

## Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Poon EG, Keohane CA, Yoon CS, et al. Effect of bar-code technology on the safety of medication administration. *N Engl J Med* 2010;362:1698-707.

**ONLINE ONLY SUPPLEMENT**

Appendix A

**Electronic Medication Administration Record and Bedside Barcode Medication Verification**



With the implementation of barcode-eMAR, the paper medication sheets were replaced by the electronic medication administration record (or eMAR). This eMAR [1] accepted orders directly from the computerized physician order entry system, allowed nurses to acknowledge orders, reminded nurses about medications that were due for each patient, allowed the nurse to document the medications administered to the patient, and made the medication administration record visible to every member of the care team. When a patient became due for a medication, the nurse used a wireless handheld scanner [2] to scan the barcode on every single medication dose [3] and then the barcode on the patient's wristband [4] to confirm that the right medication, at the right dose, strength, and form was being administered to the right patient. If eMAR detected a medication administration error during any of these steps, the application issued a warning and would not allow the nurse to proceed until the warning was acknowledged and a reason for bypassing the warning entered.

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## Appendix B. Features Active in the Barcode-eMAR technology during the Study Period

Feature Domain	Features
Medication Worklist	View original order (pre-Pharmacy verification)
	View order as verified
	View order as dispensed
	View order with location to obtain medication (e.g., cabinet, refrigerator)
	View order as to be administered
	View history of screening for contraindication (warning, override, response)
	View dispensing status
	Linked access to medication reference information
Medication Worklist Management	Select patients from unit list to create worklist
	Support online nursing verification of medication orders (“take-off”) (commonly called transcription)
	Flag orders not verified by nursing
	Flag medication orders with unacknowledged contraindication alerts
	Flag patients with order/dispensing/administration discrepancies
	Support batch HOLD of meds (e.g., patient off floor)
	Change new medication priority for verification
	“Take-off” orders for critical patients with pending transfer to unit (“virtual bed”)
Administration Scheduling Management	Ability to adjust dosing schedule for first dose
	Flag orders with more than three changes to dosing schedule in 24 hours to require consultation with pharmacy
	Following adjusted dosing schedule for first dose, calculate dosing schedule for remaining doses
	Rules-based normalizing of dosing schedule for remaining doses (to revert to standard administration times)
Task Management	Display timed reminders at set intervals
	Ability to set trigger intervals for task status based on unit or patient location
	Trigger alerts for past due meds/IVs with use of color coding for status
	Annotated patient view with outstanding tasks
	Annotated patient view with outstanding tasks color coding for status
Barcoding	Five-rights checking with bar code technology
	Support both 1D and 2D bar coding
	Include lot number and expiration date in audit trail for administration
	Accommodate multiple bar codes for the same drug
	Hard Stop for wrong patient, wrong drug
	Activate wristband
Medication Administration - Basic	Document reason for NOT administering medication
	Prompt for entry of patient information related to admin (vitals, response) or to view data
	Support witnessing by drug class or patient location
	Quick access view (or auto-display) of relevant lab test results at administration
	CDS medication checking at administration using third-party product (DD, DA, dose range)
	eMAR administration history display
Medication Administration – Complex	Support complex administration for meds (e.g., sliding scale, PCA, Portland protocol)
	Document actual time for STAT med administration
	CDS for look-alike, sound-alike drugs
	Patient-specific order checking at administration (wt-based, renal status) adults

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Med Admin Complex (cont'd)	Prompt to document pain scale post administration
	Ability to accommodate multiple pain scales
IV Administration	Display calculated drip rates (used to program IV pumps)
	Calculate end time from hung time (for order expiration management and redispensing)
	Basic IV administration and checking using third-party product (e.g., First Data Bank)
	Support complex IV's (e.g., sliding scale, weight-based titration, etc.)
	Ongoing reminders and interventions for IV products – periodic rescanning/monitoring and bag removal
	Support TPNs
Communication with Pharmacy	Missing dose request to Pharmacy
	Receive and send administration data to enterprise or pharmacy vendor's eMAR
	Send dose scheduling changes to Pharmacy
	Send verification priority changes to Pharmacy
Integration with Dispensing Cabinets	View medications and doses available in dispensing cabinet
	Integration with dispensing cabinets (e.g. obtain STAT med pre-pharmacy-verified order)
Report Writing/Viewing	Print MAR (intrahospital transfer to paper)
	eMAR display
	Support variance reporting
	Support utilization reporting
	Support ad hoc report writing
Misc	All order "take-off" (EKGs, labs, etc.)
	Document blood product administration
	Mini-chart function that displays allergies, height, weight, labs, meds, IVs
	Downtime functionality to batch print eMARs
	Downtime functionality to quickly enter admin times once system is back up and running (other than normal mode)

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## Appendix C. Classification of Error Types and Examples

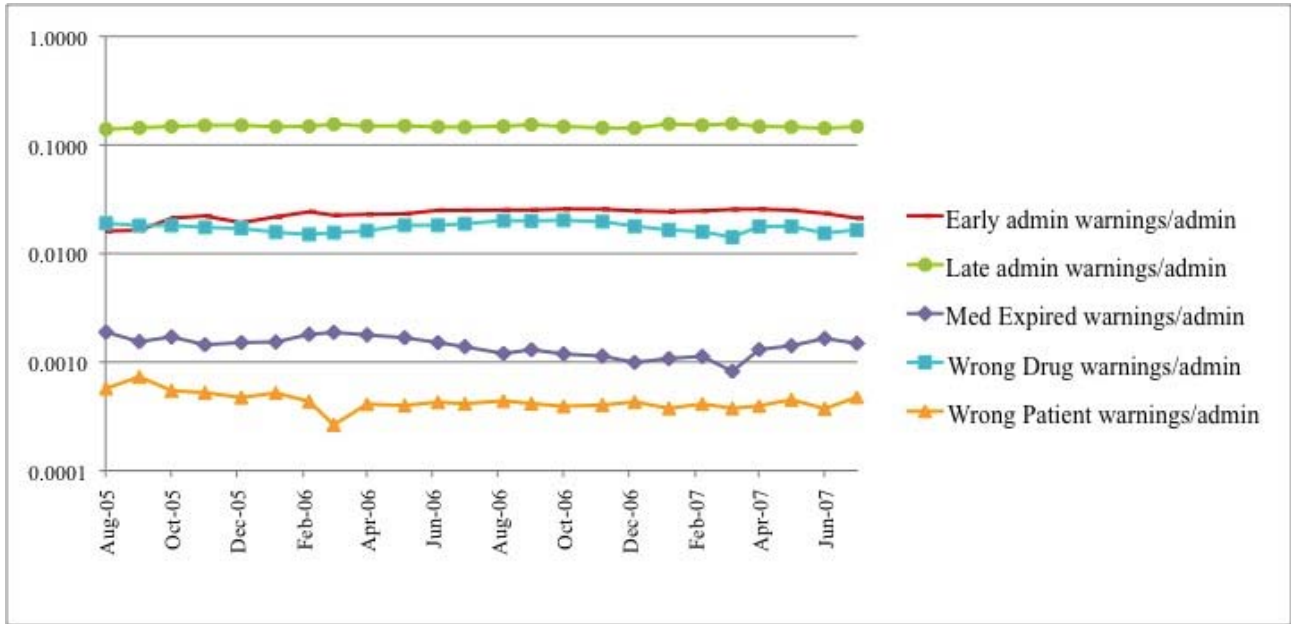
<b>Error Subtype</b>	<b>Definition</b>	<b>Example of Medication Error with little to no potential for patient harm</b>	<b>Example of Potential Adverse Event</b>
<b>Administration Errors</b>			
PO versus NG tube	A medication that is prescribed to be given PO is administered via the NG route (or vice versa).	Dilantin 100 mg PO bid was ordered but was administered via an NG tube.	Imdur 60mg PO daily was ordered but the medication was crushed and administered through an OG tube.
Administration Documentation Error	Medication dose correctly administered to patient but either not documented or incompletely/incorrectly documented in the medication administration record	Patient refused to take Senna. Nurse documented on MAR that medication was administered.	Hydromorphone 2-4mg PO was ordered every 2 hours PRN for pain. The order specifies for medication to be held for sedation. 4mg of Hydromorphone was observed to be administered, but was not recorded on the MAR.
Dose Error	Wrong dose administered to the patient. This could result in an underdose or overdose.	Patient due for 3 units of regular insulin per sliding scale orders. 2 units was administered instead (underdose)	Lopressor 25mg PO dose was ordered, but a 50mg tablet was administered to the patient. (overdose)
Wrong Medication Error	Wrong medication, or the wrong medication formulation administered to the patient	ECASA 325 mg PO daily was ordered but ASA was administered.	Lopressor 50mg po tid ordered, but Lopressor XL 50mg tablet administered to patient.
Directions/Monitoring Error	Directions for administering the medication not followed either before or after the administration. (Monitoring instructions are typically included in the order.)	Dilaudid 4-6 mg PO Q3 hours PRN pain ordered with instructions for the medication to be held for over-sedation or respiratory rate < 10 per minute. Patient's vital signs were not checked prior to administration of the dose, but respiratory rate that morning was recorded as 18 per minute.	Vancomycin IV ordered with instructions to hold administration if the patient's Vancomycin level exceeded 15. Medication was administered when patient's Vancomycin level was 28.7.
Administration without Order	Medication dose administered to patient without a documented corresponding order by physician or physician extender.	KCL 20mEq was administered without an order. Pt Labs were Creatinine 1.5, Potassium 4.4.	Patient was ordered for Fentanyl 50 - 200 mcg per hour, titrated for sedation. The patient received 2 rescue doses of Fentanyl 100 mcg boluses IV without documented MD order.
Route Error	Wrong route used for administering medication to the patient.	Mucomyst was ordered to be inhaled but was administered PO.	Zyprexa 2.5 mg SL Q6HR PRN ordered. Medication administered PO.
Early Administration Error	Administration that is more than 1 hour earlier than is scheduled in the MAR.	Zanaflex 4mg PO TID was ordered, and scheduled for 8am, 2pm, and 10pm. Dose was administered at 855am (not an error), and 11:15am (early administration error).	Atrovent QID 0.5mg INH was changed from PRN to QID at 1130 am. Pt received a dose at 10:05am and then another one at 12:00 noon as scheduled. These doses were too close together since they are supposed to be separated by 6 to 8 hours.
Late Administration Error	Administration that is more than 1 hour later than is scheduled in the MAR.	Novolog Insulin Due for administration at 08:00 but administered at 09:24am	Regular Insulin Scale SC at meal times. Observed dose at 1:10 pm when it should have been administered at 12:00 noon with the patient's meal.
<b>Transcription Errors</b>			
Directions Error	Directions stated in the order incompletely or wrongly	Directions to call the MD were not transcribed onto the MAR if the	Levofloxacin order was missing the instructions to administer at least 2 hours

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	transcribed onto the MAR	magnesium level was too high or too low. Patient has normal renal function.	before or after iron or dairy products. The patient was also ordered for iron sulfate.
Frequency	Wrong frequency or no frequency transcribed onto the MAR	Decadron 3mg PO ordered q6hr. Medication transcribed and timed on MAR as due at 06am, 12noon, 6pm, and 10pm.	Advair was ordered as BID. The medication subsequently transcribed as QID on the MAR.
Order not transcribed	Physician order not transcribed onto the MAR	None seen in study.	Sudafed 30mg PO Q12H ordered and first dose administered. Order was then changed to x1 after the first dose was administered but the change from Q12H to x1 not transcribed onto the MAR and the Q12H order remained in the MAR.
Route Error	No route or wrong route transcribed onto the MAR.	KCl Immediate Release oral replacement scale ordered. Drug route is omitted on MAR.	MS Contin was ordered PO and was transcribed onto the MAR as PNGT.
Unacceptable abbreviation	Unacceptable abbreviation used in transcription of order	Not seen in study	Magnesium Sulfate order transcribed as 'MgSO4' (which could be confused with morphine).
Dose Error	Wrong dose transcribed or dose not transcribed onto the MAR	Patient ordered for low-dose KCL replacement scale. Specifics of KCL replacement scale correctly transcribed onto MAR, except the transcription did not specify whether the scale was ordered as 'low-dose' vs 'high-dose'.	Not seen in study
Illegible transcription	Part or whole transcription not legible	Not seen in study	Losartan order illegibly transcribed.
Substitution	An incorrect formulation of a medication substituted for the correct formulation during the transcription process	Chewable form of Aspirin ordered, but enteric coated form of Aspirin transcribed.	Effexor XR 75mg ordered Effexor 75 mg transcribed.
Wrong Time	Inappropriate time scheduled for the medication administration	Heparin SC TID order written at 9pm, with specific instructions to start first dose that same evening. The first dose was scheduled for the following morning at 8am, with subsequent doses scheduled for 2pm and 8pm.	Not seen in study
Duplicate transcription from single order	Multiple active entries made in the MAR for a single order	Calcium Carbonate (500 mg Elem. CA++) 4,000 mg po QID. Two entries of the order made in the MAR.	Not seen in study
Med not discontinued	Medication order discontinued but corresponding entry left active in the MAR	Duoneb q6hr order changed to q6 PRN for SOB. New order was transcribed to the PRN section of MAR but old order was not discontinued from the recurring medication section of the MAR.	Not seen in study

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## Appendix D Administration Error Warnings Issued by Barcode-eMAR Per Dose Administrated After Go-live Period



During the 2 years after the implementation period, the usage of barcode-eMAR at the study hospital remained stable, with an average of 400876 medication doses administered with the assistance of barcode-eMAR to 4582 patients per month.