

# Introduction of Closed Loop Medication Management System for Inpatient Services in Singapore

Wu Tuck Seng

Deputy Director & Head, Pharmacy Department  
National University Hospital (NUH), Singapore

# Medication Errors in the Wards

	1	2
• Prescribing	39%	49%
• Transcription	12%	11%
• Dispensing	11%	14%
• Administration	38%	26%

<sup>1</sup> Leape et al, JAMA, 274: 35-43

<sup>2</sup> Bates, D, J Qual. Clin Practice (1999), 19:13-17

# Main Objectives of CLMMS

- Enhanced Medication Safety Process
  - Ensure 4 Rights of medication safety

✓ Right Patient

✓ Right Drug

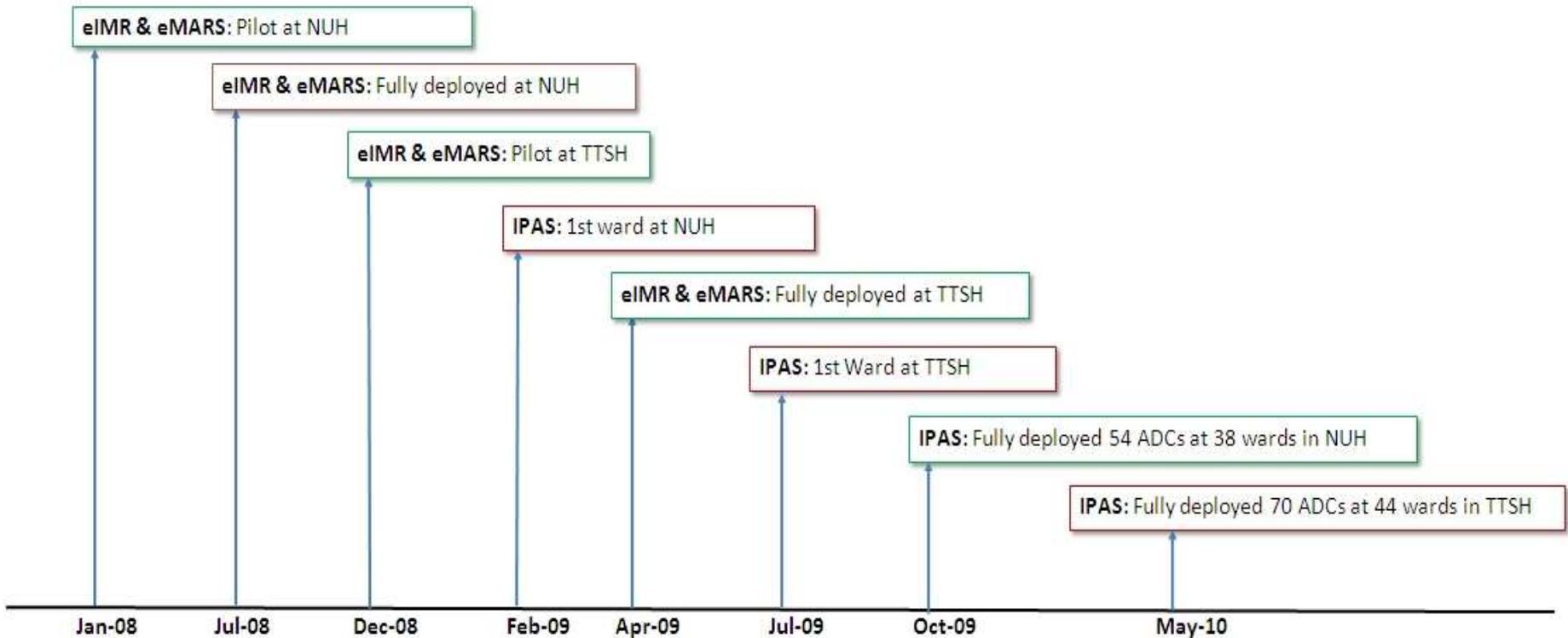
✓ Right Dose

✓ Right Time

- Review of Order by Pharmacists and automated checks

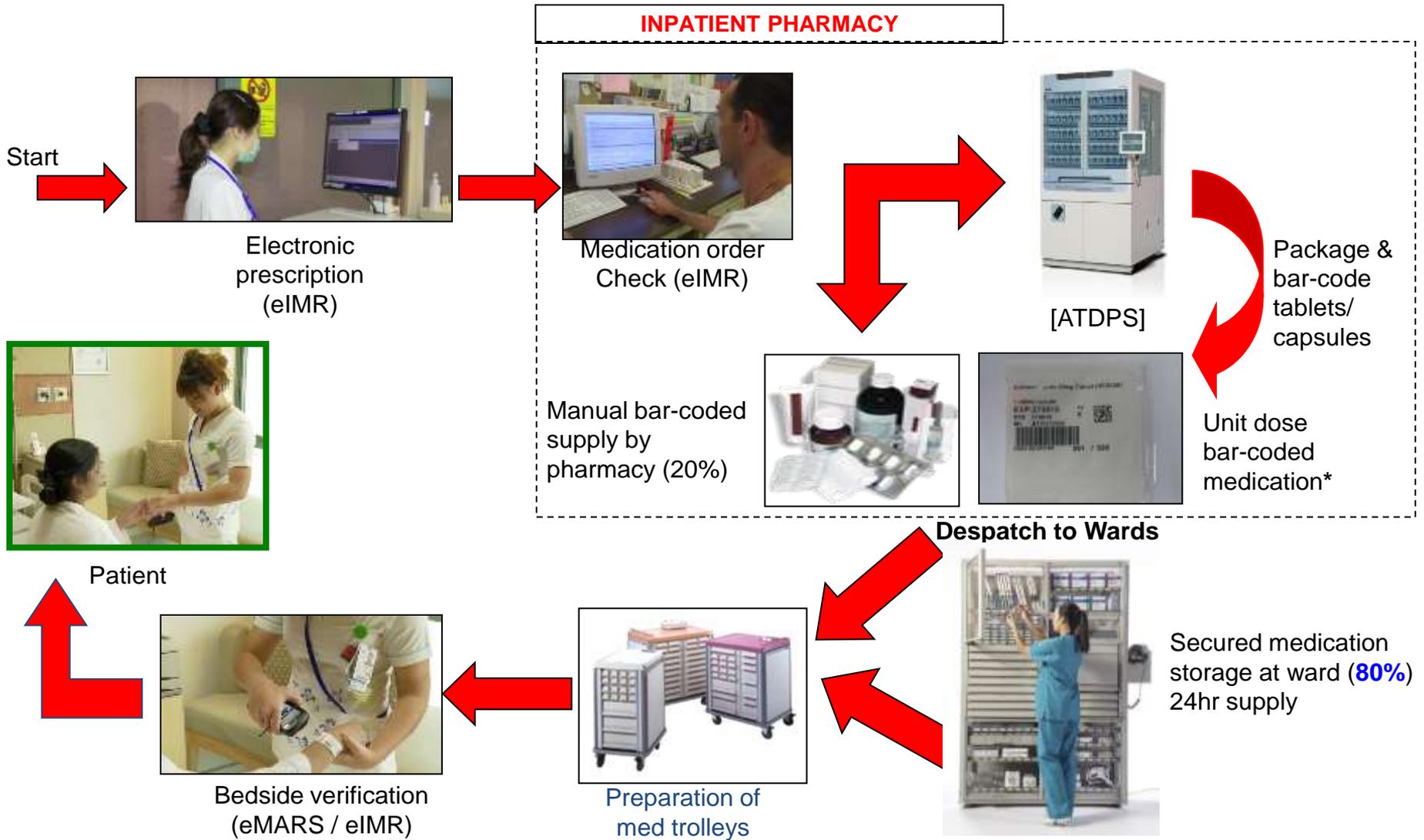
- Efficiency of ward processes
  - Reduced turn around time for medication stock.
  - Reduced time required to administer medications to patients

# Project Mile Stones : Scalability of System



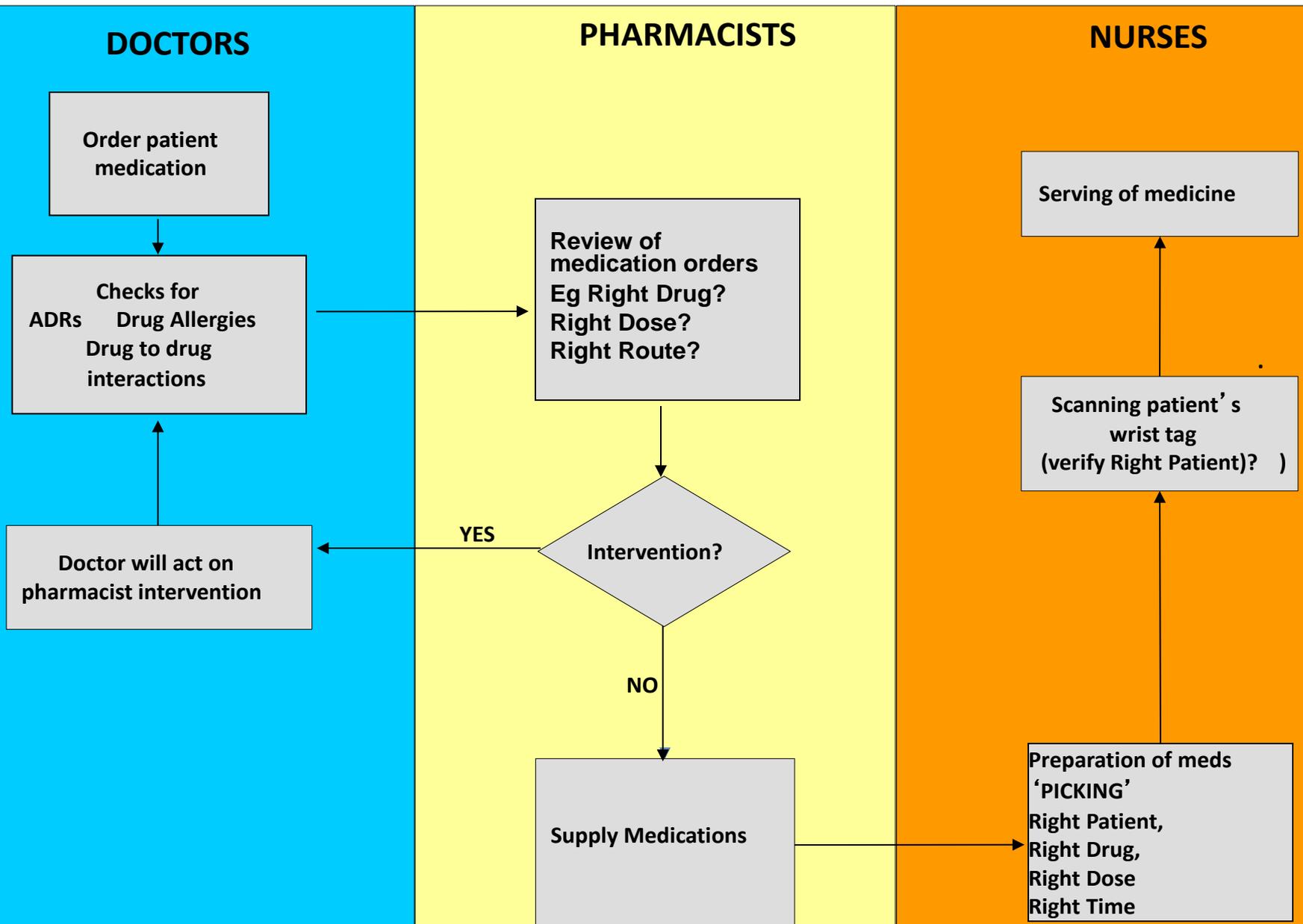


# Workflow for Inpatient Closed Loop Medication Management System (CLMMS)

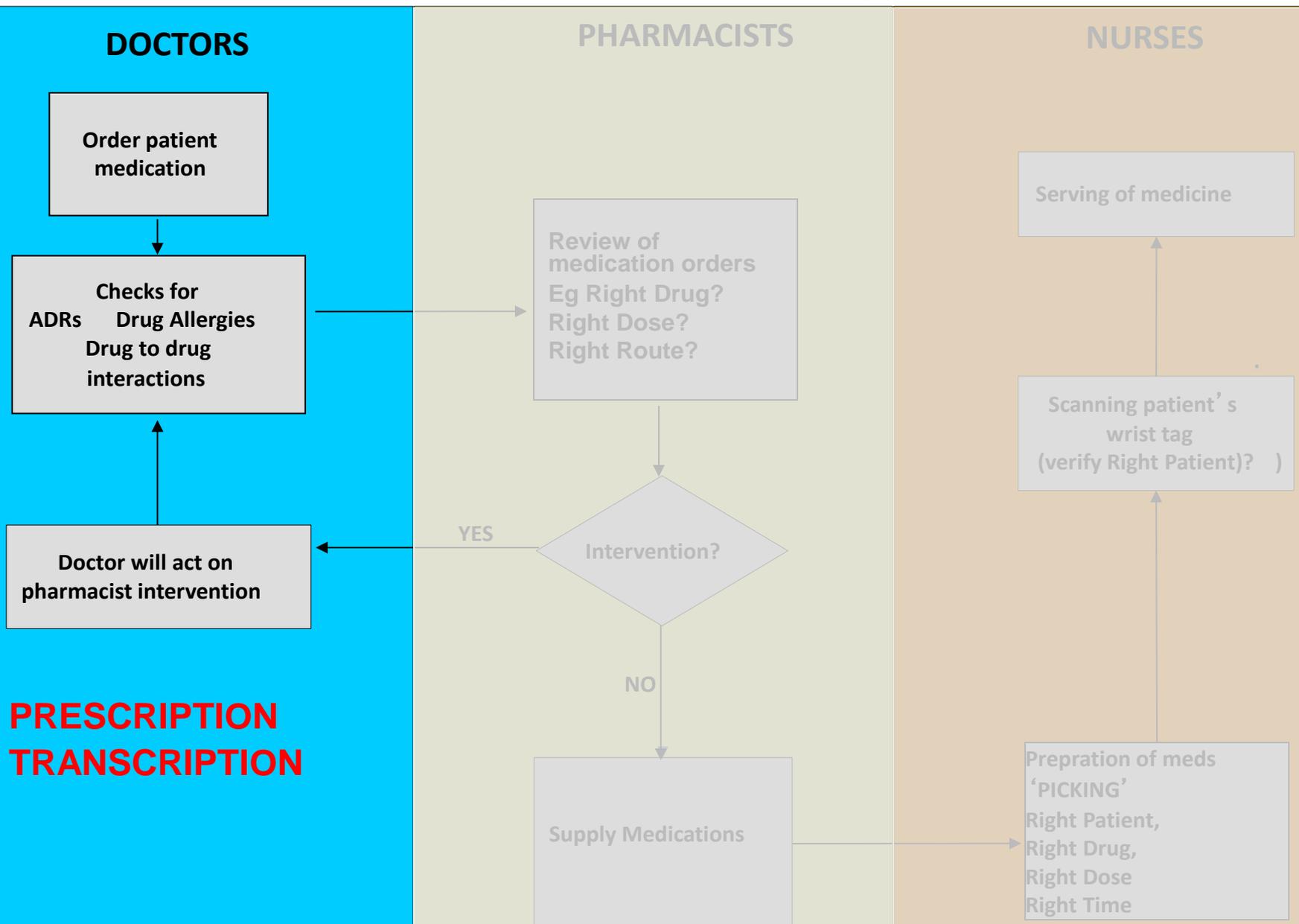


- \* Patient-specific packs delivered to med trolleys.
- Non-patient specific topped up in OmniRx units

# Introduction – Medication Use Process



# Prescription and Transcription



Patient D  
NRIC: S0287937I  
LEE JON CHOON EVAN  
Weight(kg): N/A | Height(m): N/A | BSA: N/A | NBM: NA  
MALE 73 year(s) (25 Dec 1934)  
Acct No: 1560132037I  
Ward 52 (Ortho, Surg)  
Bed: 22

**ADR/DA**  
Mefenamic Acid

**Medical Alerts**

Inpatient Med Order Med A User: linxiyan Institution Code: NUH

Oral/Non-Parenteral \* [View All Medications \\*](#)

	Start Date/Time	Route		se	Freq	Dur	No of Doses	Step	End Date	Instr
	03Sep	PO		0 mg	6H PRN					
	05Sep	Inhalat		uff	BD					Use strictly
	08Sep	PO		0 mg	ONCE				08Sep	
	08Sep	PO	Amiodarone HCl [CORDARONE®]	Tablet	200mg	200 mg	TDS	2 weeks	THEN	21Sep
	22Sep	PO	Amiodarone HCl [CORDARONE®]	Tablet	200mg	200 mg	BD	1 week		28Sep

This red flag indicates the patient has drug interaction and ADR/DA alerts that are overridden. Double click on this icon to view the detailed summary for all drugs.

Drug interaction and ADR/DA alerts that are overridden are indicated with a "red flag". Double click on this icon to view the detailed message for this drug.

Patient D  
 NRIC: S0287937I  
 LEE JON CHOON EVAN

MALE 73 year(s) (25 Dec 1934)  
 Acct No: 1560132037I

Ward 52 (Ortho, Surg)  
 Bed: 22

ADR/DA  
**Mefenamic Acid**

Medical Alerts

Weight(kg):  ADR/DA And Drug To Drug Interaction Alert Summary

Inpatient Med C

Oral/Non-Parent

Oral/Non-F

	Start Date/Ti
	03Sep
	05Sep
	08Sep
	08Sep
	22Sep

ADR/DA And Drug To Drug Interaction Alert Summary

Alert Type	Med Component	Interact With	Med Component	Reported ADR/DA
Drug Interaction	Propofol 200mg/20mL Inj	Interact With	Amiodarone HCl [CORDAR...	

Drug To Drug Alert Details

**Interaction:** Cardiovascular adverse effects (e.g. atropine-resistant bradycardia, sinus arrest, AV block) have occurred in some amiodarone-treated patients undergoing general anaesthesia. Close monitoring is recommended.

**Observation:** increases toxicity of

**Action:**

1. Use combination with extreme caution.
2. Monitor patient clinically.
3. Monitor cardiac function.

**Override Reasons:** Not Specified

**Overridden On:** 2008/09/08 14:22:07

**Overridden By:** linxiyan

**User Remarks:** Not Specified

Close

Code: NUH

Instr

Use strictly

# CDSS – Example of Drug-Lab Results Checking

NHIG eIMRIMAR [UAT ver 8.0.0.19] - [Medication Administration]

Select Patient Medication Order Pharmacist Review Medication Administration Reports System Drug Info Logout

Weight(kg): N/A | Height(m): N/A | BSA: N/A | NBM: NA

ADH/DA  
No Known AD

Patients' Overview Inpatient Med Admin **Med Administration Record**

Oral/Non-Parenteral\* Parenteral\* Fluid Infusion\* Nebulising Med Blood Product Sliding Scale View All Medications

View All Medications  View All Dates << 30/06/2010 >>  View Active Medications Only Show Columns

Start Date/Time	Route	Medication	Dosage Regimen
29Jun	PO	MAREVAN® [Warfarin Sodium] Tablet	5 mg QM
29Jun	PO	MAREVAN® [Warfarin Sodium] Tablet	5 mg ONCE
29Jun	IV	Dextrose 5%, Sodium Chloride 0.33% with Potassium Chloride 10mmol/500mL Inf 500 mL Infuse over 24 hr at 20.83 mL/hr	

CDSS prompts an alert when:

- 1) Patient is on Warfarin and INR result is high
- 2) Patient is on Potassium Supplement(s) & serum K result is high

Clinical Decision Support System

All Active Alerts [2]

29-Jun-10: 14:32 - Drug-Lab (INR) Alert

Summary Details

Pls review this MAREVAN® [Warfarin Sodium] Tablet order as patient's INR result is high.

**Select one or more of the medication(s) to discontinue:**

1. MAREVAN® [Warfarin Sodium] Tablet; PO; 5 mg QM; 29Jun-10; 11:51; NUH;

**Suggested Action(s):**

1. This patient has a recent INR result of >=4.
2. Please discontinue or lower the dose of the above order.

Feedback I'll Take Action Reject Review Later

29-Jun-10: 14:32 - Drug-Lab (Potassium) Alert

Summary Details

Pls review this Dextrose 5%, Sodium Chloride 0.33% with Potassium Chloride 10mmol/500mL Inf order as patient's serum potassium result is high.

**Select one or more of the medication(s) to discontinue:**

1. Dextrose 5%, Sodium Chloride 0.33% with Potassium Chloride 10mmol/500mL Inf 500 mL Infuse over 24 hr at 20.83 mL/hr; IV; : 29-Jun-10; 11:46; NUH;

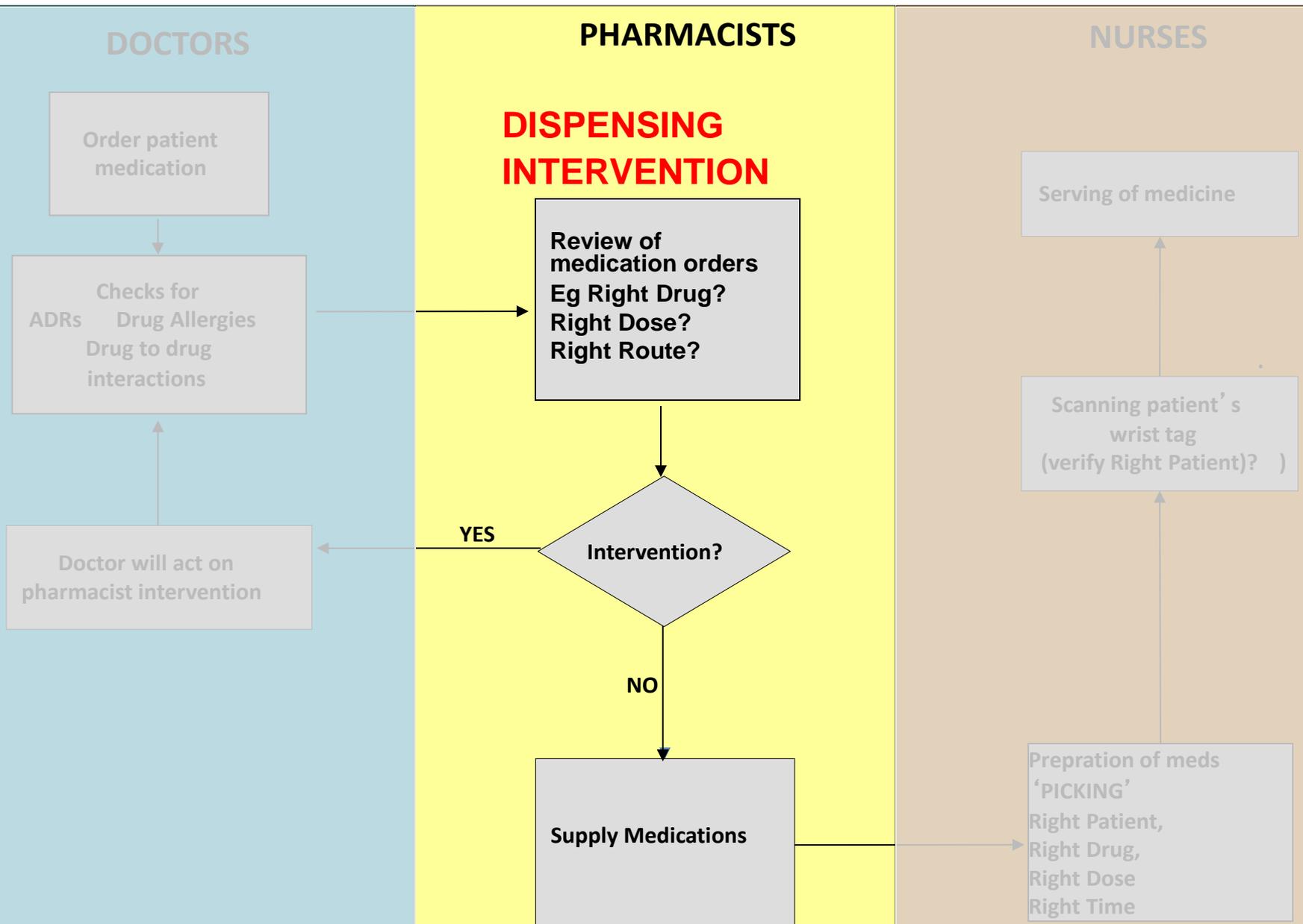
**Suggested Action(s):**

1. This patient has a recent serum potassium result of >5.5 mmol/L.
2. Please discontinue the above order.

Feedback I'll Take Action Reject Review Later

Read Me Now!

# Dispensing and Intervention



Patient D MALE 73 (25 Dec 1934) Ward/Bed :  
 NRIC : S02879371 Acct No : 15601320371  
 LEE JON CHOON EVAN Ward 52 (Ortho, Surg) / 22  
 Height(cm): N/A Weight(kg): N/A BSA: N/A NBM except medications

ADR/DA  
**Mefenamic Acid**

Medical Alerts

Patients' Overview **Inpatient Med Admin** Med Administration Record User: limtiehben Institution Code: NUH

Oral \* Non-Parenteral Parenteral \* Fluid Infusion \* Nebulising Med \* Blood Product \* Sliding Scale \* View All Medications \*

Oral [Deselect All New Orders](#) [Select All New Orders](#)

	Start Date/Time	Route	Medication	Dose Regimen	End Date	Instr	Non - Stock	ReSu	Review Status	
	14Aug	PO	VOLTAREN [Diclofenac Sodium] 25mg Tablet	25 mg TDS			STK	N	Intervention	<input type="checkbox"/>
	14Aug	PO	Aspirin [CARDIPRIN®] 100mg Tablet	100 mg OM			STK	N	Ordered	<input type="checkbox"/>
	14Aug	PO	Warfarin Sodium [MAREVAN®] Tablet	7 mg OM	21Aug		STK	N	Reviewed with comment	<input type="checkbox"/>

Review with comment

**Create Intervention** **Review Selected Orders**

Translated Order

	Day	Date	Time	No	Medication	Qty	Unit	ReSu	Admin Status	Supply Status
T	1	14 Aug 2007	20:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied
T	2	15 Aug 2007	08:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied
T	2	15 Aug 2007	13:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied
T	2	15 Aug 2007	20:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied
T	3	16 Aug 2007	08:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied
T	3	16 Aug 2007	13:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied
T	3	16 Aug 2007	20:00	1	VOLTAREN [Diclofenac Sodium]	1	Tablet	N	Intervention	Unsupplied

Change Warfarin Sodium [MAREVAN®] Status to for 1 days Apply Undo Done

**Patient D**      **MALE 73 (25 Dec 1934)**      **Ward/Bed :** ✖  
**NRIC : S02879371**      **Acct No : 15601320371**  
**LEE JON CHOON EVAN**      **Ward 52 (Ortho, Surg) / 22**  
**Height(cm): N/A**      **Weight(kg): N/A**      **BSA: N/A**      **NBM except medications**

**ADR/DA** 🔍  
**Mefenamic Acid**

**Medical Alerts**

**Patients' Overview**   **Inpatient Med Admin**   **Med Administration Record**      User: limtiehben      Institution Code: NUH

**Oral**   **Non-Parenteral**   **Parenteral \* Fluid Infusion**   **Nebulising Med \***   **Blood Product \***   **Sliding Scale \***   **View All Medications \***

**Fluid Infusion** [Deselect All New Orders](#)   [Select All New Orders](#)

	Start Date/Time	Medication	Dose Regimen	End Date	Instr	Non - Stock	ReSt	Review Status	
	14Aug	<b>Amino Acid (Paediatric) Inf 250 mL infuse over 24 hr @ 10.42 mL/hr</b>				STK	N	<b>Reviewed</b>	<input type="checkbox"/>
	14Aug	Hartmann's Solution [Compound Sodium Lactate] Inj 1000 mL + Vitamin C 100mg/2mL Inj 100 mg PER 500 mL infuse over 24 hr @ 41.67 mL/hr				STK	N	Reviewed	<input type="checkbox"/>
	14Aug	NS [Sodium Chloride 0.9%] Inf 500 mL + Calcium Gluconate 10% Inj 1 mg PER 500 mL infuse over 24 hr @ 20.83 mL/hr				STK	N	Reviewed	<input type="checkbox"/>
	14Aug	DS [Dextrose 5%, Sodium Chloride 0.9%] Inf 1.5 L + KCl [Potassium Chloride] 7.46% Inj 10 mmol PER 500 mL ALTERNATE WITH NS [Sodium Chloride 0.9%] Inf 1 L + Ascorbic Acid 100mg/2mL Inj 2 mL PER 500 mL + Vitamin B1 [Thiamine HCl] 200mg/2mL Inj 1 mL PER 500 mL + Vitamin B Complex Inj 2 mL PER 500 mL infuse over 24 hr @ 104.17 mL/hr			Alt	STK	N	Reviewed	<input type="checkbox"/>

**Create Intervention**      **Review Selected Orders**

**Translated Order**

	Day	Date	Time	No	Medication	Qty	Unit	ReSt	Admin Status	Supply Status
<b>T</b>	<b>1</b>	<b>14 Aug 2007</b>	<b>16:35</b>	<b>1</b>	<b>Amino Acid (Paediatric) Inf</b>	<b>1</b>		<b>N</b>	<b>Reviewed</b>	<b>Packed by pharmacist</b>

Change **Amino Acid (Paediatric) Inf**   Status to   for **1**   **days**   **Apply**   **Undo**   **Done**

Patient D MALE 73 (25 Dec 1934) Ward/Bed :   
 NRIC : S02879371 Acct No : 15601320371  
 LEE JON CHOON EVAN Ward 52 (Ortho, Surg) / 22  
 Height(cm): N/A Weight(kg): N/A BSA: N/A NBM except medications

ADR/DA   
**Mefenamic Acid**

Medical Alerts

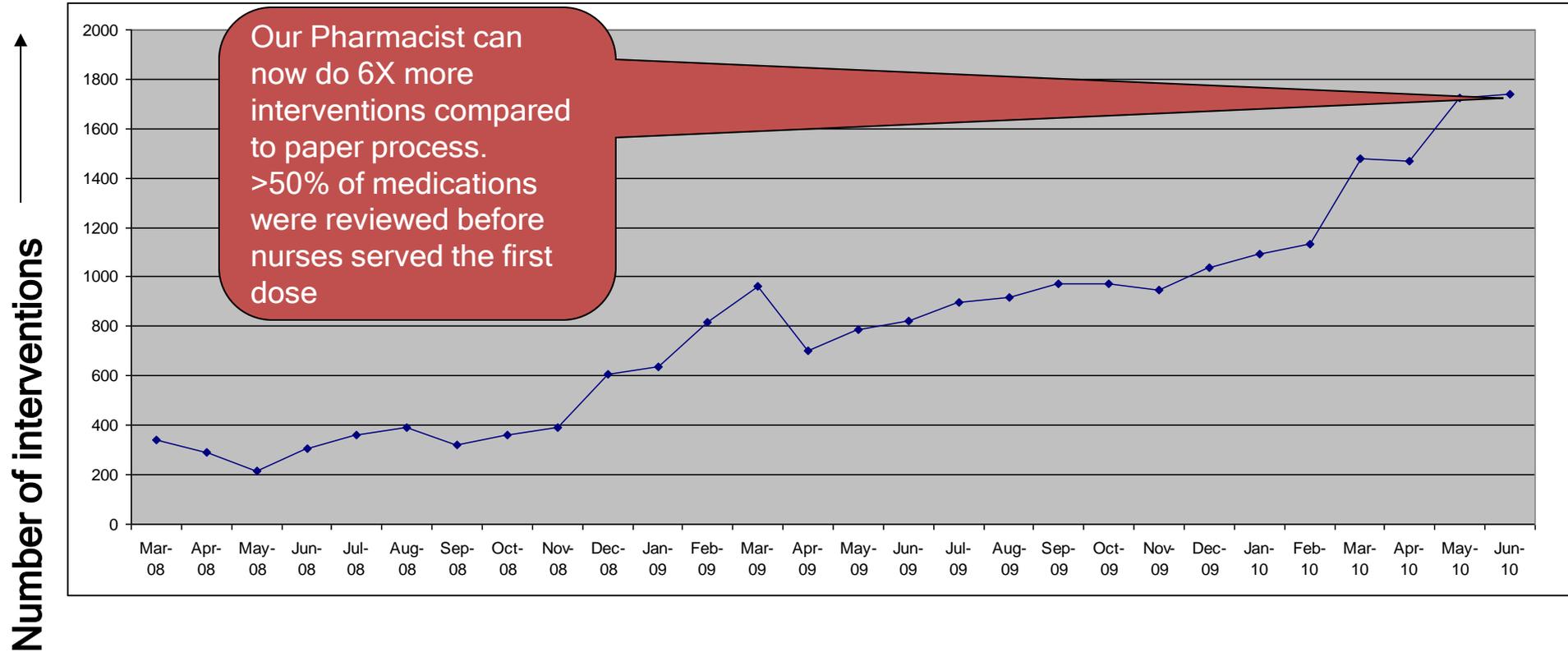
**Inpatient Med Order** **Med Administration Record** User: limtiehben Institution Code: NUH

**Oral/Non-Parenteral \*** **Parenteral Med \*** **Fluid Infusion \*** **Nebulising Med \*** **Blood Product \*** **Sliding Scale \*** **View All Medications \***

Oral/Non-Parenteral													
		Start Date/Time	Route	Medication	Dosage Form	Strength	Dose	Freq	Dur	No of Doses	Step	End Date	Instr
		14Aug	PO	Aspirin [CARDIPRIN®]	Tablet	100mg	100 mg	QM					
		14Aug	PO	Warfarin Sodium [MAREVAN®]	Tablet		7 mg	QM				21Aug	
		14Aug	PO	VOLTAREN [Diclofenac Sodium]	Tablet	25mg	25 mg	TDS				14Aug	

Doctor Reviews the Highlighted interventions

# Pharmacist Interventions in NUHS



Implementation of eIMR →

The higher number of interventions = higher avoidance of drug errors

# Inpatient Pharmacy Automated System

1



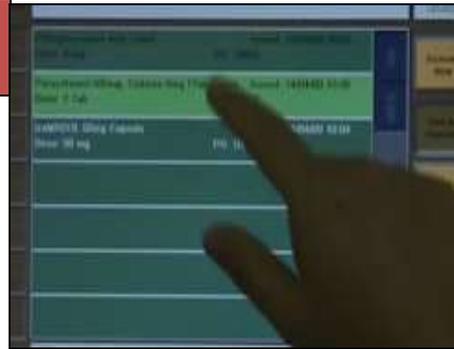
Nurse logs in

2



Nurse selects a patient

3



Nurse selects the medications

4



Guiding lights to the correct drawer

5



Nurse places medications into the medication trolley

6



Nurse scans bar-coded meds & patient id wrist tag

7



Nurse serves medication



Bar-coded Unit dose sachet

# eMARS : Electronic Medication Administration System



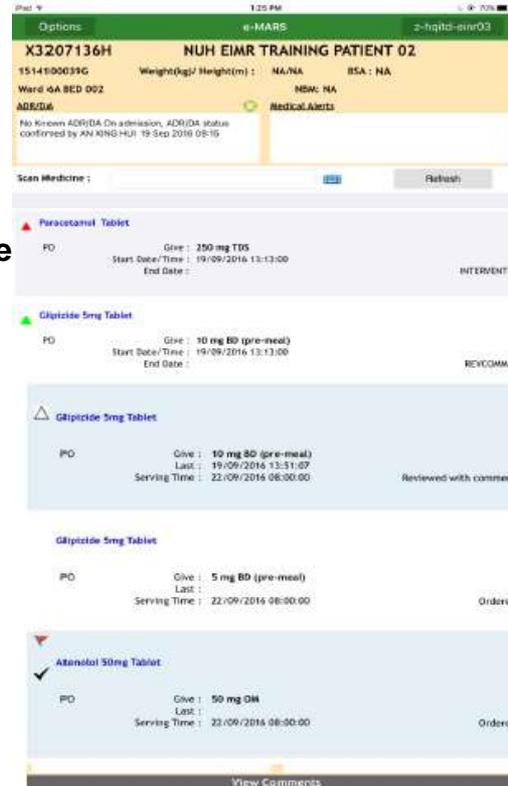
Barcoded Medication

Scans Name Tags  
&  
Medication Rings

Pharmacy Intervention  
Cannot proceed to serve

Pharmacy Intervention  
Can proceed to serve

Drug Interaction Flag



Drug allergies and alerts  
On CMIS

# Electronic Medication Administration System



Barcoded Drugs  
rollout

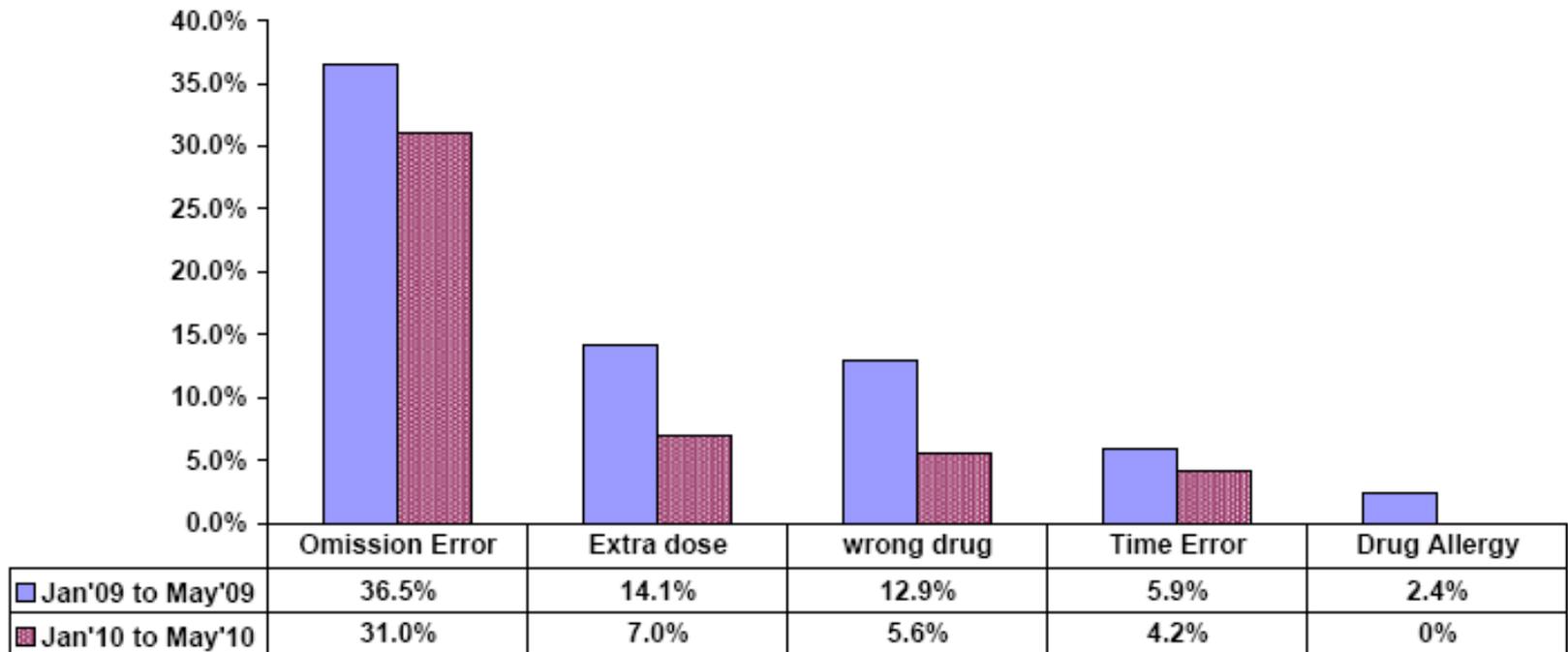
Month-Year	Prevention of Wrong Medication	Detection of Wrong Patient
Jun-10	6060	4972
May-10	5774	5682
Apr-10	5015	5649
Mar-10	2704	4783
Feb-10	846	5362
Jan-10	737	4972
Dec-09	417	4079
Nov-09	310	3656
Oct-09	312	4379

The PDA prevent about 150 wrong patient servings and 150 wrong drug servings per day.

We must leave nothing to chance !

# Reported Medication Error Rate by Type in NUHS

## Inpatient Administration Medication Error Type (Jan'10 to May'10 Compared with Jan'09 to May'09)

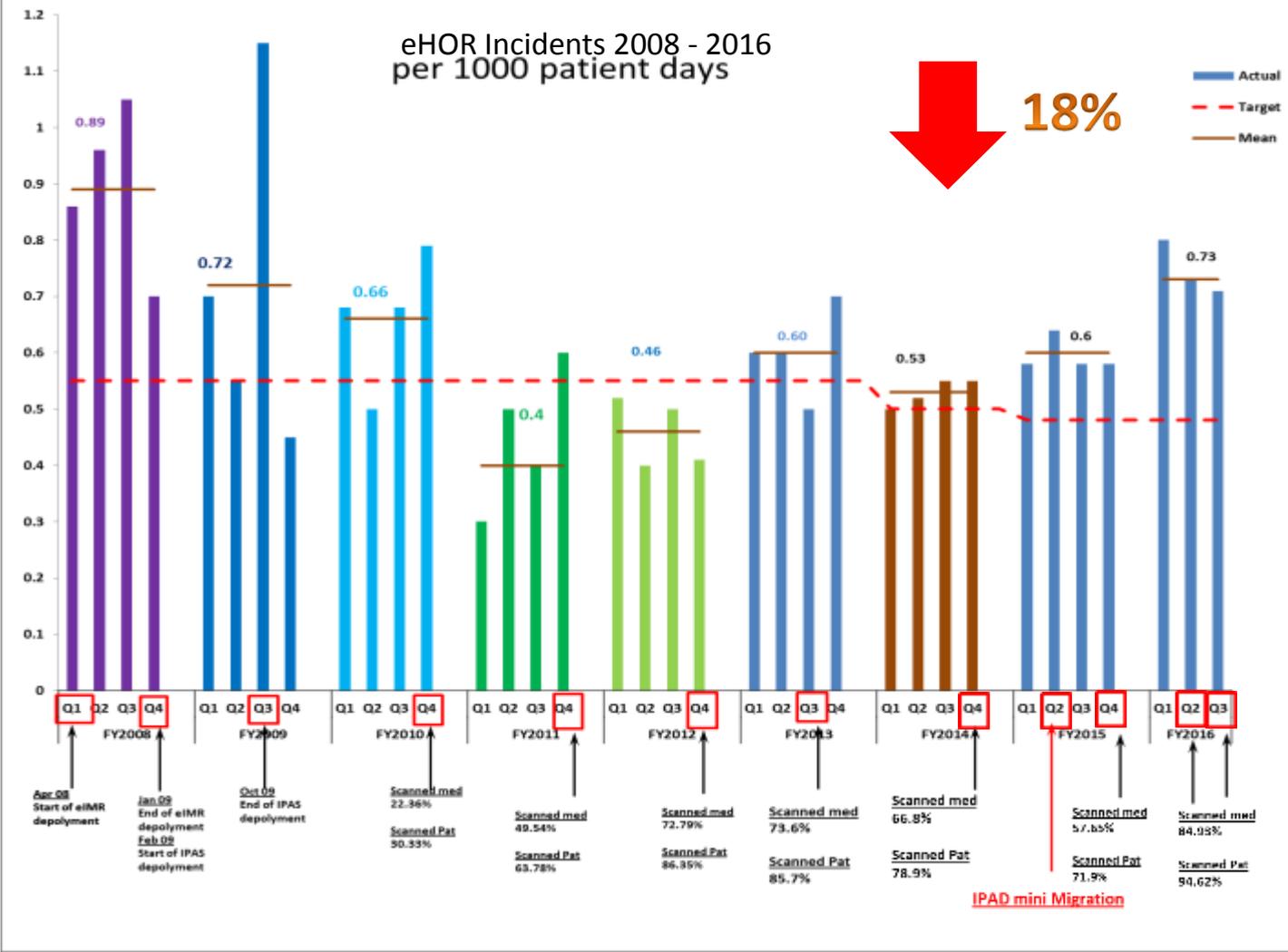


### Overall Improvements after Implementation of Closed Loop Medication Management System:

- Overall reduction of administration errors by 16.5%
- Zero incidents in drug allergy
- Reduction in extra dose
- Reduction in wrong drug

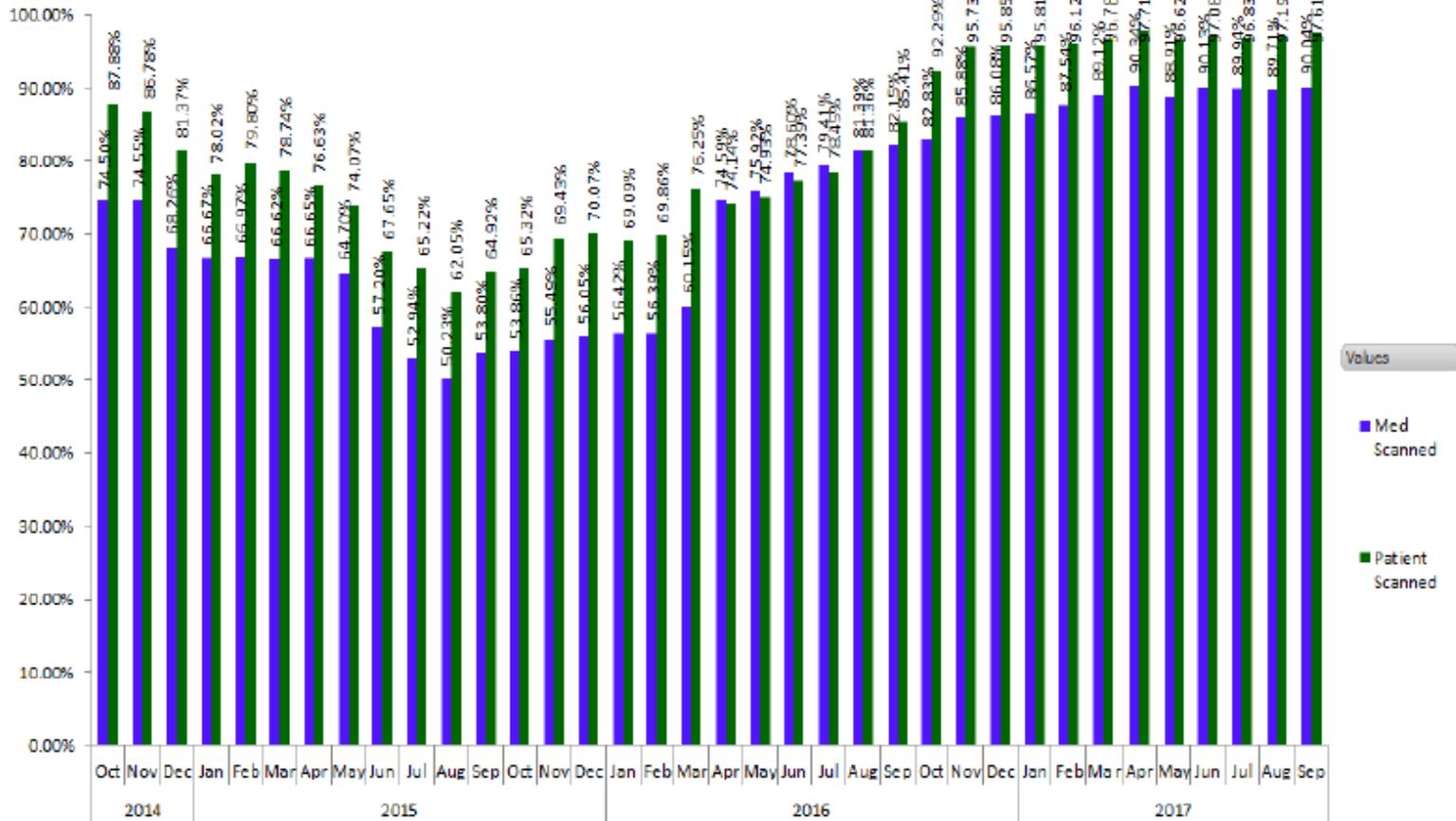
# eHOR Incidents 2008 - 2016 per 1000 patient days

**18%**

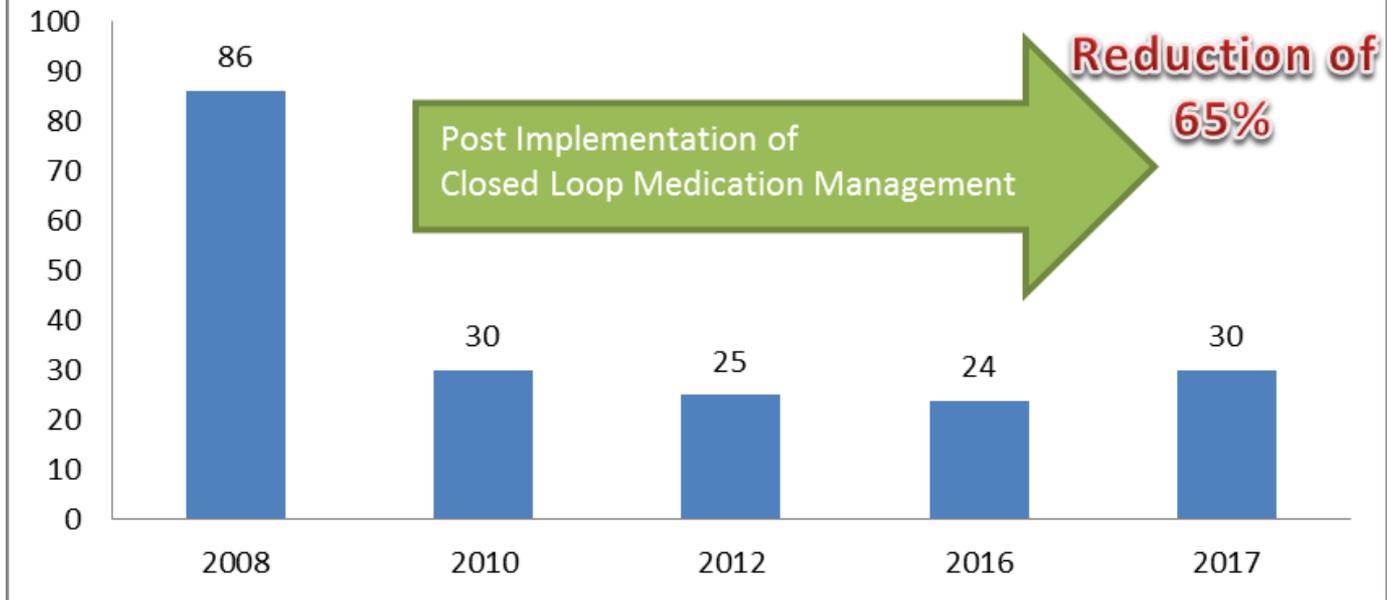


IPAD mini Migration

# eMARS : Electronic Medication Administration System Scanning Compliance



## eHOR Data: Preventable CLMMS Incidents



### Comments:

- There was a sustained 65% reduction post implementation of CLMMS
- Errors which continued to occur are due to non-compliance in usage of CLMMS, ie users did not scan available barcodes or overridden system checks.

### Notes:

- Year 2016 dataset was annualized from Oct – Dec 2016 eHOR data.
- Year 2017 dataset was annualized from May-Jun 2017 eHOR data

# Key Performance Indicators (KPIs)

<b>KPIs</b>	<b>Fulfillment</b>	<b>Current Results</b>
<b>At least 80% of Med Orders stocked in Cabinets</b>	<b>Fulfilled</b>	<b>80% of medication orders are stocked in cabinets</b>
<b>Safe Picking of Medications</b>	<b>Fulfilled</b>	<b>Prevented 3 errors per 100 Patient Days</b>
<b>Correct Medications Admin</b>	<b>Fulfilled</b>	<b>Prevented 7.1 errors per 100 Patient Days</b>
<b>Secure Medication Storage</b>	<b>Fulfilled</b>	<b>System mandates user login</b>
<b>Improved work efficiency, redeployment to patient centric activities</b>	<b>Fulfilled</b>	<b>Nursing saves 22 FTEs, but Pharmacy incurs 4 PA FTEs and saves 0.5 pharmacist FTE</b>
<b>Restocking process is streamlined with real time inventory</b>	<b>Fulfilled</b>	<b>Single trips are made to wards to restock medications, compared with double trips previously</b>
<b>Reduction of wastage</b>	<b>Fulfilled</b>	<b>Wastage reduction of \$3 406 per year (18% saving)</b>
<b>Automated billing ensures efficient, timely and accurate billing</b>	<b>Fulfilled</b>	<b>0.6 PA FTE saved with interim implementation of MCE. 1.5 PA FTE projected savings with full implementation</b>
<b>85% of medications to be barcoded</b>	<b>Exceeded</b>	<b>91% of medications administered are barcoded (Prior to outsource: 40%)</b>

# Benefits Achieved:

## Safety

Number of actual drug allergies reported **dropped from 9 to 0!**

**22** Nursing Headcounts Saved! 4 Pharmacy Asst headcounts added, 0.5 pharmacist headcount saved

Number of reported medication errors **decreased by 18%**

Increased availability of medications in wards for patients, **from 65% to 80%**

System prevents **4972** times of medication administered to wrong patient a month!

Automated Billing saves **1.5** Pharmacy Asst Headcounts

System prevents **6060** times of wrong medication administered a month!

Reduced Medication Wastage (18% savings)

## Efficiency

This translates to **SGD 1 million dollars** saved annually by avoiding costs due to medication errors and improved efficiency

# IPAS Model Comparison

1.  $A = \text{eIMR} + \text{Pill Picker (Swisslog)} + \text{ADC} + \text{eMARS}$
2.  $B = \text{eIMR} + \text{ADC only} + \text{eMARS}$

# Unit Dose Packaging Machine

**A**

**B**

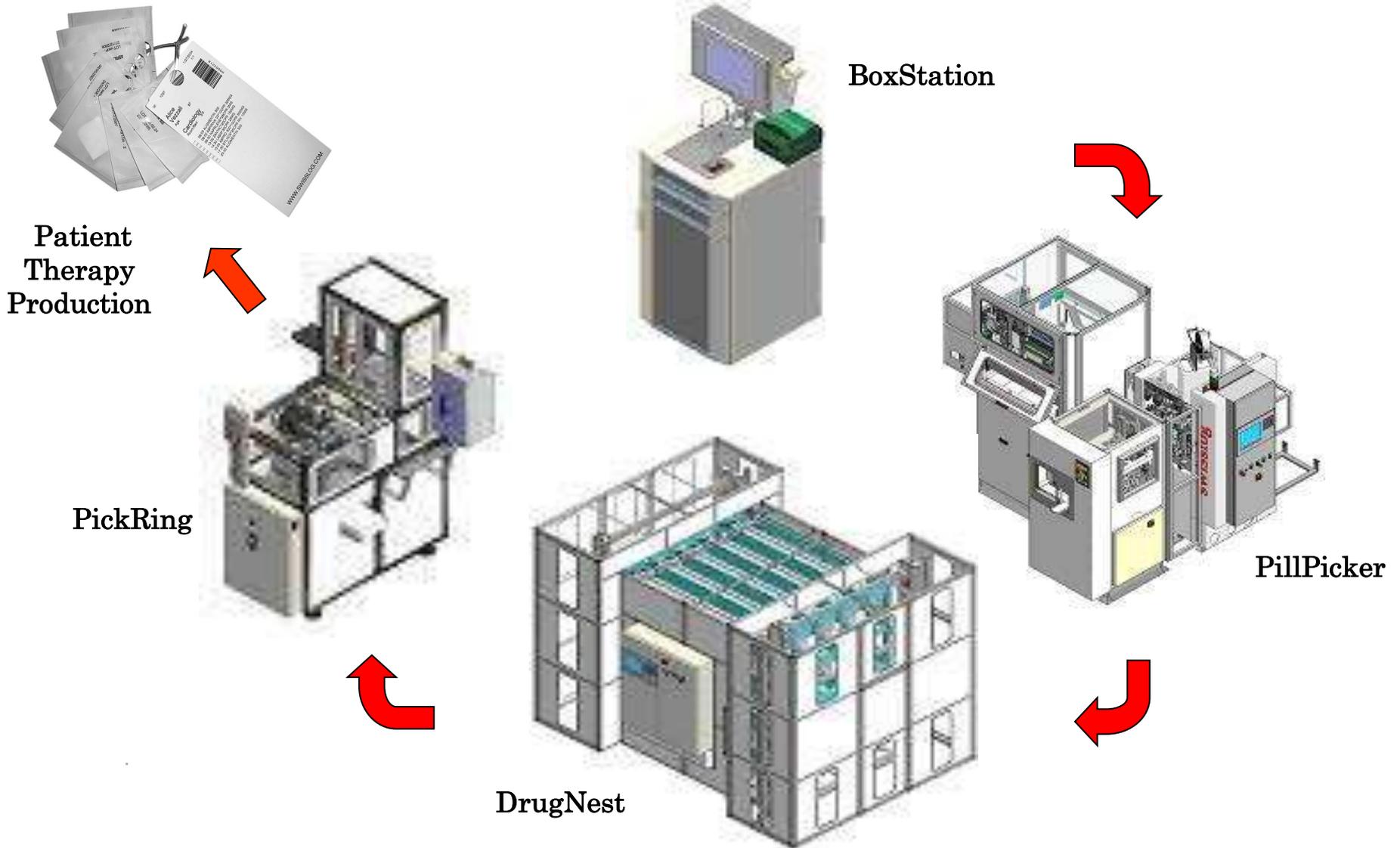
Brand

Swisslog PillPick

JVM ATDPS



# Swisslog - PillPick System



# Patient Therapy



# Unit Dose Packaging Machine Features



	A (Swisslog)	B (JVM)
Unit dose packaging	Pillpicker & Autophial (Loose tablets/capsules, blister strips, vials, ampoules)	ATDPS (Loose tablets/capsules)
Storage of unit doses	Drug Nest	Manual on shelving
Transfer, storage and retrieval of unit doses	Picking arm	Manual process
Picking, sorting, validation and assembly	Pick Ring (Assembly into patient or drug specific rings)	Manual Process
Verification of supply	Vision system	Manual Process
Return and re-use of unit doses	Return panel	Manual Process

# Automated Dispensing Cabinet (ADC)

	A	B
Physical		
Brand	Pyxis MedStation ES	Omniceil G4
Differentiating Factors	<p>Locate drugs by bin location.</p> <p>Barcode scan unlocks specific bin for re-stocking of individual drugs.</p>	<p>Locate drugs by light-guided pick and bin location.</p> <p>All bins light up at the same time; choose correct drugs to be topped up and scan barcode to confirm prior to re-stocking.</p>

# Ancillary Machines

	A	B
Machine	<p>Blispack</p>  A tall, white, industrial-grade machine with a control panel and a screen at the top. It has a cabinet with two doors and a small drawer at the bottom.	<p>Sepha Press Out Semi - Automatic</p>  A smaller, white, boxy machine with a control panel on the front featuring a red emergency stop button and a green start button. It has a hopper on top and a tray at the bottom.
Use	<ul style="list-style-type: none"><li>- Unit dose packaging for Paracetamol</li><li>- Cut asymmetrical blister strips into unit dose</li></ul>	<p>De-blistering blister strips</p>

# Workflow



	A	B
Stat / Initial Doses For First 24 Hours	85% supplied from ADC; 15% from Central Pharmacy	80% supplied from ADC; 20% from Central Pharmacy
Routine Doses	From Central Pharmacy in patient-specific rings for next 24 hours (except injections and prn doses from ADC) 28% from ADC and 72% from Central Pharmacy	Supplied from ADC (80%) and Central Pharmacy (20%) No wait time for drugs as they are sourced from ADC
Nursing Impact	Most doses combined and sequenced for easier administration	More dose picking for administration
Pharmacist Impact	Returns are processed automatically by Swisslog	Returns are done by nurses into ADC. Unused unit doses are re-useable. There is no reprocessing required

# Processing Load



	A	B
No. of Acute Beds	1,782	1,150
Unit Doses Supplied Per Day	22,344	11,327
No. of Unit Doses Packed / Day by machine	17,208	6,796
% of unit dose packed	77%	60%
<b>Cost per unit dose packed</b>	<b>\$0.062</b>	<b>\$0.033</b>

# Comparison Summary To Provide Unit Doses



	A	B
No. of Acute beds	1,782	1,150
Unit Doses Supplied Per Day	22,344	11,327
<b>Cost / Unit Dose *</b>	<b>\$0.22</b>	<b>\$0.28</b>

\* Comparison does not take into account total business costs such as manpower to run operations and differences in work processes.

# Comparison Summary of Total Costs of IPAS



	A	B
<b>Net TCO Per Year / Bed *</b>	<b>1.68 times more expensive</b>	<b>1.0</b>

\* Comparison does not take into account total business costs such as manpower to run operations and differences in work processes.

# Cost Avoidance - Manpower



	A	B
Additional Pharmacy FTE	18.3	2.5
Nursing FTE Savings	55.7	22
Porter FTE Savings	7.8 (= 3.9 FTE PT/SN)	NA
No. of FTE Saved	41.3	19.5

PT = Pharmacy Technician

SN = Staff Nurse

Assumption – PT and SN salary are similar

Thank You

# Automated Dispensing Cabinet (ADC) Comparison

## Automated Dispensing Cabinet (ADC)

- Computerized drug storage device or cabinet designed for hospitals
- Allows medications to be stored and dispensed while controlling and tracking drug distribution
- set of clients that holds barcoded/repackaged medications for dispensing which is part of the distributed solution

Features / Installation	Medquest (Pyxis)	OmniHealth (OmniceII)	Swisslog (MedTower)	Metro (Medispense)
Unit dose dispensing for solids, liquids, ampoules, syringes, vials, large volume liquid	√	√	√	√
Light-guided or guided picking for drawer unit	√	√	√	√
Light-guided picking for tower unit	X (guided to door and not to individual item)	√	X	X
Security Features e.g. user sign-on, password, biometric ID	√	√	√	√
Local Implementation	JHS, SGH, Parkway Group	NUH, TTSH, IMH	X	X
Track record working with EPIC	√	√	X	√

# NUH Automated Dispensing Cabinets

- NUH ADC's (79 units, 52 wards, OT's, EMD ) are majority profiled except those in the OT's & EMD
- The configuration we use is 1 ADC to 20 beds in general
- Can track inventory real time and system can generate report for stock up's based on minimum quantity/par level
- Pharmacy verify the par level and range of drugs with wards on a quarterly basis
- We can monitor drug consumption, identify abuse/pilferage through daily reports
- Pharmacy employ bar code scanning during topping up of stocks to ensure correct drug
- Top up is done by PA/PT two times a week

# NUH Automated Dispensing Cabinets

- A majority of the drugs are in unit doses – tablets & capsules, and 91% of NUH drugs are bar coded. We are now bar coding all HAM drugs
- We can insert electronic alerts on “High Alert Medications” including mitigating measures in the ADC to alert nurses
- We use the ADC’s to store controlled drugs. Electronic/ hard copy CD consumption reports can be generated. Two nurses are required to access CD’s.
- The G4 cabinets can also print medication labels
- Considerations & critical success factors for successful implement : location, ward discipline, number of beds, workflow, change management, Pharmacy-Nursing collaboration, IT – interface, wifi, support, staff training, vendor support(crucial) - training, maintainance, trouble shooting, optimization.

# Issues Encountered in ADC use in NUH

- ADC screen display of medication orders truncated
- Topping up wrong medication by pharmacy staff
- Override withdrawal of medication
- Picking of wrong medications due to spill over of medications in bins
- Withdrawing more than required medications
- Non unit dose medications are bulky
- Par level insufficient resulting in stock outs
- Insufficient storage space in ADC's for medications