Code Blue Intervention in JurongHealth Campus (JurongHealth Campus)

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Executive Summary (1/4 Page)

In-Hospital cardiac arrest (IHCA) is a serious inpatient adverse event and has been associated with significant morbidity and mortality. Based on previous registries, the incidence of IHCA in the United States is around 9 to 10 per 1,000 admissions while the incidence is around 1 to 1.6 in the United Kingdom. Despite the development of resuscitation strategies such as Extracorporeal Cardiopulmonary Resuscitation (ECPR) and improvement of post-cardiac arrest care over the decades, the survival to hospital discharge after IHCA is still only around 20-30% internationally.

In Singapore, IHCA also stresses the system, clinical specialties and staff. In the first year of the JurongHealth Campus opening in 2015, the incidence of cardiac arrests was 1.65 per 1,000 hospital admissions. This inspired the team to develop the "Peri-Arrest Criteria for Code-Blue Activation" (PACCA) in order to detect early signs of cardiac arrest and facilitate early intervention by the clinical team. However, the activation was still a manual process, so the team brainstormed for solutions to enhance it by automating the trigger of alerts and activation – a process known as "Post Automation". Timely intervention can save lives, and post-automation has certainly improved compliance, reduced human error, and minimised hesitation and doubts amongst junior doctors and nurses as to whether to trigger a code blue.

Define the Clinical Problem and Pre-Implementation Performance

In-Hospital Cardiac Arrest (IHCA) is potentially preventable as most cases are preceded by a deterioration in the patient's clinical condition a few hours prior to the event. Hence, the 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care recommend appropriate surveillance systems for the prevention of cardiac arrest to be the first link in the chain of survival. In order to detect patient deterioration prior to cardiac arrest, several early warning sign systems are now available. These include setting up single vital sign warning criteria or using composite risk scores such as the National Early Warning Score (NEWS). A Rapid Response Team (RRT) or medical emergency team should be available for early intervention in patients who have fulfilled the criteria of pre-determined early warning sign, to prevent IHCA.

JurongHealth Campus is comprised of Ng Teng Fong General Hospital, a 700-bed acute hospital and Jurong Community Hospital, a 400-bed community hospital that are co-located in Singapore's western region. Opened in July 2015, the hospitals have a combined catchment of nearly two million people. Within the first year, there were approximately 100,000 accident and emergency attendances followed by nearly 40,000 hospital admissions, which resulted in stress across the system and clinical specialities from having to treat acutely ill patients. Delays in recognising deteriorating patients and failure to activate help were documented contributing factors to unsatisfactory patient outcomes. The incidence of cardiac arrests was high (at 1.65 per 1,000 hospital admissions) compared to the United Kingdom's national average of 1.2 per 1,000 hospital admissions. In response, the team developed the "Peri-Arrest Criteria for Code-Blue Activation" (PACCA) to detect early signs of cardiac arrest and this is illustrated in Diagram 1. This intervention did not effect a significant change in outcomes as activation was still done manually and which was not time-efficient. A further intervention using automation was developed to enhance the manual alert process. Automatic triggering of alerts and code blue activation known as "Post Automation", has resulted in swifter response, improved compliance and reduced human errors.

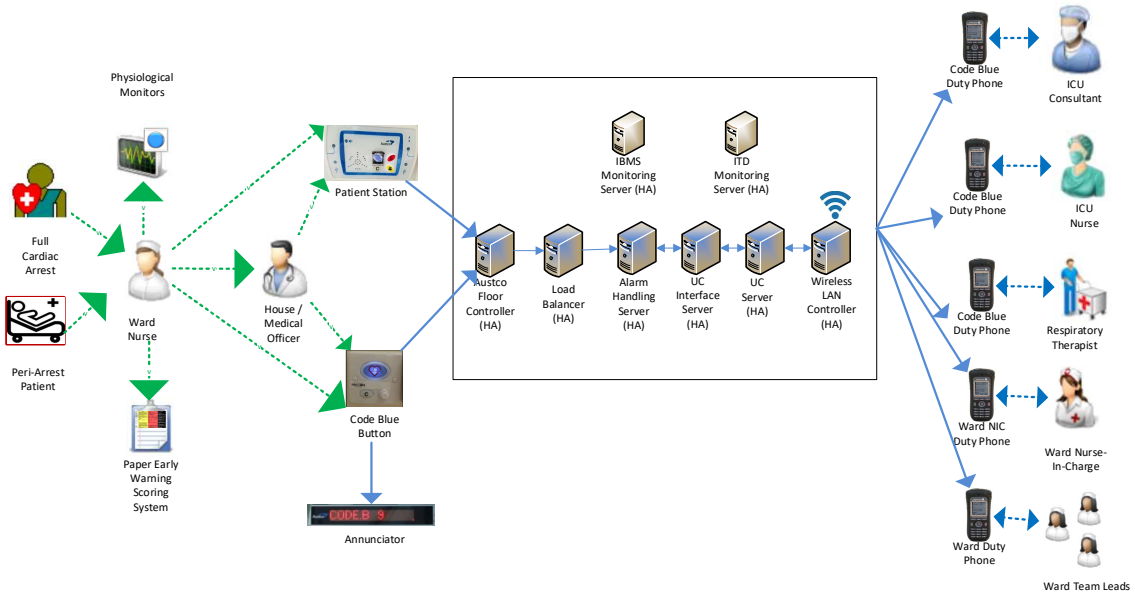


Diagram 1: Manual Alert and Activation System for Peri-Arrest and Cardiac Arrest

Design and Implementation Model Practices and Governance

The automated alert and activation system comprises a number of mobile physiological monitors configured with a proprietary algorithm and an early warning scoring system (peri-arrest criteria). This system interfaces with the electronic medical records system (EMR), and creates and sends email alerts to notify the RRT when a patient meets the peri-arrest criteria.

Vitals are taken at intermittent periods by the nurse who confirms that the vitals are accurate by pressing the button “validate”. These parameters are then sent to the electronic medical record system via HL7 message. At the same time, if the patient’s vitals meet the early warning scoring system for peri-arrest criteria, there is a visual and audio alert from the mobile physiological monitor which alerts the nurse and the local team to immediately respond to the patient and to stay with the patient until the arrival of the RRT to render critical care.

Advantages of the invention are that the mobile physiological monitor can be pushed to the point of care as a shared resource anywhere in the hospital.

The other key features are: only validated vitals of the patient whose identity is electronically verified are accurately received, thereby removing the risk of incorrect patient identity, inconsistent, erroneous or late manual input of vitals.

Another unique feature of this invention is the suppression of automated alerts from patients who do not require any urgent medical help from the RRT. For example, for patients who have opted for ‘Not for Resuscitation’ and are expected to die of natural

disease progression, alerts from the mobile physiological monitor flow into the electronic medical records and stop there. This is done so by in-building an algorithm to suppress the auto code message from going out to the Code Blue team. For the algorithm to perform, there is a need for the doctor to order and click on the `No Automated Code Blue Activation' button (Diagram 2). This feature prevents unnecessary alerts and reduces alarm fatigue.

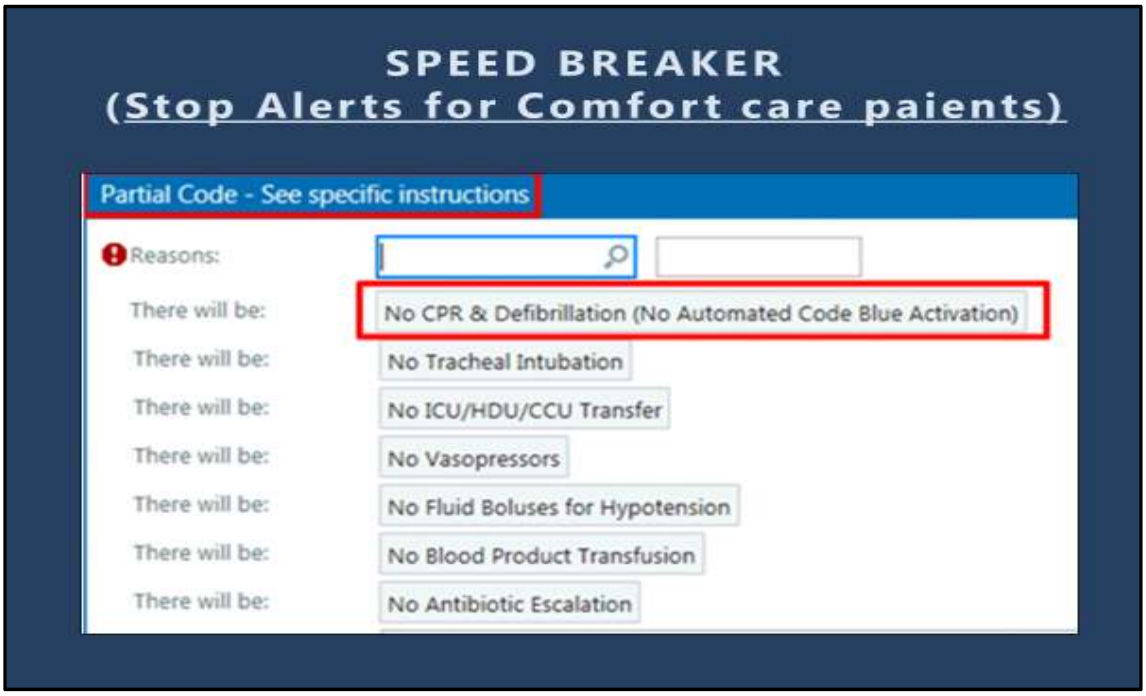


Diagram 2: Speed Breaker: Suppress Auto Code Blue for Partial Code

The whole concept was approved by the Institutional Medical Board. The various departments in the hospital – clinical and non-clinical – were involved and became stakeholders. The automated alert system is monitored on a daily basis; daily test calls are made and quarterly reports are presented to the Cardiac Life Support Committee and Institutional Medical Board. Cardiac arrest incidence rates are now one of the key performance indicators of the Institutional Medical Board.

Clinical Transformation Enabled Through Information and Technology

The workflow for Nursing Manual Alert and Manual Activation is as illustrated in Diagram 3. When a patient's vitals are measured by a nurse through the physiological monitor, the parameters are compared to the early warning scoring system values printed on a paper attached to the mobile physiological monitor. Nursing staff then manually input the patient's vitals into the electronic medical records system. Manual recognition by the nursing team is needed to determine the deterioration of the acutely-ill peri-arrest patient. If deterioration is recognised, the nurse presses the code blue

button beside the patient's bed. However, we found that human factors resulted in inconsistent use of the code blue button, mainly due to varying abilities in recognising signs of patient deterioration among our nursing staff.

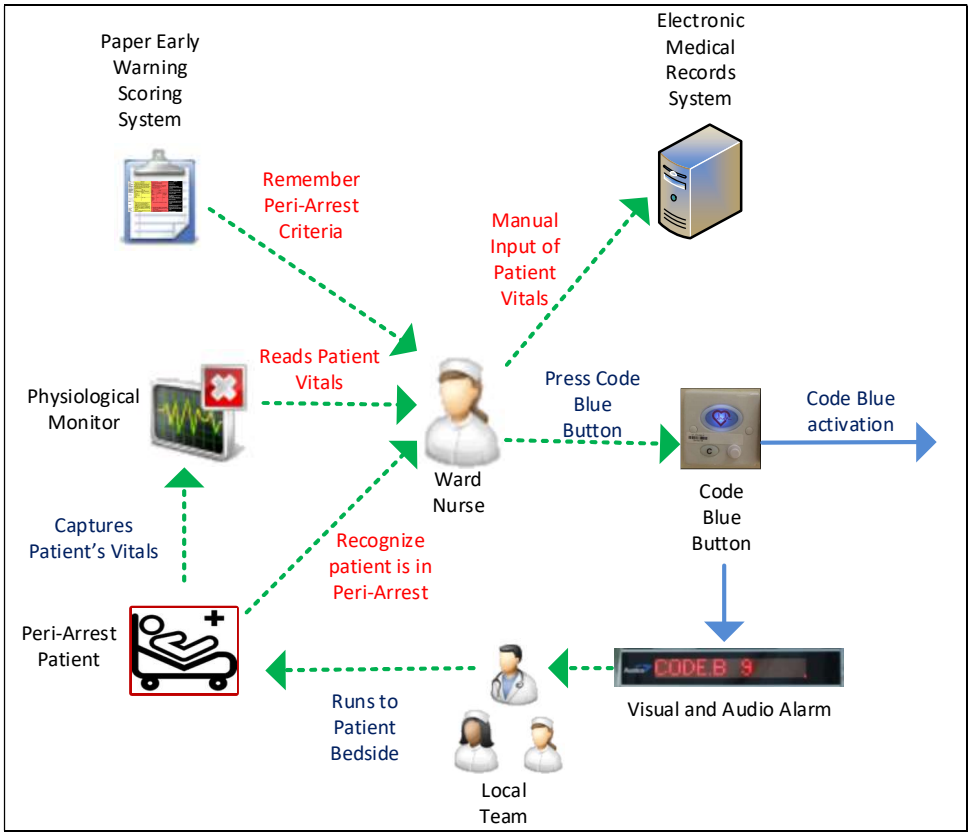


Diagram 3: Nursing Manual Alert and Manual Activation workflow

Diagram 4 explains the implemented Automated Alert and Automated Activation Workflow. The automated alert system comprises of a number of mobile physiological monitors. These monitors are configured with a proprietary algorithm with an early warning scoring system that interfaces with the electronic medical records system (EMR). Within the EMR system, another set of proprietary algorithm with an early warning scoring is configured to send email alerts.

When a patient's vitals are to be measured, the nurse pushes a mobile physiological monitor cart consisting of a user interface monitor, a bar code scanner, vitals processing unit that has a proprietary algorithm configured with the early warning scoring system, wireless transmitter that sends HL7 messages to the electronic medical records system, and visual and audio alarms that verify the acutely-ill patient's identity and captures the patient's vitals in two minutes. The nurse proceeds to confirm that the parameters are accurately taken at intermittent

periods by pressing the 'Validate' button on the user interface monitor. These parameter values are then sent to the EMR system.

Concurrently, if the patient's vitals meet the early warning scoring system for peri-arrest criteria, there is a visual and audio alert from the user interface of the mobile physiological monitor which alerts the nursing staff (Diagram 5). Nursing staff will press the code blue button. Simultaneously, in the background, an automatic activation takes place. In some cases, even if the nurse hesitates to press the bedside code blue button, the automatic activation will still occur. The Code Blue team receives the code blue activation within 22 seconds with location details of the patient.

The automated peri-arrest email alert (end user receives it as a text message) details the location of the patient i.e. the Tower, Ward and Bed number that resides on the electronic medical records system database, and sends the same unique email alert to two unique email addresses on the email server. One email address is for a central monitoring email account accessed by clinicians. The second email address is polled by the alarm handling server for activation of the RRT. Integration of the automated alert and activation system to the alarm handling and unified communications (UC) systems comprises the email system which receives the automated email alerts (that comprises the location of the acutely-ill patient that has met the peri-arrest criteria) and the alarm handling system configured with a proprietary algorithm which automatically polls the email server every 10 seconds to check for these email alerts sent by the EMR. The alarm handling system works on a proprietary algorithm and upon polling and receipt of the peri-arrest email alert, automatically sends a set of electronic alerts simultaneously through the UC system to activate a specific clinical RRT or Code Blue team consisting of several members. The clinical Code Blue team simultaneously receives the audio and visual alerts with the acutely-ill patient's location within 5 to 7 seconds and sends their individual acknowledgements on their wireless duty phones to the unified communications system, which in turn sends the acknowledgements to the alarm handling system. The Code Blue team then runs to the patient's bedside to deliver critical care and appropriate advanced cardiac life support in 1 to 3 minutes. Upon receipt of the RRT or Code Blue team's acknowledgements, the alarm handling system sends the receipt of the team's acknowledgements to the ward nurse-in-charge wireless duty phone where the acutely-ill peri-arrest patient is located, so that nursing staff are made aware that the RRT or Code Blue team are on the way.

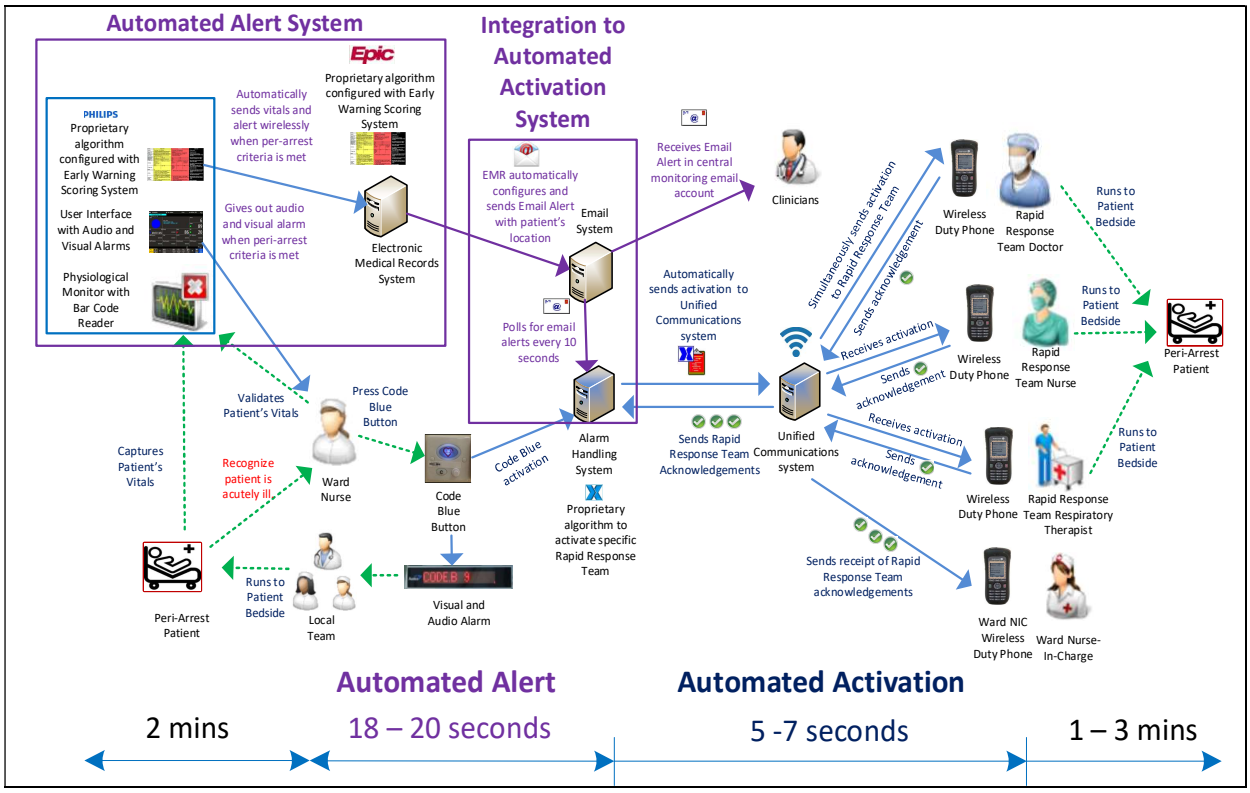


Diagram 4: Automated Alert and Automated Activation Workflow

Diagram 5: Physiological monitors configured with a proprietary algorithm with an early warning scoring system

Improving Adherence to the Standard of Care

The performance measure used is the cardiac arrest rate per 1,000 patient admissions which is benchmarked to similar cardiac arrest rates per 1,000 patients in UK, which varies from 1 to 1.2 per 1,000 admissions. Data was automatically collected from the automated email alerts and computer logs of manual activations sent to clinicians who verified and analysed the medical outcomes of individual cardiac arrests and peri-arrests cases from the EMR system. False activations from non-activation of speed breaker and inaccurate manual data entry of patient's vitals are removed to obtain the total number of cardiac arrests per month as the numerator. Monthly patient admissions are obtained from the EMR system to provide the denominator. The monthly cardiac arrest rate per 1,000 patient admissions is then plotted and the annual average cardiac arrest rate per 1,000 patient admissions is calculated as a trend line. The upper control limit was to lower and maintain the annual average cardiac arrest rate per 1,000 patient admissions from 1.65 (first year of opening data) to <1.0.

Diagram 6 below shows the cardiac arrest rate per 1,000 patient admissions from August 2015 to Feb 2020. From August 2015 to Feb 2017, the cardiac arrest rate was 1.41 per 1,000 patient admissions where there as manual alert and manual activation by pressing the code blue button for activation for cardiac arrest patients only.

For the 24 months, post-implementation of the Automated Alerts and Activation System based plus continued Manual activation. The annual cardiac arrest rate per 1,000 patient admissions was lowered from 1.65 (first year of opening data) and maintained at 0.8.

There were two months (June 2018 and Nov 2019) in the Automation period during which there were no cardiac arrests.

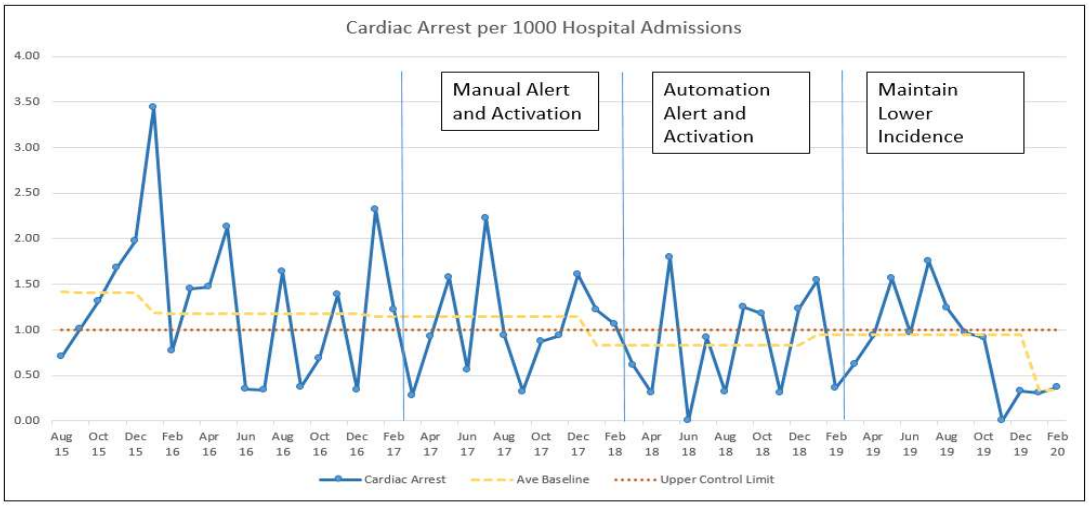


Diagram 6: Cardiac arrest per 1,000 Hospital Admissions from the period of Aug 2015 to Feb 2020

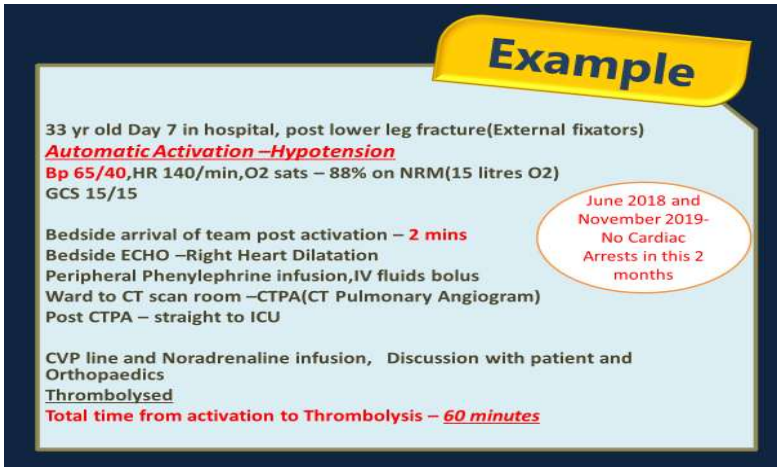


Diagram 7: Example of Successful Automated Alert and Activation

Improving Patient Outcomes

From March 2017 to February 2018, after one year of implementation of the Manual Alert and manual activation by pressing the code blue button for acutely-ill peri-arrest and cardiac arrest patients, the IHCA incidence **came down to 1.2 to 1.03 per 1,000 patient admissions**. However, during the year, anecdotal data showed that there were still patients who had met the peri-arrest criteria for code blue activation who were missed. Previous studies have revealed that poor adherence to early warning scoring protocols was one of the major contributors leading to serious patient-related adverse events during

admission. In the local context, the prevailing culture of 'code blue button – for cardiac arrest only' had likely further attributed to delays in code blue activation for peri-arrest situations. One year after the implementation of the Automatic Activation system, the incidence of IHCA dropped further to 0.88 per 1,000 admissions. This is lower than the incidences reported in the UK literature which are mostly above 1.0 to 1.2 per 1,000 admissions. **In the following year (1 March 2019 to 29 February 2020), the IHCA incidence remained low at 0.84 per 1,000 hospital admissions**. This demonstrated that the Automatic Alert and Activation system was an effective and sustainable system to reduce IHCA.

Earlier studies have shown that RRT response by automated alert via various scoring system such as NEWS could reduce IHCA incidence and inpatient mortality. However, the effect of automated alert from a single abnormal vital sign for code blue activation has not been reported. Single vital sign for peri-arrest criteria as code blue activation was used in the Automatic Activation system instead of the commonly-used acute illness scoring system, as the scoring system might not be sensitive enough in identifying patients who needed emergent intervention. For illustration, a hypoxic patient who is on 100% oxygen via a non-rebreather mask may have a NEWS score of 3 which is below the usual alert level for NEWS.

The implementation of this system has shown a trend towards improved hospital survival to home discharge for both peri-arrest activation and cardiac arrest activation. The survival to home discharge rate after IHCA was 23% after our intervention, compared to international registries at 20%.

The survival to home discharge was nearly 70% in the peri-arrest group, highlighting the significance of identifying deteriorating patients earlier. Survival improvements in the peri-arrest group after automation were also possibly related to shorter response time. As for the cardiac arrest group, institutional guidance with regards to IHCA management and post-IHCA management has been consistent over the study period. Hence, the automated system could have contributed to the improvement in survival to home discharge rate for the cardiac arrest group.

Accountability and Driving Resilient Care Redesign

Clinicians receive automated alert emails in real-time from the monitoring email account, which indicate the time and location of the peri-arrest event. See Diagram 8.

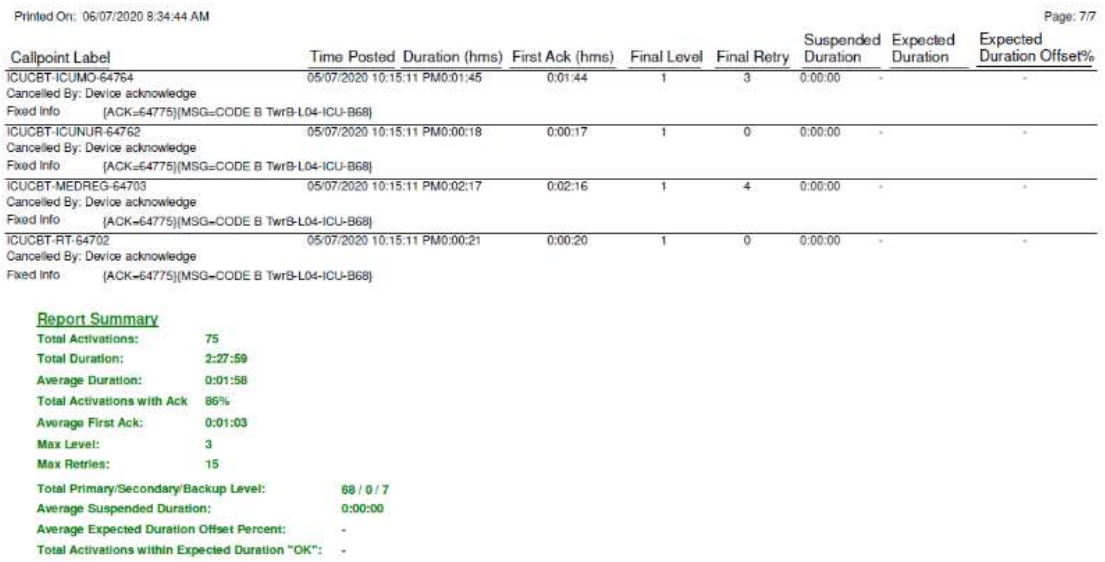
Diagram 8: Peri-Arrest Central Monitoring Email Alert generated by EMR

Clinicians pull information from the electronic medical records system to examine the patient's condition over time leading to the event, subsequent treatment and medical outcomes. Diagram 9 shows a part of the weekly report generated from system logs, detailing each code blue activation event.

1539	26-Nov-19	TwrB-L10-B59	8:00:47 AM	HCBT1	Manual Activation
1540	26-Nov-19	TwrC-L10-B05	10:18:41 AM	HCBT1 & IRT	Automated Code Blue
1541	26-Nov-19	TwrC-L10-B05	10:18:42 AM	HCBT2	Manual Activation
1542	26-Nov-19	TwrB-L10-B59	11:01:09 AM	HCBT1	Manual Activation
1543	26-Nov-19	TwrB-L03-ENDO-RM01	1:10:18 PM	HCBT1	Manual Activation
1544	27-Nov-19	TwrB-L05-B47	5:25:41 AM	HCBT1	Automated Code Blue

Diagram 9: Weekly Report of Peri-Arrest and Cardiac Arrest Activations from Machine logs

Diagram 10 shows a machine log which gives an overall picture of weekly user compliance to the workflow. All these help identify any gaps in the medical response and treatment.



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Page: 7/7

Callpoint Label	Time Posted	Duration (hms)	First Ack (hms)	Final Level	Final Retry	Suspended Duration	Expected Duration	Expected Duration Offset%
ICUCBT-ICUMO-64764	05/07/2020 10:15:11 PM	0:01:45	0:01:44	1	3	0:00:00	-	-
Cancelled By: Device acknowledge								
Fixed Info {ACK=64775}{MSG=CODE B TwrB-L04-ICU-B68}								
ICUCBT-ICUNUR-64762	05/07/2020 10:15:11 PM	0:00:18	0:00:17	1	0	0:00:00	-	-
Cancelled By: Device acknowledge								
Fixed Info {ACK=64775}{MSG=CODE B TwrB-L04-ICU-B68}								
ICUCBT-MEDREG-64703	05/07/2020 10:15:11 PM	0:02:17	0:02:16	1	4	0:00:00	-	-
Cancelled By: Device acknowledge								
Fixed Info {ACK=64775}{MSG=CODE B TwrB-L04-ICU-B68}								
ICUCBT-RT-64702	05/07/2020 10:15:11 PM	0:00:21	0:00:20	1	0	0:00:00	-	-
Cancelled By: Device acknowledge								
Fixed Info {ACK=64775}{MSG=CODE B TwrB-L04-ICU-B68}								

Report Summary

Total Activations:	75
Total Duration:	2:27:59
Average Duration:	0:01:58
Total Activations with Ack	86%
Average First Ack:	0:01:03
Max Level:	3
Max Retries:	15
Total Primary/Secondary/Backup Level:	68 / 0 / 7
Average Suspended Duration:	0:00:00
Average Expected Duration Offset Percent:	-
Total Activations within Expected Duration "OK":	-

Diagram 10: Weekly Summary of Activations and Acknowledgements from Machine Logs

Updates which include performance, gaps and opportunities are periodically presented to the Institutional Medical Board. One of the opportunities identified, based on the concept of pre-empting peri-arrest, has been to include less sick patients based on National Early Warning signs (Red Zone) with more patient data. See Diagram 11.

EPIC in Basket: Automated Alert Notice
Hospital: NTFGH
Alert Type: Red Zone
Tower: TwrC
Level: L09
Specialty: xxxxx
Bed: xxxxxxx
NRIC: xxxxxx
Surname: xxxxxxx
Doctor: xxxxxx
Nurse ID: xxxxxxx
Code:
RR: 25
HR: 73
SBP: 122
Spo2: 94
Temp: 35.5
ACVPU: V
O2 Delivery: NC
Trigger: NEWS,
Drug Allergy:
Prelim-Diagnosis:
JurongHealth Campus

Diagram 11: Red Zone Central Monitoring Email Alert

System performance is maintained through daily automated Self-Tests. As the system supporting the workflow consists of more than 60 servers and controllers, planned downtime is managed through activation of business continuity planning and qualification after maintenance. Unplanned downtime is detected through user feedback, automated monitoring of IT equipment and automatic feedback when a daily Self-Test fails. Each unplanned downtime is investigated, the root cause identified, and corrective measures implemented and documented in work instructions that are used for training.

Clinical transformation through the generation of automated alerts for peri-arrest patient has impacted and influenced nursing efficacy and behaviours. Initially, nursing staff would use a paper early warning scoring system (JETS) (Diagram 11 – JETS) to manually check if a patient's validated vitals met the peri-arrest criteria before manually pressing the code blue button to activate the code blue team.

Criteria	Yellow Zone		Red Zone			Black Zone
General	• **Blood loss**: Overt Bleeding. • Greater than expected fluid loss from a drain		• Peripheries: Cold and clammy • Airway Obstruction OR Stridor • Seizures • **Arterial Blood Gas**: PO_2 < 50 mmHg OR PCO_2 >60 mmHg OR pH<7.2 OR BE <-5 • **Venous Blood Gas**: pH<7.2 • Other serious concerns			• **Cardiac arrest** • **Respiratory arrest** • **Airway obstruction requiring immediate intubation (Activate Airway team also)** • **RR <8 OR >45 (per min) in spite of maximum O_2 therapy (15 L NRM)** • **SpO_2 <80% in spite of maximum O_2 therapy (15L NRM)** • **HR <40/min in patients with signs of hypoperfusion** • **SBP <70mmHg in spite of fluid therapy with signs of hypoperfusion** **Activate Code Blue**
Urine Output (ml/hr)	No output per shift **OR** urine output<30ml/hr >200ml/hr for 2hr in the absence of diuretics					
Temperature	**New onset** Temperature: <35.5°C **OR** >38.5°C					
Pain Score	>7 **OR** New **OR** increasing **OR** uncontrolled (including chest pain)					
BGM (mmol/L)	<4	>20				
SBP(mmHg)	90 - 100	180 - 200	<90		>200	
SpO_2 (%)	90-95 **AND/OR** Increase in O_2 requirement		<90%			
RR (per min)	9-11	25-30	≤8		>30	
Alertness	Decreases from alert (A) to rousable only by voice (V) in the AVPU	New onset of confusion	Only responds to pain (P)	Unresponsive (U)	Sudden ↓of GCS level by ≥ 2 points	
HR (per min)	40 - 50	120 – 140	Newly detected irregular pulse	<40	>140	
NEWS	4-6		≥7			
Actions	• **Nursing staff** must call the responsible team or after hours (HO/MO) **immediately**. • **Primary Care Team/After-Hours HO/MO** is required to conduct a Clinical Review. • **HO/MO** needs to discuss or review the case with Registrar or Consultant **as appropriate**.		• **Nursing staff to call Registrar or above**			• **No response after 30min of Red Zone activation from the team or on-call registrar.** • **Inadequate response /treatment after 1hr of Red Zone activation** • **Nursing staff to inform the Nurse in charge and any of the team member to call:** **Call ICU consultant**
Criteria for further escalation	• **No review** within **30mins**, to call **Registrar** • Parameters **not stabilised** within **1hr**, to call **Registrar** • Patient's condition **deteriorates** into the Red Zone, to call Registrar		• **No review** within **30min**, to call ICU MO2. • Parameters **not stabilised** within 1hr, to call ICU Consultant • Patient's condition deteriorates to arrest, activate Code Blue team			

Diagram 11: Early Warning System JETS

Through the use of a proprietary algorithm built into the EMR system (Diagram 12), nursing workflows (Diagram 13) were changed as the system processed the validated vitals input by the nurses and created the peri-arrest email to activate the code blue team.

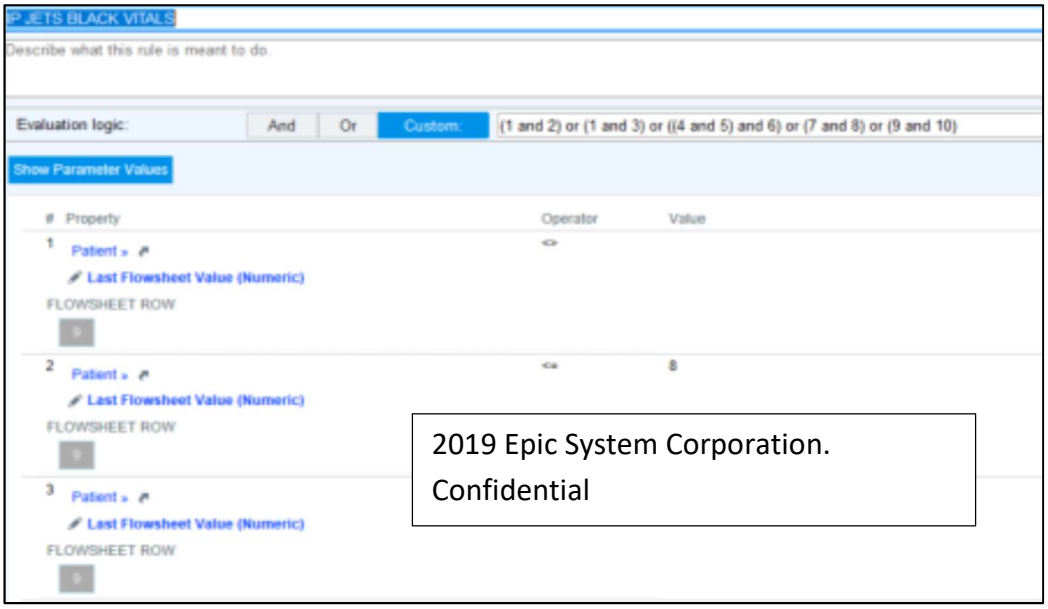

Diagram 12: Algorithm build in EMR System

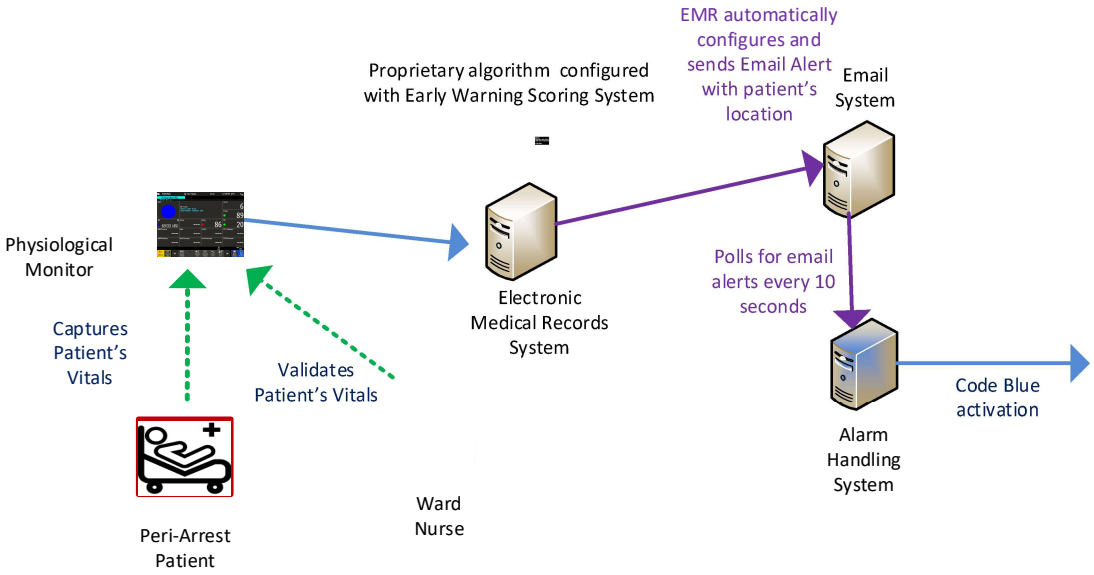

Diagram 13: Automated Alert and Activation Workflow with Algorithm built into EMR

With the change from Manual alert and activation to Automated alert and activation, the **cardiac arrest rate per 1,000 patient admissions fell from 1.03 (March 2017 to Feb 2018) to 0.8 (Mar 2018 to Feb 2020).**

HIMSS Global Conference Audience Guidance (This will not be published)

Topic Guidance: Check three which apply to this case study

Clinical Informatics and Clinician Engagement

Healthcare Applications and Technologies Enabling Care Delivery

Process Improvement, Workflow, and Change Management