EDITOR'S CHOICE

Effects of bar code-assisted medication administration (BCMA) on frequency, type and severity of medication administration errors: a review of the literature

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ABSTRACT

Bar code-assisted medication administration (BCMA) is increasingly being adopted as an additional tool in the prevention of medication administration errors. This literature review summarises the evidence behind the effects of BCMA technology on medication safety. Although most studies show an error-reducing effect of BCMA technology, compliance with the new technology after its implementation and the long-term effects on error reduction are often not assessed. Most importantly, the effect of medication error reduction on patient outcomes is limited.

Introduction

The medication distribution process is an important source of medication errors. Medication error rates reported in the literature vary widely depending on the methodologies and definitions used. A recent review summarised the prevalence of medication errors as 5.7% of administrations (range 0.038–56.1%, n = 31 studies), 1.07 errors per 100 patient-days (range 0.35–12, n = 9) or 6% of patients hospitalised (range 0.93–24%, n = 7).[1] Most errors originate in the medication administration process (median 53%, range 9–90.7%).[1] With few barriers to prevent them from occurring, only 2% of medication administration errors are intercepted at the patient bedside.[2] Bar code-assisted medication administration (BCMA) is increasingly adopted as an additional barrier in the prevention of medication administration errors. In 2009, 27.9% of hospitals in the USA had implemented BCMA,[3] which increased to 50.2% in 2011.[4]

BCMA technology is developed to improve compliance with checking the 'five rights' of medication administration: right patient, right route, right drug, right dose and right time. The right patient is identified by matching the unique bar code on the patient wristband to the patient information in the electronic medication administration record (eMAR). The right drug, right dose, right dosage form and right time are checked by matching the bar code on every unit- or multidose medication to the information in the eMAR. In a 2009 position statement, the American Society of Health-System Pharmacists encouraged health systems to adopt BCMA technology to improve patient safety and the accuracy of medication administration and documentation.[5] Most studies evaluating the effect of BCMA on medication administration errors have been conducted in the USA. However, this technology is also used in European countries including Denmark, Italy and the Netherlands[6] and, in 2006, the Council of Europe Expert Group on Safe Medication Practices also encouraged the use of electronic systems to improve the safety of medication administration.[7] In June 2010 the general assembly of the European Association of Hospital Pharmacists called for the implementation of bar-coded single dose-packed drugs in national and European regulations.[8]

While BCMA as a tool in the prevention of medication administration errors makes intuitive sense, there is limited evidence demonstrating the effect of this intervention on medication administration errors and patient outcomes. In addition, increased workload is a commonly voiced concern by nursing staff as the use of bar coding technology can potentially result in a longer duration of medication administration. This review of the literature focuses on (1) the effect of BCMA on frequency, type and severity of medication administration errors and (2) the effect of BCMA technology on the duration of the medication administration process.

Methods

Study selection

In May 2012 a PubMed search was performed to select studies investigating at least one of the following topics: the effect of BCMA on the rate or severity of medication administration errors or studies evaluating the effect of BCMA on the duration of administering medication. Only studies with a prospective design and in which observational techniques were used to measure medication errors and/or administration time were included. The detailed search criteria and selection procedure of the 10 articles included in this study are shown in figure 1.[9–18] We also reviewed the reference lists of the selected articles. This revealed the full text article[19] of an abstract we had already selected.[15] In addition, we included a study that met the abovementioned criteria and was published in this journal and a Dutch pharmaceutical journal, not indexed in PubMed.[20 21] As a result, a total of 11 studies were included.[9–14 16–21]

Settings and intervention

The studies were conducted on wards with different levels of care and in organisations with varying medication use processes (table 1).

Implementation of BCMA was accompanied by the implementation of an eMAR in all studies. In two studies the introduction of BCMA was accompanied

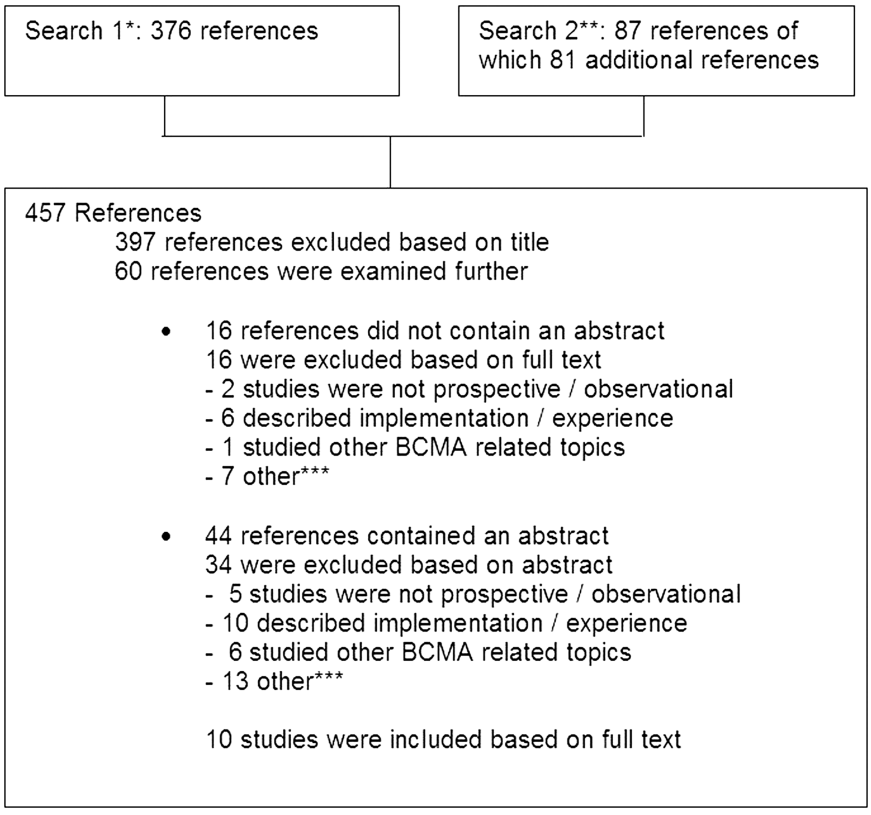

Figure 1 Details of literature search. *Search 1: ('automatic data processing'(MeSH Terms) OR ('automatic'(All Fields) AND 'data'(All Fields) AND 'processing'(All Fields)) OR 'automatic data processing'(All Fields) OR ('bar'(All Fields) AND 'code'(All Fields)) OR 'bar code'(All Fields) OR 'barcode'(All Fields)) AND ('pharmaceutical preparations'(MeSH Terms) OR ('pharmaceutical'(All Fields) AND 'preparations'(All Fields)) OR 'pharmaceutical preparations'(All Fields) OR 'medication'(All Fields)) AND ('organisation and administration'(MeSH Terms) OR ('organisation'(All Fields) AND 'administration'(All Fields)) OR 'organisation and administration'(All Fields) OR 'administration'(All Fields)). **Search 2: ('pharmaceutical preparations'(MeSH Terms) OR ('pharmaceutical'(All Fields) AND 'preparations'(All Fields)) OR 'pharmaceutical preparations'(All Fields) OR 'medication'(All Fields)) AND verification(All Fields) AND ('technology'(MeSH Terms) OR 'technology'(All Fields)). ***The category 'other' includes review articles describing articles on bar code-assisted medication administration (BCMA) and/or technology, summary of a research published in another journal, perspective, editorial, letter to the editor.

by additional interventions such as simultaneously implementing bedside assortment picking (table 1).[11 20] In all studies, error rates were calculated using the same formula: total errors divided by the sum of observed administrations and omissions. In the study by Franklin *et al*, bar code technology was used to stock the automated dispensing cabinet and assure the correct identity of the medication. At the bedside, BCMA was then used to assure the correct identity of the patient.[11]

Results

Error frequency

Error rates before and after implementation of BCMA are summarised in table 2.

As wrong time errors are generally considered to be less severe,[22] the results are reported as total errors and errors excluding wrong time errors. Baseline error rate varied between 5.8% and 25.3% if time errors were included and between 1.6% and 27.3% when time errors were excluded. Most studies show a 30–50% reduction in medication administration errors after implementation of BCMA when time errors are excluded. However, implementation of BCMA does not result in a consistent reduction when time errors are included.

Error type

The type and number of error categories varied between studies. Error categories that were assessed in at least three studies and are expected to be reduced by BCMA are omissions, wrong drug errors, unauthorised drug errors, wrong dosage form errors and extra dose errors. Only one study did not find a reduction in unauthorised drug errors and omissions and wrong drug and wrong dose errors even increased.[13] Wrong dose errors also increased in the ICU setting in the study by Helmons *et al.*[12] Wrong dosage form errors and extra dose errors increased in the study by Ros *et al.*[20]

Wrong route errors are not expected to be influenced by BCMA and wrong time errors only partially. Reduction of these errors was inconsistent among studies. Most studies were underpowered to identify statistically significant differences within individual categories.

Overall it seems that wrong time errors are the most frequently occurring.[9 10 13 20]

Error severity

Adverse drug events (ADEs) are defined as an injury resulting from the use of a medicine or omission of an intended medicine.[23] This definition includes adverse drug reactions and harm from medication incidents. As a result, medication errors resulting in harm are considered ADEs. An error that could potentially lead to harm is a potential ADE. One study[14] assessed the severity of observed ADEs and two studies[10 11] categorised the potential severity of observed administration errors (table 3).

Morris *et al* found that BCMA reduced the risk of preventable ADEs by 47%[14] and Poon *et al* showed a 50.8% reduction in potential ADEs.[10] In this latter study the reduction in many of the potential ADEs could be attributed to improved medication administration documentation.[10] Franklin *et al* did not find a reduction in error severity.[11]

Table 1 Study characteristics

Study	Type of ward	Hospital	Setting pre-intervention	Setting post-intervention	Other points of interest	Observation period
Paoletti *et al*[9]	Cardiac (telemetry) Medical-surgical	20-bed cardiac ward 36-bed medical Surgical ward in a general hospital, Lancaster, USA	Decentralised cabinet distribution system Handwritten order Handwritten paper MAR	Decentralised cabinet distribution system Handwritten order eMAR with pharmacist order entry BCMA	1.5 year surveillance data	ND
Poon *et al*[10]	ICU Medical Surgical	35 units in a 735-bed tertiary academic medical centre, Boston, USA	CPOE MAR transcribed by nurses	CPOE eMAR BCMA	Transcription errors Severity classification of potential ADEs 2 year surveillance data (in supplement)	2–4 weeks before and 4–8 weeks afterwards. 4 h observation of staff nurses on 35 observed units
Franklin *et al*[11]	Surgical	28-bed ward in a teaching hospital, London, UK	Stock cupboards and two drug trolleys Drug prescription on paper MAR	ADC and two electronic drug trolleys CPOE bar code scan used to confirm drug identity when loading medication into drawer ADC and for patient identification eMAR with manual confirmation of administration	Prescribing errors Staff time spent on medication tasks Potential severity assessment of observed errors	3–6 months before and 6–12 months after. Sample of 56 drug rounds before and 55 after (including nights and weekends) during a 2-week period
Helmons *et al*[12]	ICU (medical-surgical) Medical-surgical	13- and 20-bed ICU 22-, 26-bed medical surgical ward in a 386-bed academic teaching hospital, San Diego, USA	Unit-based ADCs CPOE Printed paper MAR manually updated	Unit-based ADCs CPOE eMAR BCMA	Medication administration accuracy Time spent on medication tasks	1 month before and 3 months after implementation. During week and weekend days focus on medication round 09:00
DeYoung *et al*[13]	ICU	38-bed medical ICU in a 744-bed community teaching hospital, Grand Rapids, USA	ND	Handwritten or preprinted orders eMAR with pharmacist order entry BCMA	–	1 month before and 4 months after. 24 h a day during 4 days
Morris[14]	NICU	36-bed ward in a children's hospital, Iowa City, USA	Handwritten orders entered by pharmacist in pharmacy information system Paper MAR on which orders were transcribed and administrations recorded	Handwritten orders entered by pharmacist in pharmacy information system eMAR bidirectionally interfaced with pharmacy information system BCMA	Severity assessment of observed preventable ADEs	19 consecutive weeks before implementation and 1 month after implementation during 31 weeks
Ros *et al*, [20] Wesselink *et al* [21]	Neurological	42-bed ward, community teaching hospital, Apeldoorn, The Netherlands	Dispensing to the ward from pharmacy by drug trolley CPOE eMAR with manual confirmation of administration	BAP cart CPOE eMAR BCMA	Time spent on medication tasks	1 year and 8 months before and 3 months after. Three daily medication rounds during 21 days

ADC, automated dispending cabinet; ADE, adverse drug events; BAP, bedside assortment picking; BCMA, bar code-assisted medication administration; CPOE, computerised physician order entry; eMAR, electronic medication administration record; ICU, intensive care unit; MAR, medication administration record; ND, not determined.

Table 2 Number of observations, and error rates before and after BCMA implementation

Study	Ward type	No of observations		Frequency of errors including time errors		Change from baseline	p Value	Frequency of errors excluding time errors		Change from baseline	p
		Baseline	Post-BCMA	Baseline	Post-BCMA			Baseline	Post-BCMA		
Paoletti *et al*[9]	Cardiac telemetry	308	318	25.3%	19.2%	24.1%	0.065	1.6%*	1.6%*	0.0%	0.959
Poon *et al*[10]	Medical	2008	2232	ND	ND	ND	ND	5.3%†	3.8%†	28.5%‡	ND
Paoletti *et al*[9]	Medical-surgical	320	310	15.6%	10.0%	35.9%	0.035	6.3%*	2.9%*	53.5%	0.045
Franklin *et al*[11]	Surgical	1473	1139	7.0%	4.3%	38.6%	0.005	ND	ND	ND	ND
Helmons *et al*[12]	Medical-surgical	888	697	10.7%	8.2%	23.6%	ND	8.0%	3.4%	56.9%	ND
Poon *et al*[10]	Surgical	3528	3856	ND	ND	ND	ND	9.8%†	5.4%†	45.1%‡	ND
De Young *et al*[13]	ICU	775	690	19.7%	8.7%	56.0%	<0.001	3.6%	4.2%	–16.3%	ND
Helmons *et al*[12]	ICU	374	394	12.6%	13.5%	–7.0%	ND	11.0%	9.9%	9.7%	ND
Poon *et al*[10]	ICU	1187	1230	ND	ND	ND	ND	27.3%†	16.5%†	39.5%‡	ND
Morris *et al*[13]	NICU	46090	46308	6.7%	8.0%	–14.7%‡	ND	ND	ND	ND	ND
Ros *et al*[20]	Neurology	3814	4300	5.8%	7.0%	–20,4%	<0.03	1.7%	0.8%	48.5%	<0.0008
Poon *et al*[10]	Overall	6723	7318	16.7%§	12.2%§	27.3%	0.001	11.5%	6.8%	41.4%	<0.001

*Excluding time and technique errors.
†Frequency calculated based on numbers presented in original publication (number of errors per ward type/number of observed doses per ward type ×100%).
‡Reduction calculated based on numbers presented in original publication.
§Only time errors.
BCMA, bar code-assisted medication administration; ND, not determined.

Table 3 Severity of observed errors or (potential) ADEs before and after implementation of BCMA

	Outcome measure	Baseline	Post-BCMA	% Change from baseline	p Value
Poon *et al*[10]	Percentage clinically significant potential ADEs	1.8	0.9	48.5	<0.001
	Percentage serious potential ADEs	1.3	0.6	54.1	<0.001
	Percentage life-threatening potential ADEs	0.03	0.01	53.9	0.34
Franklin *et al*[11]	Mean score of potential error severity*	2.7	2.5		0.39
Morris *et al*[14]	n/1000 doses of preventable ADEs†	0.86/1000 doses	0.43/1000 doses	47	0.044

*Scoring on a scale from 0 to 10 where 0 is no effect and 10 is death.
†Severity was assigned using the National Coordinating Council for Medication Error Reporting and Prevention index. All preventable ADEs were assigned class E (temporary harm that required intervention) except five cases assigned to class G because it was not possible to exclude permanent harm.
ADE, adverse drug event; BCMA, bar code-assisted medication administration.

Duration of medication administration

The general idea that the use of BCMA technology is time-consuming for nursing staff is considered a barrier to implementation. Seven studies addressed this topic (table 4).[11 12 16–19 21]

Two studies[11 12] evaluated the time spent by nursing staff to complete the medication administration task and three[16 17 21] studies measured the duration of each administration. Two studies determined the percentage of total nursing time spent on medication administration by using either the time and motion method[15] or the work sampling method.[18] No increase in medication administration time was found. Poon *et al*[19] reported a shift in the percentage of time spent on each medication administration task—for example, management of physician orders decreased but verifying patient identity and inefficient waiting increased. Three studies found a reduction in time spent on medication administration.[11 16 17]

Poon *et al*[19] and Dwibebi *et al*[16] also found that, after implementation of BCMA, the time spent on direct patient care activities increased.

Discussion

The effect of BCMA on the medication error rate is variable among the studies included in this review. BCMA technology seems to decrease the incidence of medication administration errors when time errors are excluded. However, the studies included in this review are heterogeneous.

First, the number and types of administration errors included in the studies vary. In some studies error categories that are not reduced by BCMA are included (eg, technique errors, wrong route errors). This influences the baseline error rate and dilutes the overall effect size of BCMA technology.[10–12 21] Second, the study setting has an effect on the baseline prevalence of medication errors and therefore on the potential effect after implementation of BCMA. As an example, medication in an ICU is generally administered intravenously in an area with a higher nurse-to-patient ratio. Indeed, observation of medication administration in an ICU setting resulted in the detection of different types of medication errors than observations performed on a general medicine ward.[12] Furthermore, medication use processes varied among the different study settings (table 1)—for example, dispensing of drugs by the pharmacy, use of traditional ward stock or use of automatic dispensing cabinets.

There is also a difference between studies in the time of observation (eg, continuous observation or observing specific medication rounds). As the time of the medication administration round is a determinant for medication errors,[24 25] the moment of observation could influence the baseline error rate.

In two studies,[11 20] the intervention was comprised of more than BCMA and an eMAR. It is therefore not possible to contribute the

Table 4 Results of studies evaluating the influence of BCMA on time spent on medication administration related tasks

	Outcome measure	Baseline	Post-BCMA	p Value
Franklin *et al*[11]	Mean (range) duration of each drug round (min)	50 (15–105)	40 (16–78)	0.006
Helmons *et al*[12]	Median (range) duration of a medication administration round on the general medicine ward (min)	10 (1–30)	10 (1–50)	ND
	Median (range) duration of a medication administration round on the ICU (min)	12 (1–58)	13.5 (1–53)	ND
Wesselink *et al*[21]	Mean duration of administration per drug (min)			
	Drug round 08:00	0.906	1.050	<0.006
	Drug round 12:00	1.848	1.596	<0.282
	Drug round 17:00	1.249	1.198	<0.616
Poon *et al*[19]	Percentage of time spent on administering medication	26.9%	24.9%	0.16
	Percentage of time spent on direct patient care	26.1%	29.9%	0.03
Dwibedi *et al*[16]	Mean duration of administration activity (s)	59.8	45.5	0.01
	Mean duration of time spent on direct patient care (s)	47.4	182.3	<0.0001
Tsai *et al*[17]	Mean working time for oral medication administration (s)	36.49	18.42	ND
		Paper group	BCMA group	
Huang *et al*[18]*	Percentage of time spent on medication-related tasks	25.0%	17.4%	<0.001
	Percentage of time spent on direct patient care	28.2%	28.1%	

*In this study a cross-sectional design rather than a before-after design was used.
BCMA, bar code-assisted medication administration; ND, not determined in original publication.

error reductions either to BCMA technology or to the other intervention (eg, automated dispensing cabinet) in these studies.

The degree of implementation of the technology is of importance to the results. Shortcomings in design, implementation and workflow integration encourage workarounds.[10 19 26] The current study results might therefore reflect the impact of the technology in the context of its implementation rather than the impact of the technology itself.[19]

Not all studies evaluated user compliance with the new technology. As a result, workarounds could have influenced the effect of BCMA on medication administration errors. Helmons *et al* and Paoletti *et al* reported on the compliance rate which was around 90%.[9 12] Poon *et al* reported that 20% of the drugs administered using bar code eMAR technology were given without the bar code scanning step during the study period.[10] However, no studies evaluated which errors detected in the study were the result of non-compliance.

Although the goal of BCMA is to enhance medication safety, studies that evaluate the prevention of potential harm after implementation of BCMA are limited.[10 11 14] Only two studies showed a reduction in the severity of potential ADEs.[14 19] These limited data support the beneficial effects of BCMA and eMAR on patient outcomes.

Evidence on the long-term effect and safety of BCMA is also limited. However, this information is important as workarounds evolve over time. The duration of the positive effects of BCMA on medication administration errors varied from 1 month to 12 months after implementation. Paoletti *et al* and Poon *et al* reported data on long-term medication administration error warnings after BCMA implementation. In both studies the number of warnings remained constant during periods of 1.5 and 2 years after implementation of BCMA, respectively, suggesting a long-term effect of this technology in the detection of medication errors.[9 27]

BCMA did not increase the time spent on medication administration. This is a reassuring finding as nursing staff are concerned about the time-consuming aspects of BCMA technology. The successful implementation of BCMA is the culmination of judicious planning, design, testing, training and support that occurred before, during and after BCMA deployment.[19] The degree of implementation of BCMA technology is therefore an important variable in studies evaluating the effect of BCMA.

This review of the literature generally found a positive effect of BCMA on decreasing medication errors without increasing medication administration time. However, these results are difficult to interpret because of the variability in study design, intervention and reporting of outcome measures and confounders. We have created a study design and reporting checklist as a guide for future research in this area (figure 2), although we realise that conducting a study that meets all of these criteria will not be easy.

Design:
- longitudinal design, measurements periodically, during at least a week, in a period before implementation and a follow up period of more than 2 years after implementation
- 24/7 observation
- disguised observation method
- sufficient power to test for statistical significance in individual error categories
- include different ward types

Intervention:
- limit intervention to BCMA and eMAR

Outcome measures:
- medication errors expected to be influenced by BCMA
- scoring of severity of observed errors

Information on confounders:
- BCMA compliance rate
- try to measure workarounds
- analysis of origin of the observed errors
- description of the implemented BCMA process including percentage realisation of preconditions (e.g. percentage of barcoded unit-doses)

Figure 2 Checklist for future research on the long-term effect of bar code-assisted medication administration (BCMA) technology on error frequency and severity.

Key messages

- Current studies generally support the potential of bar code-assisted medication administration (BCMA) technology to reduce medication administration errors.
- Current studies do not indicate an increase in nursing time spent on medication administration when using BCMA technology.

Conclusions

The results of this review generally support the medication administration error reducing potential of BCMA technology up to 1 year after implementation without indications of increasing nursing time spent on medication administration. However, current studies do not always mention user compliance and degree of implementation, factors narrowly related to the effectivity of BCMA technology and necessary to ascertain the maximum achievable effectivity. Future research should focus on the long-term effects of BCMA on medication error reduction, the causes of errors after BCMA implementation, the effects on nursing workflow and the harm prevented by this technology.

Correction notice This article has been corrected since it was first published Online First. 'Dr' has been removed from the beginning of Jeroen Jules Margriet Hassink's name in the 'Correspondence to' section of the article.

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