SMART-CARES – USE OF DIGITAL TWIN DATA IN WARD AND ARTIFICIAL INTELLIGENCE FOR EARLY WARNING OF AT-RISK DETERIORATION

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醫院管理局
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WHY EARLY DETECTION OF DETERIORATION CAN HELP?

Scale and Impact of the problem

- From AUS study, 1 out of 9 patients in acute ward suffers significant **in-patient complications**
  - Sepsis / pneumonia
  - Pulmonary embolism
  - Myocardial infarction
  - Hemorrhage
- **All specialties**
  - Medical – complications of the presenting illness
  - Surgical – post-op complications
- **Huge healthcare cost** and economic burden
  - AUS public hospitals - $5 billions per year

EARLY WARNING SCORES VS AI

	Early Warning Scores e.g. MEWS	AI
Predictive Parameters	Vitals	Vitals, demographics, laboratory markers (eHR medical records, wearables, multimodal)
Parameters trends	Not involved in prediction	Involved in prediction
Accuracy	Lower	**Higher**
Calculation	Manual or automatic	**Automatic**
Trust by clinical team	Probably more difficult	**Better**

Smart-CARES Bundle with AI Patient Deterioration Prediction

Auto-notification of at-risk deterioration for escalation

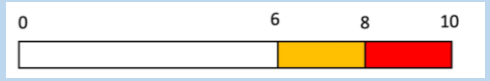
Real-time Patient Clinical Data

Demographics

Vital Signs

Laboratory Results

Automated AI Prediction

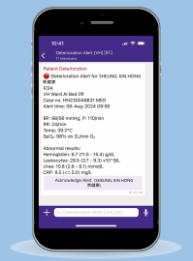


Identify Patients with Risk of Adverse Outcomes in next 48 hrs

Mortality, ICU Consultation, or CPR

Instant Notification to Clinical Team

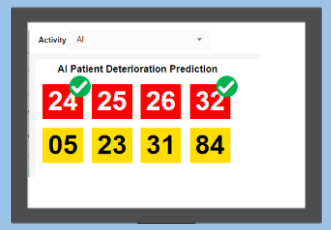
Red



HA Chat Instant Message

Red

Yellow



Ward TV Dashboard

Clinical Escalation

Red

Yellow

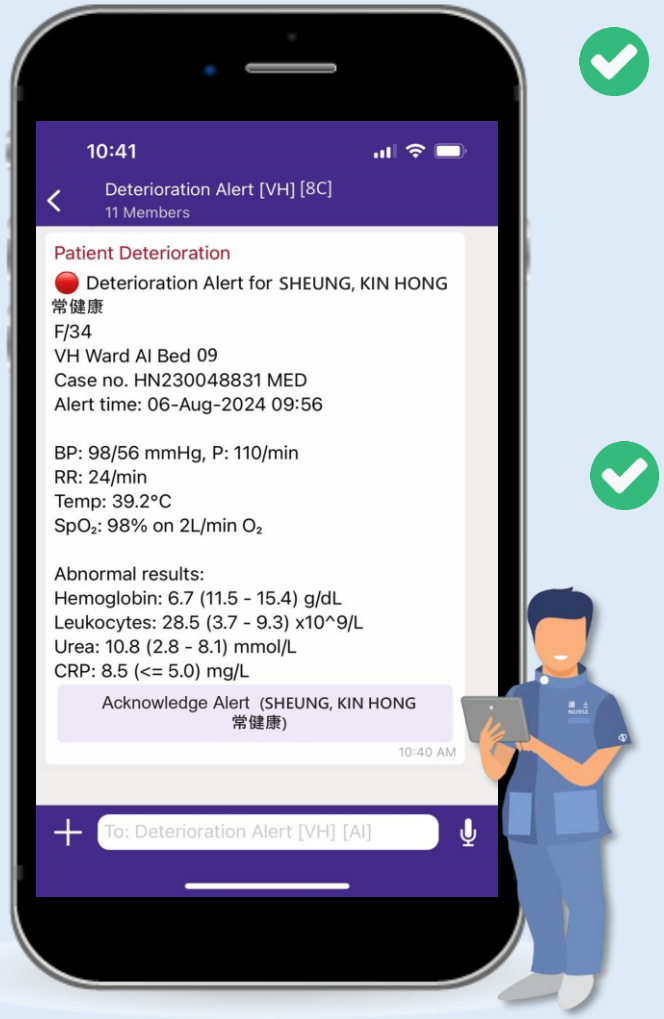
Raised Vigilance on Ward round

***Early Detection & Intervention* for Patients at Risk of Deterioration**

AI Patient Deterioration Prediction Overview

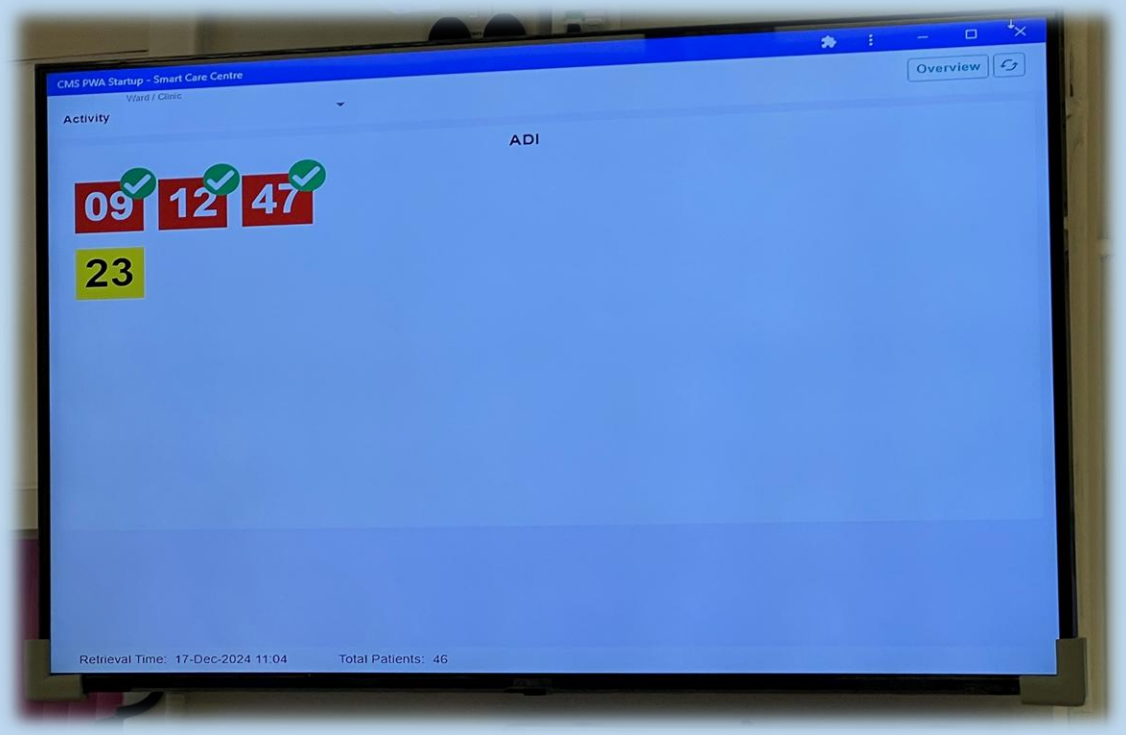
Auto-notification of at-risk deterioration for escalation

HA Chat Instant Alert Message



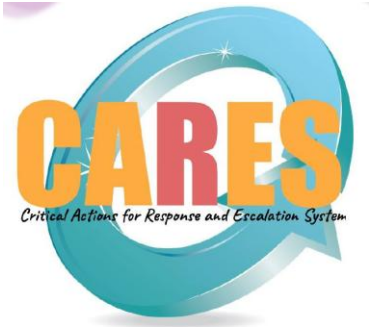
- ***Instant Alert Message to Ward Nurses***
  - ***Patient identifier and bed no***
  - ***Vital signs***
  - ***Abnormal lab results***
- ***Close-loop & Perform Clinical Assessment & Intervention***

Smart Care Center TV Dashboard at Ward



- ***Ward Patient Deterioration Risk at a glance***

Smart-CARES Bundle for Clinical Escalation & Response



Critical Actions for Response and Escalation System

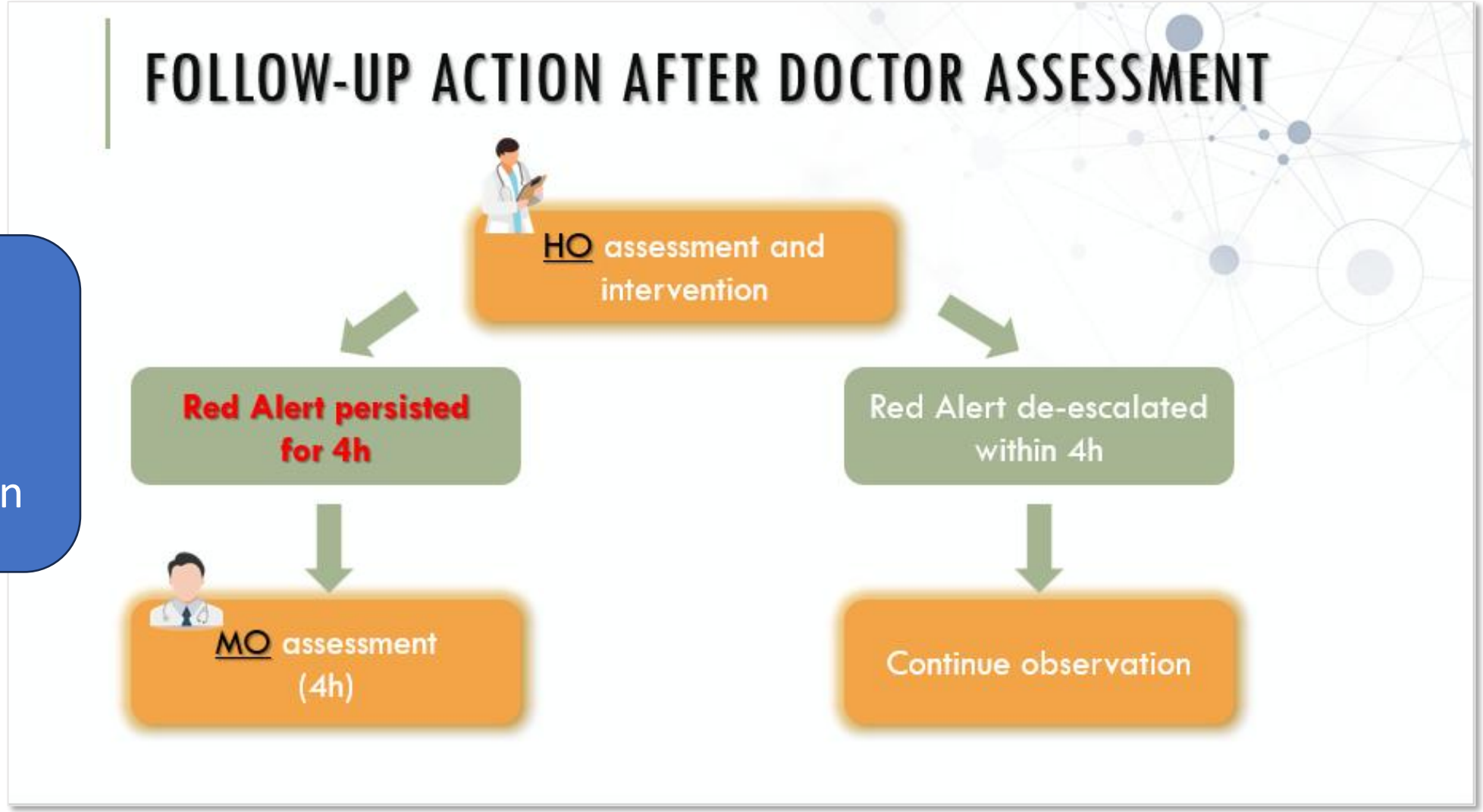
- Smart-CARES nurse bundle
  - Attend the patient
  - General appearance + Vital
  - A-G approach if deteriorated
  - Call and communicate (SBAR)
- Smart-CARES doctor bundle
  - SBAR communication with nurse – urgency and priority
  - Attend the patient
  - MORE
    - **M**onitoring plan
    - **O**rgan support
    - **R**oot cause and Treat
    - **E**scalate if required

SMART-CARES FOR NURSES (IN DETERIORATED CASES)

	Check and monitor	Perform
Airway	Airway obstruction	Suction + Oxygen
Breathing	Respiratory rate SpO2 monitoring	Titrate O2 to keep SpO2 > 94%
Circulation	BP Pulse Continuous cardiac monitoring	If doctor verbal orders ECG, perform 12-lead paperless ECG
Disability	GCS	H'stix
Exposure & **E**scalation	Temperature	Escalation to doctor
Fluid	Set / ensure patency of IV access	
Goal	ABCDE for improvement	Reassess

Smart-CARES Bundle for Clinical Escalation & Response

Situation
Background
Assessment
Recommendation



Smart-CARES Bundle for Clinical Escalation & Response

	Check	Perform
Airway	Airway obstruction	Suction + Triple manoeuvre Give O2 ± Airway gadget
Breathing	RR < 8 + SpO2 < 90% RR > 30 + SpO2 < 90%	
Circulation	Chest pain SBP < 90 mmHg SBP > 220 mmHg P < 40 or > 130 bpm	

	Check	Perform
Disability	Check H'stix Check CBC+DC, RFT, CP GCS < 8, unequal pupil sizes / light reflexes	Give glucose for hypoglycemia Look for electrolyte disturbances Protect airway with intubation CTB for intracranial lesions
Exposure & **E**scalation	Febrile / septic Rapid deterioration	

Responses by HO/MO

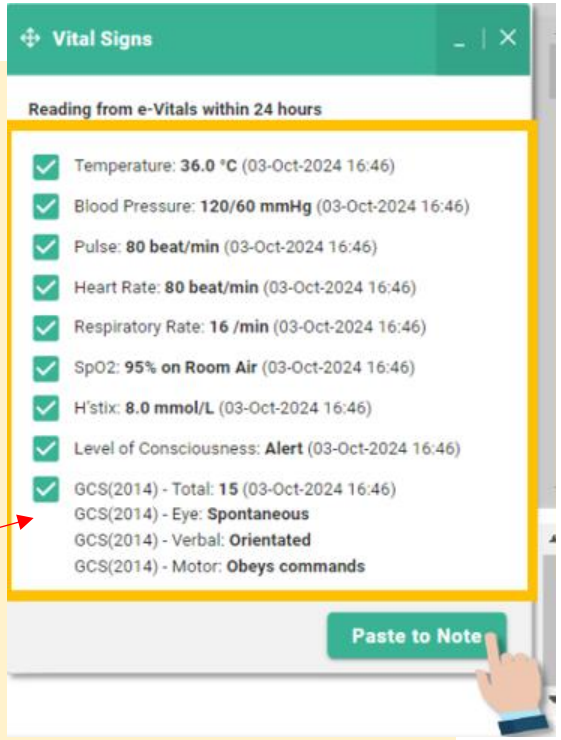
- **Monitoring plan**
- **Organ support**
- **Root cause and Treat**
- **Escalate**

	Check	Perform
Fluid and Lab results	IV access, Monitor urine output	Check the lab result of patient for • Dropping Hb • Leukocytosis or Leukopenia • Thrombocytopenia • Acute kidney injury • Hypo/hypernatremia • Hypo/hyperkalemia • Metabolic acidosis • Hyperglycemia AnElevated cardiac enzymes/troponin • d treat accordingly
Goal	Reassess ABCDE for improvement	Go for a working diagnosis + treatment

Documentation – Synergy with eDOC

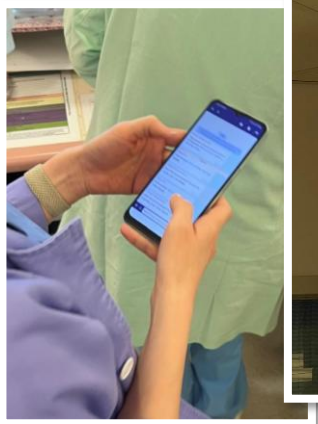
<CARES Red Alert>
Acknowledge at_____
Patient's GC:_____
Patient nil complaint/complains : _____
Vital signs/GCS: Measure latest vital signs and 'paste to note'
Nursing intervention: Keep Observe/...

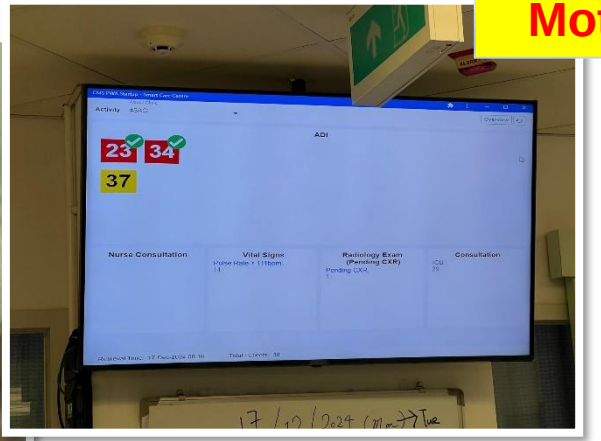
Escalate to HO / MO Dr_____ at _____ for further assessment
Remarks: _____



Standardized documentation
Guide on Smart-CARES bundle

Motivations





Teamwork

Training & Standard

TIMELINE OF PILOT IN POH

11 Sep. 2024
Pilot in 3S/7C (Phase 1)

14 Dec 2024
Rollout Phase 2
MG (8C, 8N, 8S)
MS (4S, 5S)

Late May 2025
Silent Parallel run of AI v2

3Q 25
Full evaluation

Interim Evaluation completed
4 Dec 2024

MS (4N, 4C, 5C)
MG (7N)
25 Mar 2025

Switchover to AI v2
EMW (7S)
6N, 6S, 6C
Jul 2025

Codeliverable
3-4Q 2025

Continuous improvement

MVP 11 Sep 2024

Phase 2b (May 2025)
Hard rules
Refractory period review
DNACPR
Error Handling & Re-run

Phase 4
Codeliverable package

Refractory Period
PAS for supporting timely HA Chat notification during intra/inter-ward transfer

Phase 2a (Dec 2024)

AI v2
M&G vs SUR threshold

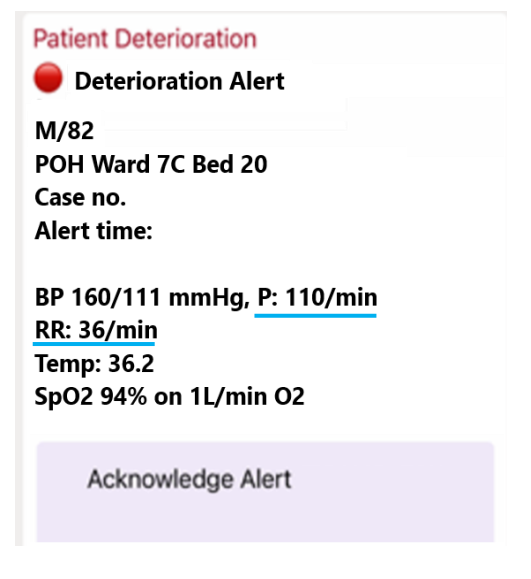
Phase 3

INTERIM EVALUATION

1. Model accuracy and performance
2. Compliance on response and escalation
3. Staff acceptance
4. Patient outcome

Case Example from Current Pilot at POH

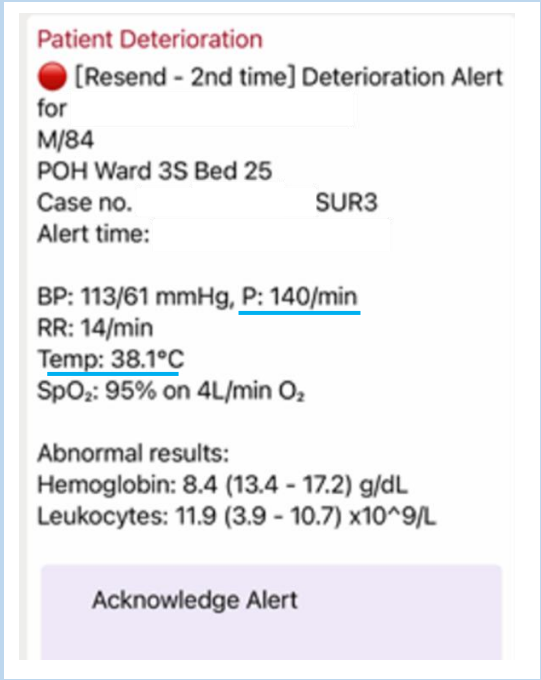
Pick up cases of **Deteriorating COAD & Pneumonia** in a medical ward



The alert was flagged up right sooner after admission which let clinical team to stay vigilant on the case.

The case was accessed by Case MO and further management was ordered including Blood Cultures, Blood Gas, and empirical antibiotics. The case was eventually discharged home.

Pick up cases of **Blood Transfusion related Allergic Reaction** in a surgical ward



Also as backup system in case clinical team had not noticed or escalated.

The case was handled based on Guideline of Acute Reaction in Blood Transfusion.

Model Validation with Various Specialties Collaboration

Prospective Validation

Timeframe: August 2024 – January 2025 (5 months)
Hospitals: POH
Admissions: 13,230

Clinicians & Specialties involved:
MED, SUR, AED, ICU,

Definition of Adverse Event:
Death, ICU Consultation, CPR

Vitals Deterioration Analyzed:
Hypotension, Hypoxemia, Decreased Consciousness

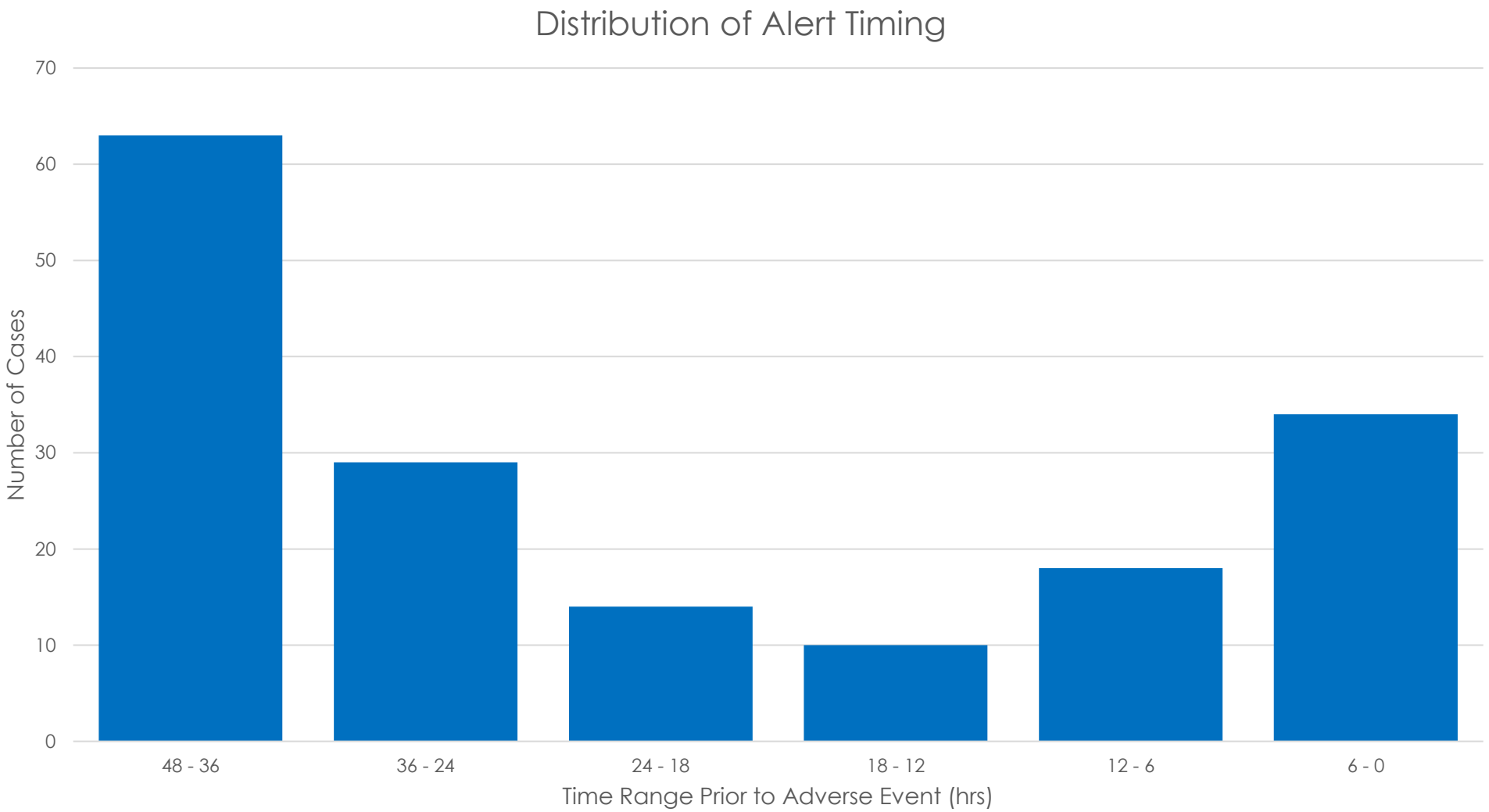
Model Accuracy – AI vs MEWS
(Prospective cohort Sep – Jan 2025 at NTWC POH)

Confusion Matrices	MEWS ≥ 5 (or +2)		AI version 1 (pilot)		AI version 2	
	With AE	Without AE	With AE	Without AE	With AE	Without AE
With Alert (Predicted)	377	3571	364	1229	361	101
Without Alert (Predicted)	187	9095	200	11437	202	12566

Metrics	MEWS ≥ 5 (or +2)	AI version 1 (pilot)	AI version 2
Sensitivity (True Positive Rate, Recall)	0.66	0.64	0.64
TNR (True Negative Rate)	0.85	0.97	0.99
FPR (False Positive Rate)	**0.15**	↓ **0.03**	↓ **0.01**
FNR (False Negative Rate)	0.34	0.36	0.36
Precision	**0.16**	↑ **0.45**	↑ **0.78**
AUROC	**0.82**	↑ **0.86**	↑ **0.92**
AUPRC	0.51	0.60	0.67

Less false alarm → Better trust by clinical team

ALERT TIMING



MODEL ACCURACY

1. **Accuracy**
    1. Sensitivity 64%
    2. Precision (positive predictive value)
        - 1 / 2 patients demonstrated vital deterioration in next 24h
        - 1 / 5 patients deteriorated to cardiac arrest or requiring ICU consultation
2. **Medical vs Surgical patients**
    1. Medical > Surgical
3. **Flagging rate** (included anticipated deteriorations)
    1. Acute SUR = 0-3 alerts per day.
    2. Acute MED = 4-6 alerts per day

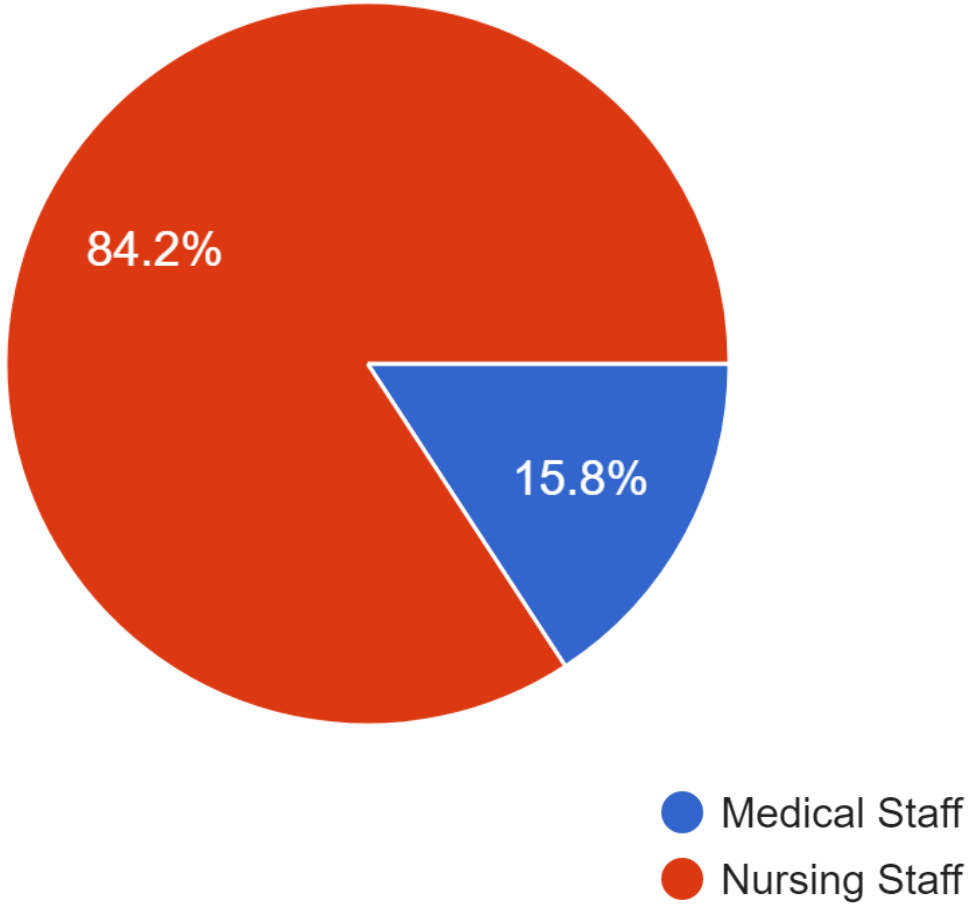
RESPONSE EVALUATION – CHART REVIEW

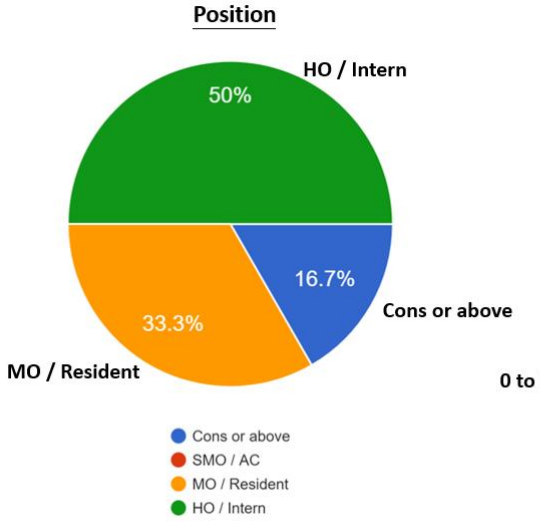
Chart reviews on 389 flagged up case records (11 Sep – 10 Nov 2024)

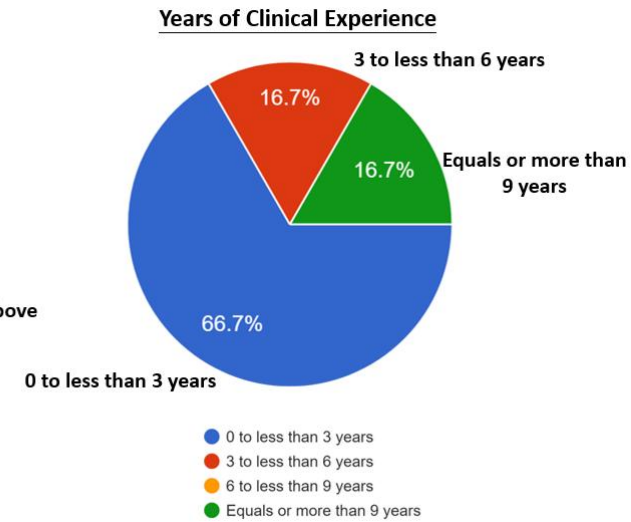
	Nursing	HO	MO
Acknowledge HA Chat	63s (median)	--	--
Timing of assessment	Within 1h: 100%	Within 1h: 51% Within 4h: 84%	Within 1h: 70% Within 4h: 97%
Response	Assessment and monitor: 71% Intervention: **29%** Escalation: 93%	+Monitoring: 11% +Organ support: 19% **Root cause workup: 15%** **Targeted Tx: 11%**	+Monitoring: 26% +Organ support: 51% Root cause workup: 59% Targeted Tx: 66%
Aligned all Smart-CARES bundle	88%	81%	89%

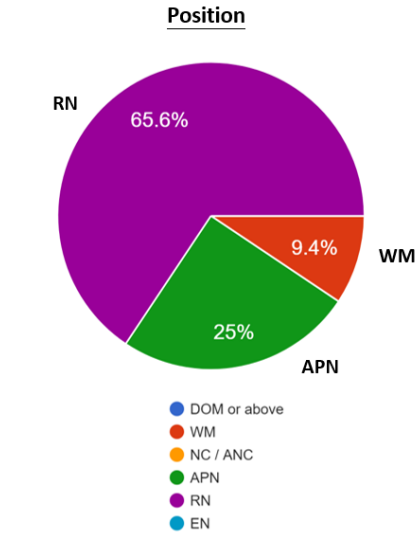
STAFF SURVEY

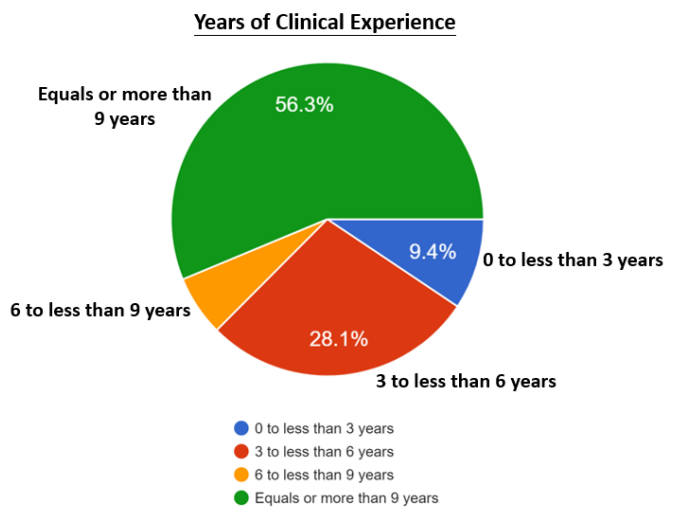
38 PARTICIPANTS











STAFF SURVEY

	Questions	1-4 = negative. 5-6 = neutral. 7-10 = positive
1	Early identification and notification of at-risk deterioration cases can facilitate early intervention and improve patient outcomes.	Positive: 60.6% Neutral: 21%
2	Smart-CARES can help to detect patient deterioration early.	Positive: 55.3% Neutral: 29%
3	The workload related to assessment and management on Smart-CARES predicted patients is justifiable to improve patient outcomes.	Positive: 42.2% Neutral: 29%
4	Smart-CARES deterioration is particularly useful for junior nurses and doctors.	Positive: 60.7% Neutral: 15.8%
5	Auto-calculation in Smart-CARES is better than MEWS manual calculation.	Positive: 55.3% Neutral: 26.4%
6	Smart-CARES AI is more accurate than MEWS.	Positive: 60.6% Neutral: 21%
7	Smart-CARES prediction of at-risk deterioration cases is accurate.	Positive: **68.4%** Neutral: 10.6%
8	The pipeline of HA Chat and Smart Care Centre TV dashboard is user-friendly, and they can meet the clinical workflow in wards.	Positive: 65.9% Neutral: 26.3%
9	I am familiarized and well-trained on Smart-CARES bundle.	Positive: **79%** Neutral: 10.6%
10	I support to continue and rollout of Smart-CARES.	Positive: **68.4%** Neutral: **10.6%**

MONITORING ON LOS & BDO

Average LOS (days) for Patient who stayed in Single Ward		
	Sep 23 - Jan 24	**Sep 24 - Jan 25**
3S	5.5	**4.6**
4S	4.7	**3.6**
5S		**6.5**
7C	6.4	**6.4**
8C	9.1	**6.2**
8N	7.2	**5.9**
8S	8.0	**6.2**

5S ward was relocated to 8S from 1.8.23 and reopen on 21.2.24

Inadequate robustness

Evaluation at full hospital rollout

Average Bed Occupancy (Rate) for Patient				
	Sep 23 - Jan 24		**Sep 24 - Jan 25**	
	Average BDO	**Average BDO%**	**Average BDO**	**Average BDO%**
3S	39.7	92.4%	41.8	94.6%
4S	35.4	82.4%	39.5	83.3%
5S	N.A.	N.A.	41.8	90.0%
7C	33.3	90.0%	32.0	86.5%
8C	43.4	114.1%	45.8	107.9%
8N	45.2	115.8%	48.6	112.0%
8S	43.3	117.0%	46.1	106.2%

WAY FORWARD

1. AI version 2 migration in July 2025
2. Complete rollout in POH by July 2025 and Reevaluation
3. Readiness for Codelivery to other hospitals
4. Scientific Publications in Digital Journals
5. Exploration of further Model enhancement → AI version 3
   - Sub-models for secondary outcomes – sepsis, AMI
   - Multimodal AI – Internet-of-bodies integration

ACKNOWLEDGEMENT

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Teamwork
Workflow integration
Clinical Care