daniels, C.E. (2009). Effect of bar-code-assisted medication administration on medication administration errors and accuracy in multiple patient care areas. *American Journal of Health-System Pharmacy, 66,* 1202–1210. https://doi.org/10.2146/ajhp080357

Huang, H.-Y., & Lee, T.-T. (2011). Impact of bar-code medication administration on nursing activity patterns and usage experience in Taiwan. *Computers, Informatics, Nursing, 29,* 554–563. https://doi.org/10.1097/NCN.0b013e31820662c1

Keers, R.N., Williams, S.D., Cooke, J., & Ashcroft, D.M. (2013). Prevalence and nature of medication administration errors in health care settings: A systematic review of direct observational evidence. *Annals of Pharmacotherapy, 47,* 237–256. https://doi.org/10.1345/aph.1R147

Lefkowitz, S., Cheiken, H., & Barnhart, M.R. (1991). A trial of the use of bar code technology to restructure a drug distribution and administration system. *Hospital Pharmacy, 26,* 239–242.

León Villar, J., Aranda García, A., Tobaruela Soto, M., & Iranzo Fernández, M.D. (2008). [Analysis of the errors associated with the prescription, preparation and administration of cytostatic drugs] [Article in Spanish]. *Farmacia Hospitalaria, 32,* 163–169.

Leung, A.A., Denham, C.R., Gandhi, T.K., Bane, A., Churchill, W.W., Bates, D.W., & Poon, E.G. (2015). A safe practice standard for barcode technology. *Journal of Patient Safety, 11,* 89–99. https://doi.org/10.1097/PTS.0000000000000049

McCarthy, B.C., Tuiskula, K.A., Driscoll, T.P., & Davis, A.M. (2017). Medication errors resulting in harm: Using chargemaster data to determine association with cost of hospitalization and length of stay. *American Journal of Health-System Pharmacy, 74*(Suppl. 4), S102–S107. https://doi.org/10.2146/ajhp160848

Morriss, F.H., Jr., Abramowitz, P.W., Carmen, L., & Wallis, A.B. (2009). "Nurses don't hate change"—Survey of nurses in a neonatal intensive care unit regarding the implementation, use and effectiveness of a bar code medication administration system. *Healthcare Quarterly, 12,* 135–140. https://doi.org/10.12927/hcq.2009.20981

Morriss, F.H., Jr., Abramowitz, P.W., Nelson, S.P., Milavetz, G., Michael, S.L., Gordon, S.N., . . . Cook, E.F. (2009). Effectiveness of a barcode medication administration system in reducing preventable adverse drug events in a neonatal intensive care unit: A prospective cohort study. *Journal of Pediatrics, 154,* 363–368. https://doi.org/10.1016/j.jpeds.2008.08.025

Neuenschwander, M., Cohen, M.R., Vaida, A.J., Patchett, J.A., Kelly, J., & Trohimovich, B. (2003). Practical guide to bar coding for patient medication safety. *American Journal of Health-System Pharmacy, 60,* 768–779.

Paoletti, R.D., Suess, T.M., Lesko, M.G., Feroli, A.A., Kennel, J.A., Mahler, J.M., & Sauders, T. (2007). Using bar-code technology and medication observation methodology for safer medication administration. *American Journal of Health-System Pharmacy, 64,* 536–543. https://doi.org/10.2146/ajhp060140

Poon, E.G., Cina, J.L., Churchill, W., Patel, N., Featherstone, E., Rothschild, J.M., . . . Gandhi, T.K. (2006). Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in the pharmacy. *Annals of Internal Medicine, 145,* 426–434. https://doi.org/10.7326/0003-4819-145-6-200609190-00006

Poon, E.G., Keohane, C.A., Yoon, C.S., Ditmore, M., Bane, A., Levtzion-Korach, O., . . . Gandhi, T.K. (2010). Effect of bar-code technology on the safety of medication administration. *New England Journal of Medicine, 362,* 1698–1707. https://doi.org/10.1056/NEJMsa0907115

Rinke, M.L., Shore, A.D., Morlock, L., Hicks, R.W., & Miller, M.R. (2007). Characteristics of pediatric chemotherapy medication errors in a national error reporting database. *Cancer, 110,* 186–195. https://doi.org/10.1002/cncr.22742

Saedder, E.A., Brock, B., Nielsen, L.P., Bonnerup, D.K., & Lisby, M. (2014). Identifying high-risk medication: A systematic literature review. *European Journal of Clinical Pharmacology, 70,* 637–645. https://doi.org/10.1007/s00228-014-1668-z

Sakowski, J., Newman, J.M., & Dozier, K. (2008). Severity of medication administration errors detected by a bar-code medication administration system. *American Journal of Health-System Pharmacy, 65,* 1661–1666. https://doi.org/10.2146/ajhp070634

Seibert, H.H., Maddox, R.R., Flynn, E.A., & Williams, C.K. (2014). Effect of barcode technology with electronic medication

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administration record on medication accuracy rates. *American Journal of Health-System Pharmacy, 71,* 209–218. https://doi.org/10.2146/ajhp130332

Serrano-Fabiá, A., Albert-Marí, A., Almenar-Cubells, D., & Jiménez-Torres, N.V. (2010). Multidisciplinary system for detecting medication errors in antineoplastic chemotherapy. *Journal of Oncology Pharmacy Practice, 16,* 105–112. https://doi.org/10.1177/1078155209340482

Skibinski, K.A., White, B.A., Lin, L.I., Dong, Y., & Wu, W. (2007). Effects of technological interventions on the safety of a medication-use system. *American Journal of Health-System Pharmacy, 64,* 90–96. https://doi.org/10.2146/ajhp060060

Strudwick, G., Reisdorfer, E., Warnock, C., Kalia, K., Sulkers, H., Clark, C., & Booth, R. (2017). Factors associated with barcode medication administration technology that contribute to patient safety: An integrative review. *Journal of Nursing Care Quality.* Advance online publication. https://doi.org/10.1097/NCQ.0000000000000270

Taxis, K., Dean, B., & Barber, N. (2002). The validation of an existing method of scoring the severity of medication administration errors for use in Germany. *Pharmacy World and Science, 24,* 236–239.

Tsai, S.L., Sun, Y.C., & Taur, F.M. (2010). Comparing the working time between bar-code medication administration system and traditional medication administration system: An observational study. *International Journal of Medical Informatics, 79,* 681–689. https://doi.org/10.1016/j.ijmedinf.2010.07.002

Ulas, A., Silay, K., Akinci, S., Dede, D.S., Akinci, M.B., Sendur, M.A., . . . Yalcin, B. (2015). Medication errors in chemotherapy preparation and administration: A survey conducted among oncology nurses in Turkey. *Asian Pacific Journal of Cancer Prevention, 16,* 1699–1705.

Walsh, K.E., Dodd, K.S., Seetharaman, K., Roblin, D.W., Herrinton, L.J., Von Worley, A., . . . Gurwitz, J.H. (2009). Medication errors among adults and children with cancer in the outpatient setting. *Journal of Clinical Oncology, 27,* 891–896. https://doi.org/10.1200/JCO.2008.18.6072

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