A BRIEF INTRODUCTION TO EARLY WARNING SCORES

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OVERVIEW

- What is the clinical problem that Early Warning Scores (EWS) were designed to solve?
- What is an EWS and what are the particular design features?
- What data-driven approaches have been used to derive and validate EWS algorithms?
- What are the unsolved problems that are relevant to COVID?


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25
Peter King

511-117

NSN 7540-00-634-4124

MEDICAL RECORD — VITAL SIGNS RECORD

HOSPITAL DAY	1	2								
POST- DAY										
MONTH-YEAR DAY	14	15								
Dec 19 95 HOUR	6 10 2 6 10 2 6 10									

PULSE (0) | TEMP. F (°)

105° 104° 103° 102° 101° 100° 99° 98.6° 98° 97° 96° 95°

180 170 160 150 140 130 120 110 100 90 80 70 60 50 40

TEMP. C: 40.6° 40.0° 39.4° 38.9° 38.3° 37.8° 37.2° 37.0° 36.7° 36.1° 35.6° 35.0°

(Centigrade Equivalents, for Reference only)

RESPIRATION RECORD: 22 19 | 18 20 | 12 20 | 12 20

BLOOD PRESSURE: 140/90 | 138/94 | 126/96 | 134/92 | 134/88 | 122/80 | 130/90 | 134/96 | 130/84

HEIGHT: 71" WEIGHT: 162

Record special data only when so ordered

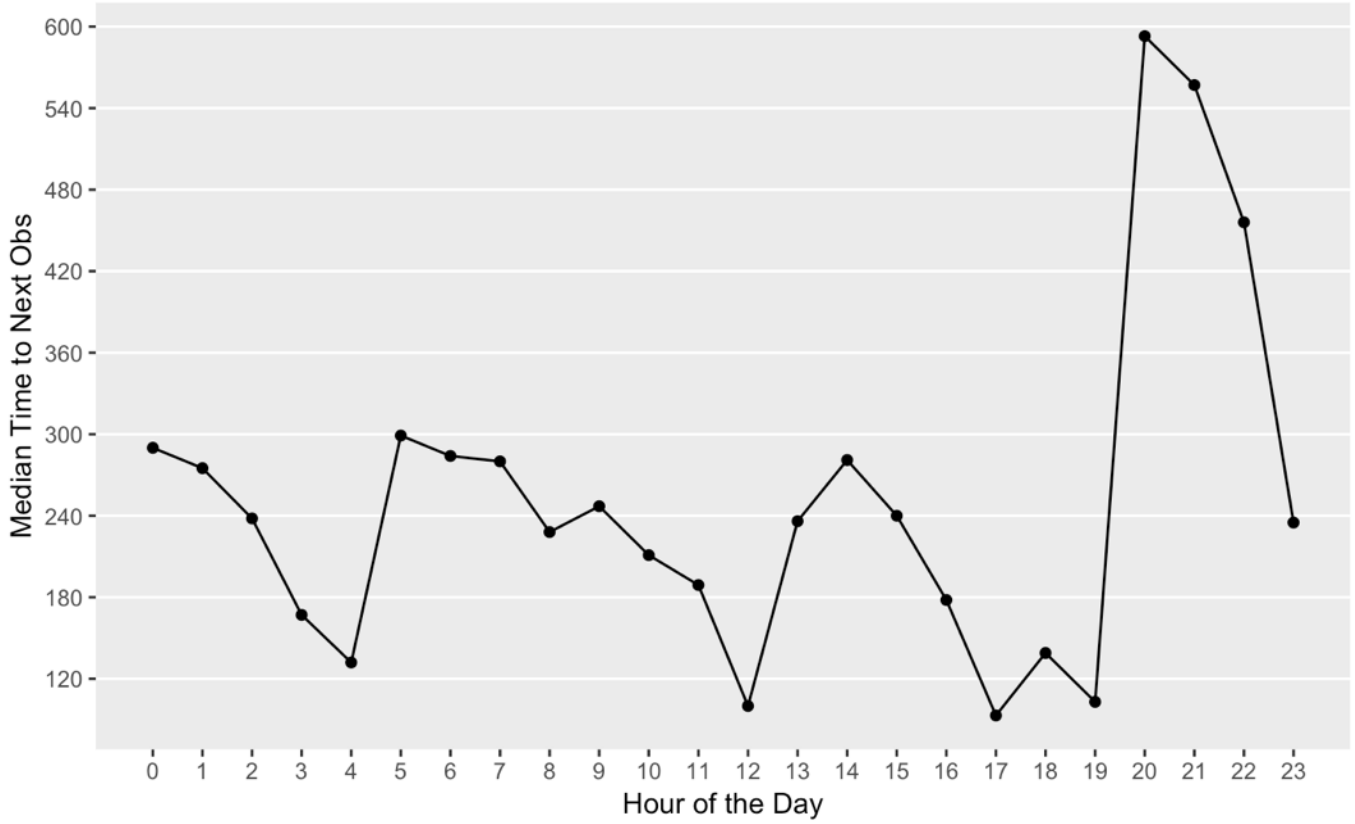
PATIENT'S IDENTIFICATION (For typed or written entries give: Name--last, first, middle; grade; rank; rate; hospital or medical facility)

REGISTER NO.

WARD NO.

VITAL SIGNS RECORDS
Medical Record
STANDARD FORM 511 (REV. 7-91)
Prescribed by GSA/ICMR
FIRMR (41 CFR) 201-45.505
511-113

OBSERVATION TIMINGS



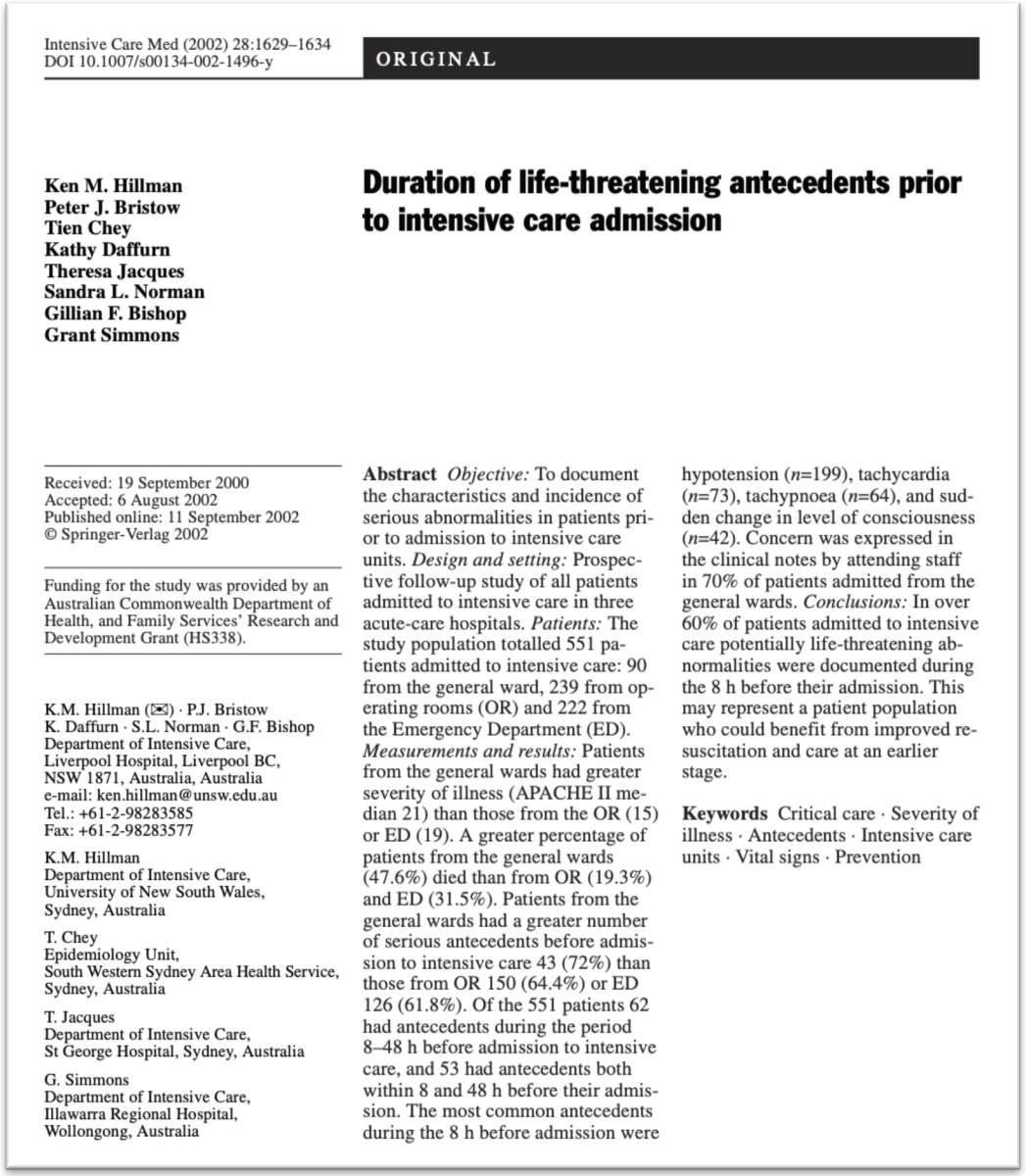
Clinical Antecedents to In-Hospital Cardiopulmonary Arrest*

Roland M.H. Schein, M.D.; Nelson Hazday, M.D.; Maria Pena, R.N.; Bradley H. Ruben, D.O., F.C.C.P.; and Charles L. Sprung, M.D., F.C.C.P.

While the outcome of in-hospital cardiopulmonary arrest has been studied extensively, the clinical antecedents of arrest are less well defined. We studied a group of consecutive general hospital ward patients developing cardiopulmonary arrest. Prospectively determined definitions of underlying pathophysiology, severity of underlying disease, patient complaints, and clinical observations were used to determine common clinical features. Sixty-four patients arrested 161 ± 26 hours following hospital admission. Pathophysiologic alterations preceding arrest were classified as respiratory in 24 patients (38 percent), metabolic in 7 (11 percent), cardiac in 6 (9 percent), neurologic in 4 (6 percent), multiple in 17 (27 percent), and unclassified in 6 (9 percent). Patients with multiple disturbances had mainly respiratory (39 percent) and metabolic (44 percent) disorders. Fifty-four patients (84 percent) had documented observations of clinical deterioration or new complaints within eight hours of arrest. Seventy percent of all patients had either deterioration of respiratory or mental function observed during this time. Routine laboratory tests obtained before arrest showed no consistent abnormalities, but vital signs showed a mean respiratory rate of 29 ± 1 breaths per minute. The prognoses of patients' underlying diseases were classified as ultimately fatal in 26 (41 percent), nonfatal in 23 (36 percent), and rapidly fatal in 15 (23 percent). Five patients (8 percent) survived to hospital discharge. Patients developing arrest on the general hospital ward services have predominantly respiratory and metabolic derangements immediately preceding their arrests. Their underlying diseases are generally not rapidly fatal. Arrest is frequently preceded by a clinical deterioration involving either respiratory or mental function. These features and the high mortality associated with arrest suggest that efforts to predict and prevent arrest might prove beneficial. ***(Chest 1990; 98:1388-92)***

ACLS = advanced cardiac life support

Schein RM, Hazday N, Pena M, Ruben BH, Sprung CL.
Clinical antecedents to in-hospital cardiopulmonary arrest. Chest. 1990 Dec;98(6):1388–92.



Intensive Care Med (2002) 28:1629–1634
DOI 10.1007/s00134-002-1496-y

ORIGINAL

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Duration of life-threatening antecedents prior to intensive care admission

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Abstract *Objective:* To document the characteristics and incidence of serious abnormalities in patients prior to admission to intensive care units. *Design and setting:* Prospective follow-up study of all patients admitted to intensive care in three acute-care hospitals. *Patients:* The study population totalled 551 patients admitted to intensive care: 90 from the general ward, 239 from operating rooms (OR) and 222 from the Emergency Department (ED). *Measurements and results:* Patients from the general wards had greater severity of illness (APACHE II median 21) than those from the OR (15) or ED (19). A greater percentage of patients from the general wards (47.6%) died than from OR (19.3%) and ED (31.5%). Patients from the general wards had a greater number of serious antecedents before admission to intensive care 43 (72%) than those from OR 150 (64.4%) or ED 126 (61.8%). Of the 551 patients 62 had antecedents during the period 8–48 h before admission to intensive care, and 53 had antecedents both within 8 and 48 h before their admission. The most common antecedents during the 8 h before admission were hypotension (n=199), tachycardia (n=73), tachypnoea (n=64), and sudden change in level of consciousness (n=42). Concern was expressed in the clinical notes by attending staff in 70% of patients admitted from the general wards. *Conclusions:* In over 60% of patients admitted to intensive care potentially life-threatening abnormalities were documented during the 8 h before their admission. This may represent a patient population who could benefit from improved resuscitation and care at an earlier stage.

Keywords Critical care · Severity of illness · Antecedents · Intensive care units · Vital signs · Prevention

Conclusions

In **over 60%** of patients admitted to intensive care potentially **life-threatening abnormalities** were documented during the **8 h before their admission**

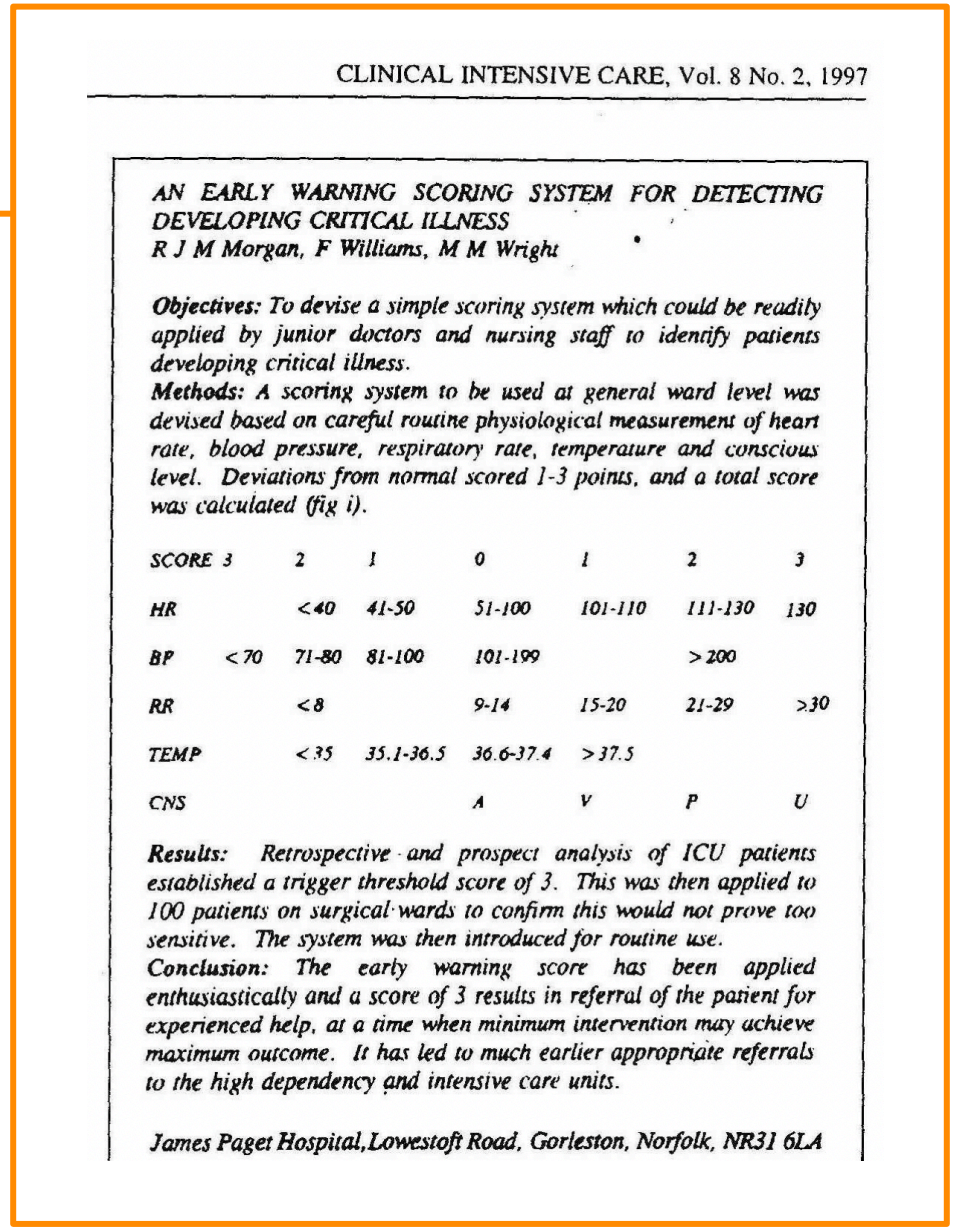
This may represent a patient population who could benefit from improved resuscitation and care at an earlier stage.

Hillman KM, Bristow PJ, Chey T, Daffurn K, Jacques T, Norman SL, et al. Duration of life-threatening antecedents prior to intensive care admission. Intensive Care Med. 2002 Nov;28(11):1629–34.

MET Calling Criteria – 1994

First EWS – 1997

MEWS – 2001



CLINICAL INTENSIVE CARE, Vol. 8 No. 2, 1997

AN EARLY WARNING SCORING SYSTEM FOR DETECTING DEVELOPING CRITICAL ILLNESS

R J M Morgan, F Williams, M M Wright

Objectives: To devise a simple scoring system which could be readily applied by junior doctors and nursing staff to identify patients developing critical illness.

Methods: A scoring system to be used at general ward level was devised based on careful routine physiological measurement of heart rate, blood pressure, respiratory rate, temperature and conscious level. Deviations from normal scored 1-3 points, and a total score was calculated (fig i).

SCORE	3	2	1	0	1	2	3
HR		<40	41-50	51-100	101-110	111-130	130
BP	<70	71-80	81-100	101-199		>200	
RR		<8		9-14	15-20	21-29	>30
TEMP		<35	35.1-36.5	36.6-37.4	>37.5		
CNS				A	V	P	U

Results: Retrospective and prospect analysis of ICU patients established a trigger threshold score of 3. This was then applied to 100 patients on surgical wards to confirm this would not prove too sensitive. The system was then introduced for routine use.

Conclusion: The early warning score has been applied enthusiastically and a score of 3 results in referral of the patient for experienced help, at a time when minimum intervention may achieve maximum outcome. It has led to much earlier appropriate referrals to the high dependency and intensive care units.

James Paget Hospital, Lowestoft Road, Gorleston, Norfolk, NR31 6LA

Morgan RJM, Williams F, Wright MM.
An early warning scoring system for detecting developing critical illness.
Clinical Intensive Care. 1997;8(2):100.

MET Calling Criteria – 1994

First EWS – 1997

MEWS – 2001

EWS mandated as a standard of care – 2007

> 33 published EWS – 2008

Table 1 Thirty-three aggregate weighted track and trigger systems used in the study with their physiological components (marked with ●)

Year	System	Author and citation	PR	BR	sBP	AVPU	Temp	Urine	Age	S_pO_2	F_iO_2
1997	1	Morgan[25]	●	●	●	●	●				
2000	2	Wright[45]	●	●	●	●	●				
2001	3	Subbe[79]	●	●	●	●	●				
2001	4	Subbe[79]	●	●	●	●	●		●		
2001	5	Fox[33]	●	●	●	●	●	●			
2001	6	Riley[77]	●	●	●	●	●	●			
2001	7	Cooper[41]	●	●	●	●	●	●			
2002	8	Subbe[70]	●	●	●	●			●		
2002	9	Wasson[81]	●	●	●	●	●				
2002	10	Odell[31]	●	●	●	●		●			
2002	11	Carberry[34]	●	●	●	●	●	●			
2003	12	Rees[29]	●	●	●	●	●	●			
2004	13	Rees[27]	●	●	●	●					
2004	14	Priestley[28]	●	●	●	●		●			
2004	15	Ryan[36]	●	●	●	●	●	●			
2004	16	Allen[37]	●	●	●	●	●	●			
2005	17	Goldhill[35]	●	●	●	●	●	●		●	?
2005	18	Chatterjee[38]	●	●	●	●					
2005	19	Heaps[39]	●	●	●	●	●	●			
2005	20	Andrews[40]	●	●	●	●	●				
2005	21	Bakir[73]	●	●	●	●	●		●	●	Air
2006	22	Smith[6]	●	●	●	●	●	●			
2006	23	Paterson[3]	●	●	●	●	●			●	?
2006	24	Lam[26]	●	●	●	●	●				
2006	25	Smith[30]	●	●	●	●	●	●			
2006	26	Gardner-Thorpe[32]	●	●	●	●	●	●			
2006	27	Hancock[43]	●	●	●	●	●				
2007	28	Duckitt[4]	●	●	●	●	●			●	Air
2007	29	Subbe[22]	●	●	●	●			●		
2007	30	Odell[42]	●	●	●	●		●			
2007	31	Barlow[44]	●	●	●	●	●	●		●	?
2007	32	Von Lilienfeld-Toal[82]	●	●	●	●	●				
2007	33	Von Lilienfeld-Toal[82]	●	●	●	●	●	●		●	?

PR = pulse rate; BR = breathing rate; sBP = systolic BP; Temp = temperature

Smith GB, Prytherch DR, Schmidt PE, Featherstone PI.
Review and performance evaluation of aggregate weighted "track and trigger" systems. Resuscitation. 2008 May;77(2):170–9.

MET Calling Criteria – 1994

First EWS – 1997

MEWS – 2001

EWS mandated as a standard of care – 2007

> 33 published EWS – 2008

NEWS – 2012

Recommended *standard of care*

National Early Warning Score (NEWS)*

PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
Systolic BP	≤90	91 - 100	101 - 110	111 - 219			≥220
Heart Rate	≤40		41 - 50	51 - 90	91 - 110	111 - 130	≥131
Level of Consciousness				A			V, P, or U

Prytherch DR, Smith GB, Schmidt PE, Featherstone PI.
ViEWS – Towards a national early warning score for detecting adult inpatient deterioration.
Resuscitation. 2010 Aug;81(8):932–7.

MET Calling Criteria – 1994

First EWS – 1997

MEWS – 2001

EWS mandated as a standard of care – 2007

> 33 published EWS – 2008

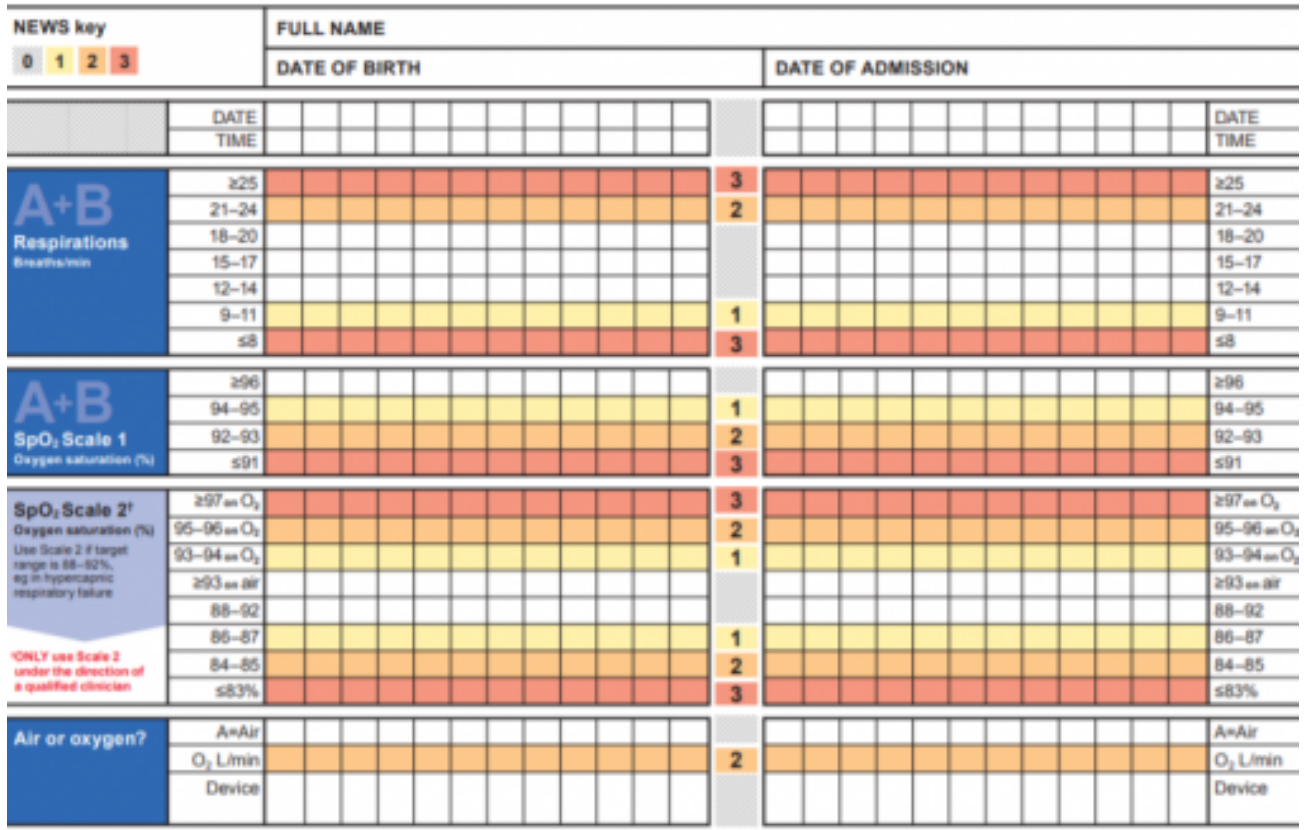
NEWS – 2012

Recommended *standard of care*

NEWS2 – 2019

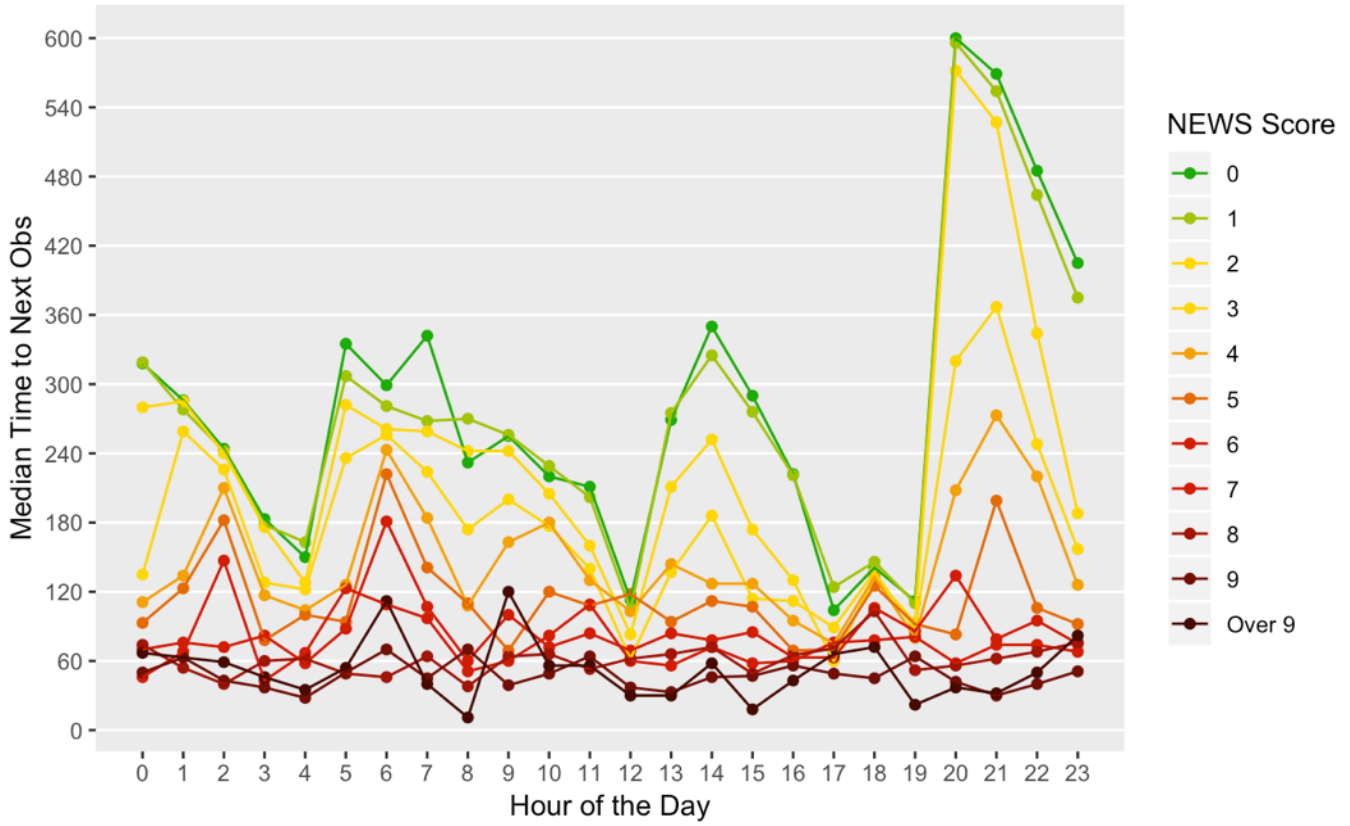
Mandated *standard of care*

Physiological parameter	Score 3	2	1	0	1	2	3
Respiration rate (per minute)	≤8		9–11	12–20		21–24	≥25
SpO_2 Scale 1 (%)	≤91	92–93	94–95	≥96			
SpO_2 Scale 2 (%)	≤83	84–85	86–87	88–92 ≥93 on air	93–94 on oxygen	95–96 on oxygen	≥97 on oxygen
Air or oxygen?		Oxygen		Air			
Systolic blood pressure (mmHg)	≤90	91–100	101–110	111–219			≥220
Pulse (per minute)	≤40		41–50	51–90	91–110	111–130	≥131
Consciousness				Alert			CVPU
Temperature (°C)	≤35.0		35.1–36.0	36.1–38.0	38.1–39.0	≥39.1	

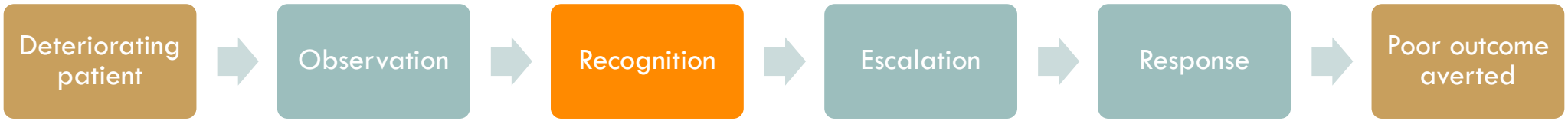


NEWS SCORE	FREQUENCY OF MONITORING	CLINICAL RESPONSE
0	Minimum 12 hourly	• Continue routine NEWS monitoring with every set of observations
Total: 1-4	Minimum 4-6 hourly	• Inform registered nurse who must assess the patient; • Registered nurse to decide if increased frequency of monitoring and / or escalation of clinical care is required;
Total: 5 or more or 3 in one parameter	Increased frequency to a minimum of 1 hourly	• Registered nurse to urgently inform the medical team caring for the patient; • Urgent assessment by a clinician with core competencies to assess acutely ill patients; • Clinical care in an environment with monitoring facilities;
Total: 7 or more	Continuous monitoring of vital signs	• Registered nurse to **immediately** inform the medical team caring for the patient – this should be at least at Specialist Registrar level; • Emergency assessment by a clinical team with critical care competencies, which also includes a practitioner/s with advanced airway skills; • Consider transfer of Clinical care to a level 2 or 3 care facility, i.e. higher dependency or ITU;

OBSERVATION TIMINGS



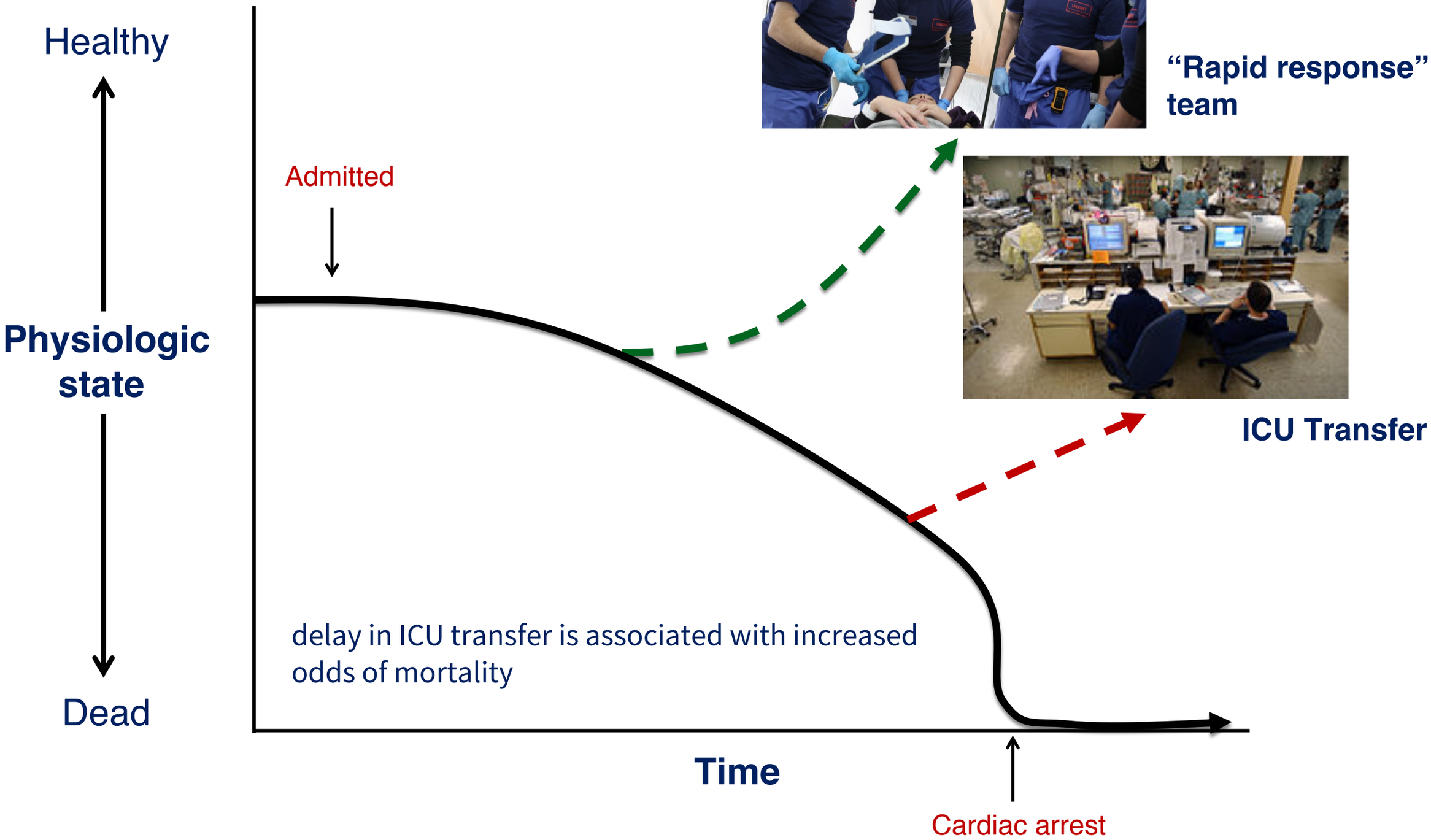
EARLY WARNING SCORES



- Aim
  - To help clinical staff recognise abnormal physiology
  - To **support** (augment) clinical decision making (not to automate)
- Design constraints
  - Simple enough to be computed with pen and paper at the bedside (cf: more complex risk scoring algorithms)
- Underlying hypotheses
  - Deterioration is (always) predicted by deviations in vital signs from normality
  - The risk of deterioration is (always) correlated with the degree of observed physiological abnormality
  - Early intervention (always) averts further deterioration

the need

hospitalisation time course



early warning scores

ViEWS – 2010

NEWS – 2012

National Early Warning Score (NEWS), based on hand-tuned thresholds in order to maximise the AUROC

PHYSIOLOGICAL PARAMETERS	3	2	1	0	1	2	3
Respiration Rate	≤8		9 - 11	12 - 20		21 - 24	≥25
Oxygen Saturations	≤91	92 - 93	94 - 95	≥96			
Any Supplemental Oxygen		Yes		No			
Temperature	≤35.0		35.1 - 36.0	36.1 - 38.0	38.1 - 39.0	≥39.1	
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Level of Consciousness				A			V, P, or U

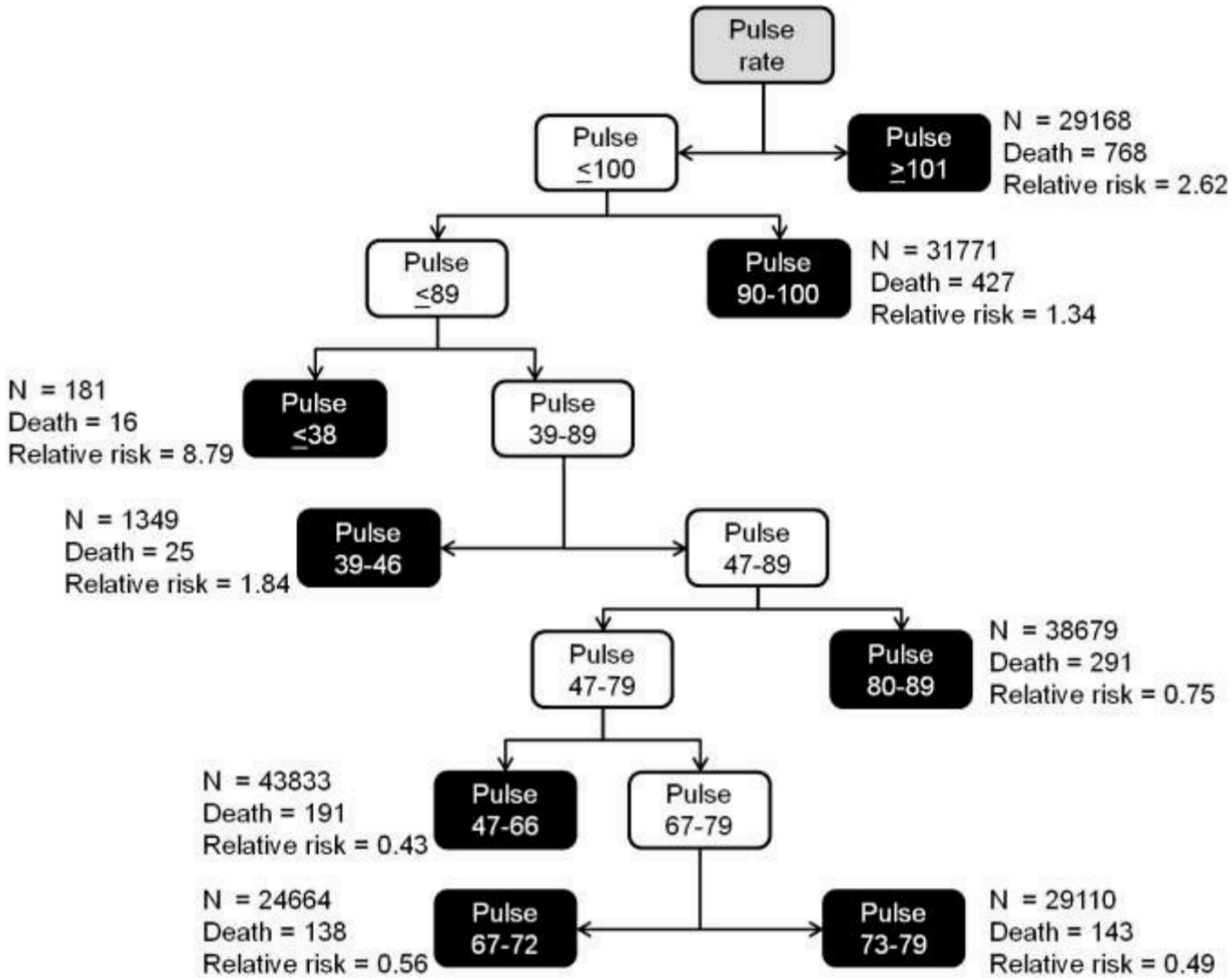
Prytherch et al. (2010) Resuscitation

NHS, Royal College of Physicians 2012

early warning scores

DTEWS – 2014

EWS based on decision trees



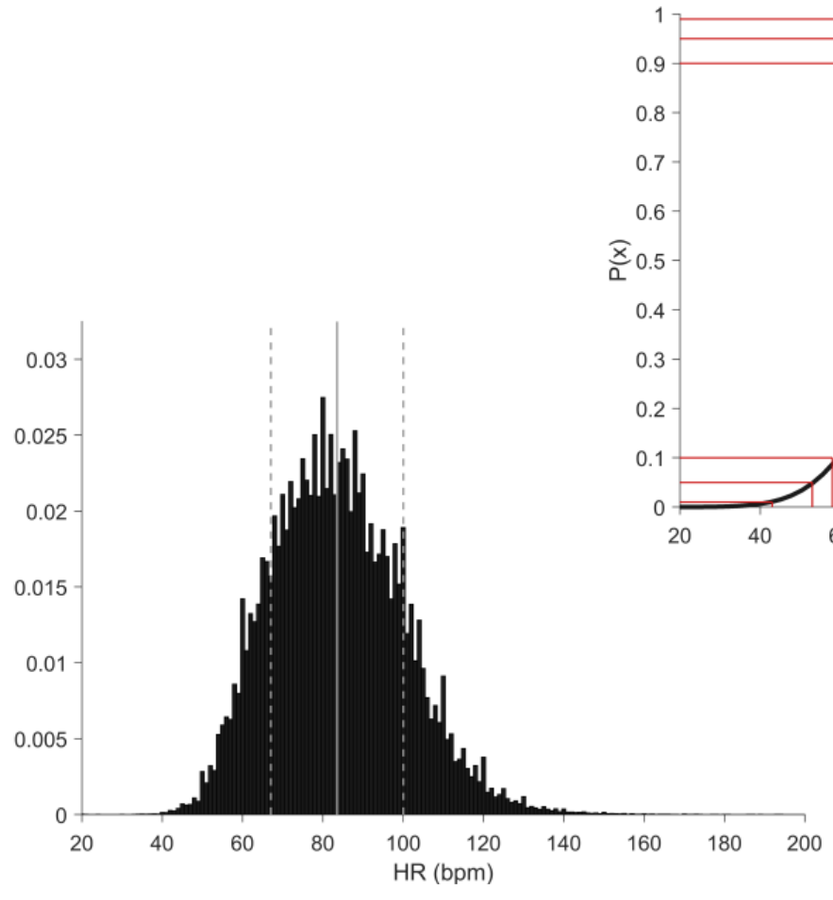
Badriyah et al. (2014) Resuscitation 85: 418-23

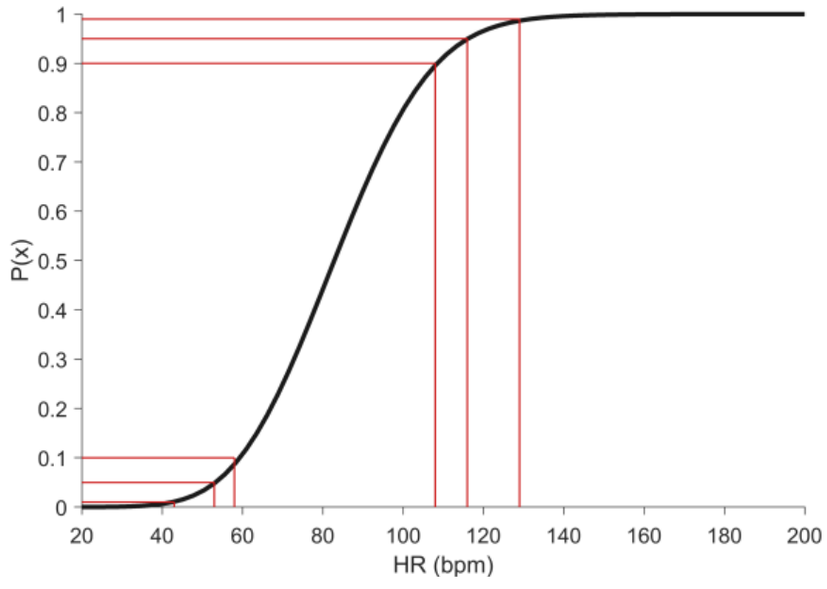
early warning scores

CEWS – 2011

CEWS – 2018

a “centile-based” EWS based on the statistical distributions of the vital signs

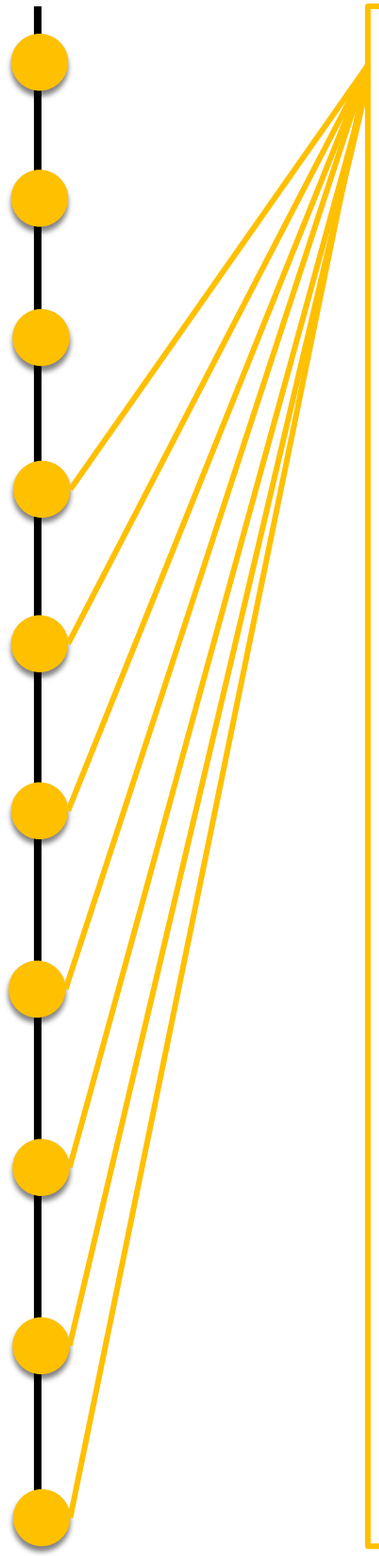




Tarassenko et al. (2011) Resuscitation 82: 1013-8

Watkinson, et al. (2018) Resuscitation 129: 55-60

early warning scores



scoring systems based on a broader list of clinical data items stored in the EHR

demographic data

age, gender, ethnic group

vital signs

heart rate, blood pressure, temperature

e-prescriptions

vasopressors, oxygen, sedation

labs

creatinine, haemoglobin, blood cells count

procedures and diagnosis

surgical interventions, pneumonia, diabetes

administrative info

transfers, medical specialty, elective surgery

challenges in designing a scoring system

general methodological issues when training and validating EWSs

- choice of **outcome**
- **EWSs** are attached to protocols (not to a binary decision)
- dealing with sparsely, irregularly-sampled, multivariate data

other issues

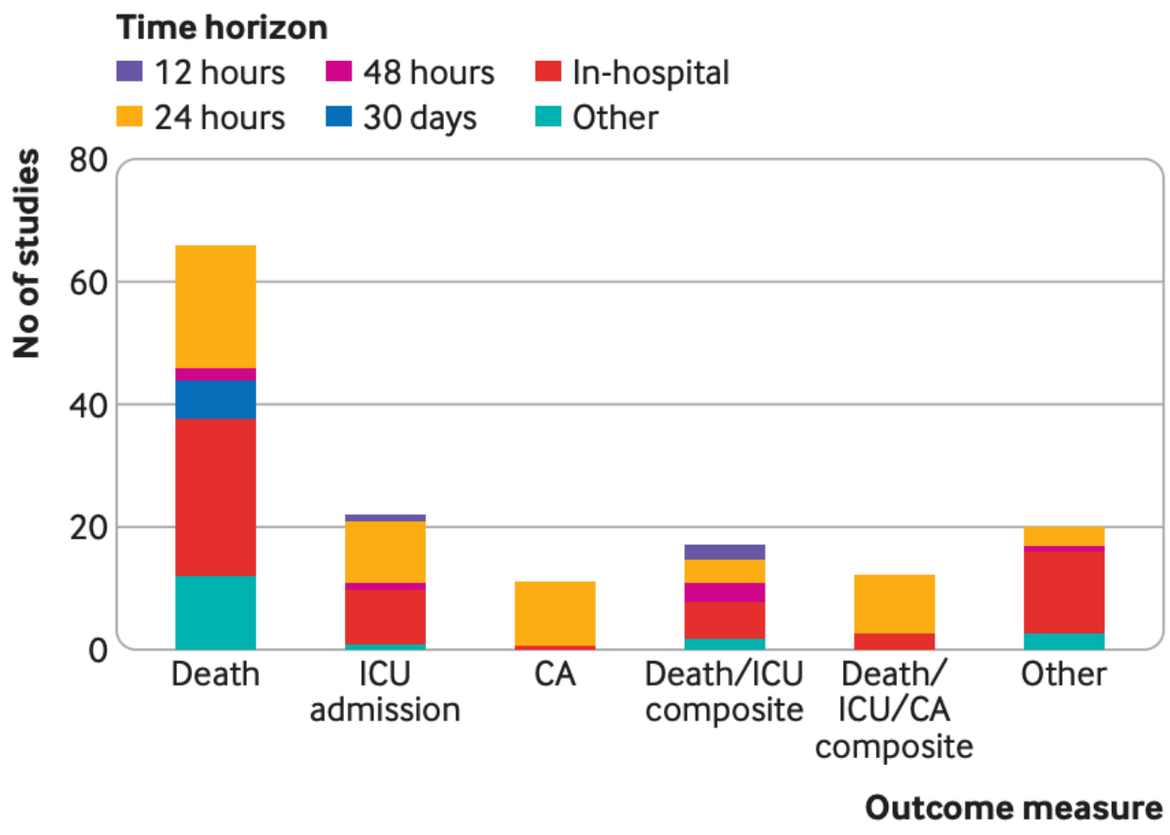
- personalisation
- confounding

challenges in designing a scoring system

choice of outcome

- what clinical adverse **event** (e.g., in-hospital mortality, ICU admission, cardiac arrest, composite outcome)

- prediction time horizon

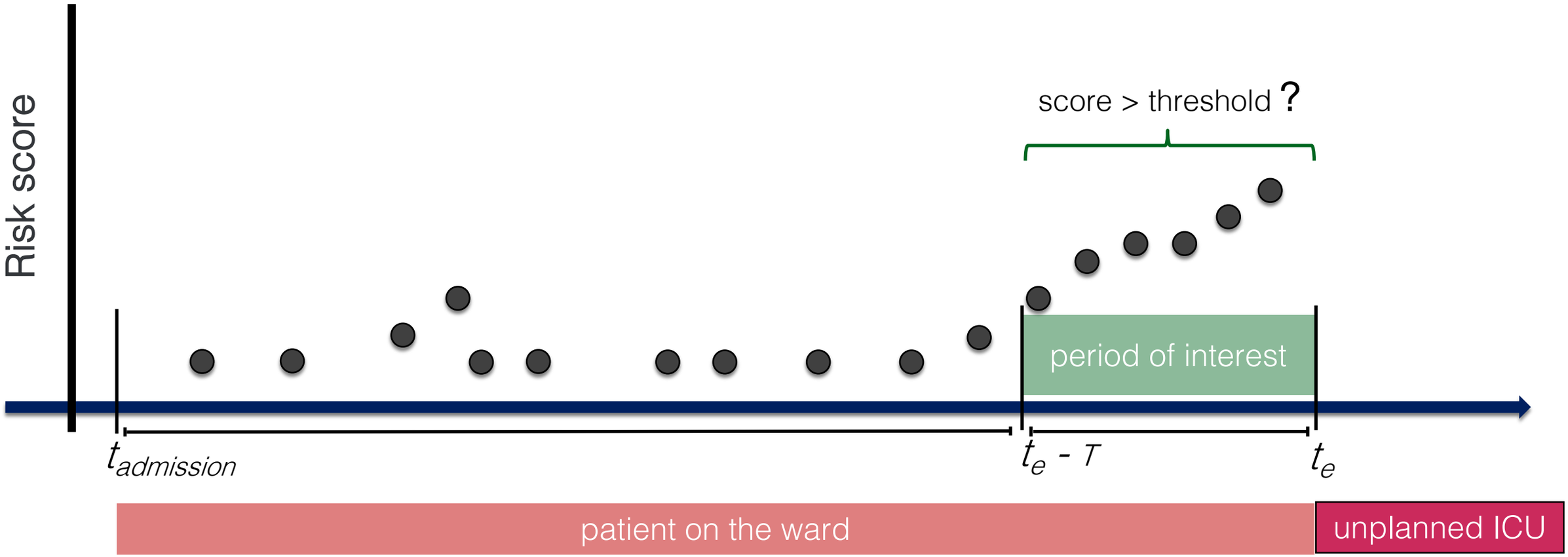


Gerry et al. (2020) BMJ [Systematic Review]

challenges in designing a scoring system

choice of outcome

- what clinical adverse **event** (e.g., in-hospital mortality, ICU admission, cardiac arrest, composite outcome)
- prediction time horizon
- derived outcome: “event” within the next T hours (e.g., 24 hours)



challenges in designing a scoring system

general methodological issues when training and validating EWSs

- choice of **outcome**
- **EWSs** are typically attached to protocols (not to a binary decision)
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other issues

- personalisation
- confounding

challenges in designing a scoring system

“call-out cascade” for NEWS2

Clinical response to the NEWS2 trigger thresholds		
NEWS2 SCORE	**Frequency of monitoring**	**Clinical Response**
0	**Minimum 12 hourly**	• Continue routine NEWS2 monitoring
Total 1-4	**Minimum 4-6 hourly** Consider urine output	• Inform Registered Nurse (RN), who must assess the patient, put nursing interventions in place and document actions on observation chart • RN must inform the ward co-ordinator if concerned • RN must decide whether increased frequency of observations and /or doctor review is required
3 in single parameter THINK SEPSIS	**Minimum 1 hourly** Consider urine output	• Inform Registered Nurse (RN), who must assess the patient • RN to inform ward co-ordinator and medical team, who will review and decide whether escalation of care is necessary • Document actions on observation chart
Total 5 or more **URGENT** Response threshold THINK SEPSIS	**Minimum 1 hourly** Consider urine output	• Inform Registered Nurse (RN), who must assess the patient • RN to immediately inform ward co-ordinator • RN to immediately request urgent assessment by medical team, using the SBARD communication tool • If the medical team unable to attend within 30 mins, they must escalate to senior member of their own medical team or H@N Team (as detailed below). Document actions on the observation chart
Consider referral to the Critical Care Outreach Nursing Team Bleep [redacted] for advice and support		
Total 7 or more EMERGENCY response threshold THINK SEPSIS	**Continuous monitoring of vital signs Including urine output**	• Inform Registered Nurse (RN), who must assess the patient • RN to immediately inform ward co-ordinator who must attend and assess patient immediately • RN to refer to medical team (Specialist Registrar level) using SBARD • Escalate to Consultant level and consider whether Critical Care Medical Referral required (via a Consultant to Consultant referral) • Consider transfer of care to clinical environment with monitoring facilities (coronary care / high dependency/intensive care units)
Refer to the Critical Care Outreach Nursing Team Bleep [redacted] or H&N Team for advice and support		
Help needed urgently?	If the patient’s condition continues to deteriorate and prompt medical review required, consider putting a cardiac arrest call out (2222) or if Critical Care Medical referral required Bleep [redacted]	

based on NHS, Royal College of Physicians 2018

challenges in designing a scoring system

general methodological issues when training and validating EWSs

- choice of **outcome**
- **EWSs** are attached to protocols (not to a binary decision)
- dealing with sparsely, irregularly-sampled, multivariate data

other issues

- personalisation
- confounding

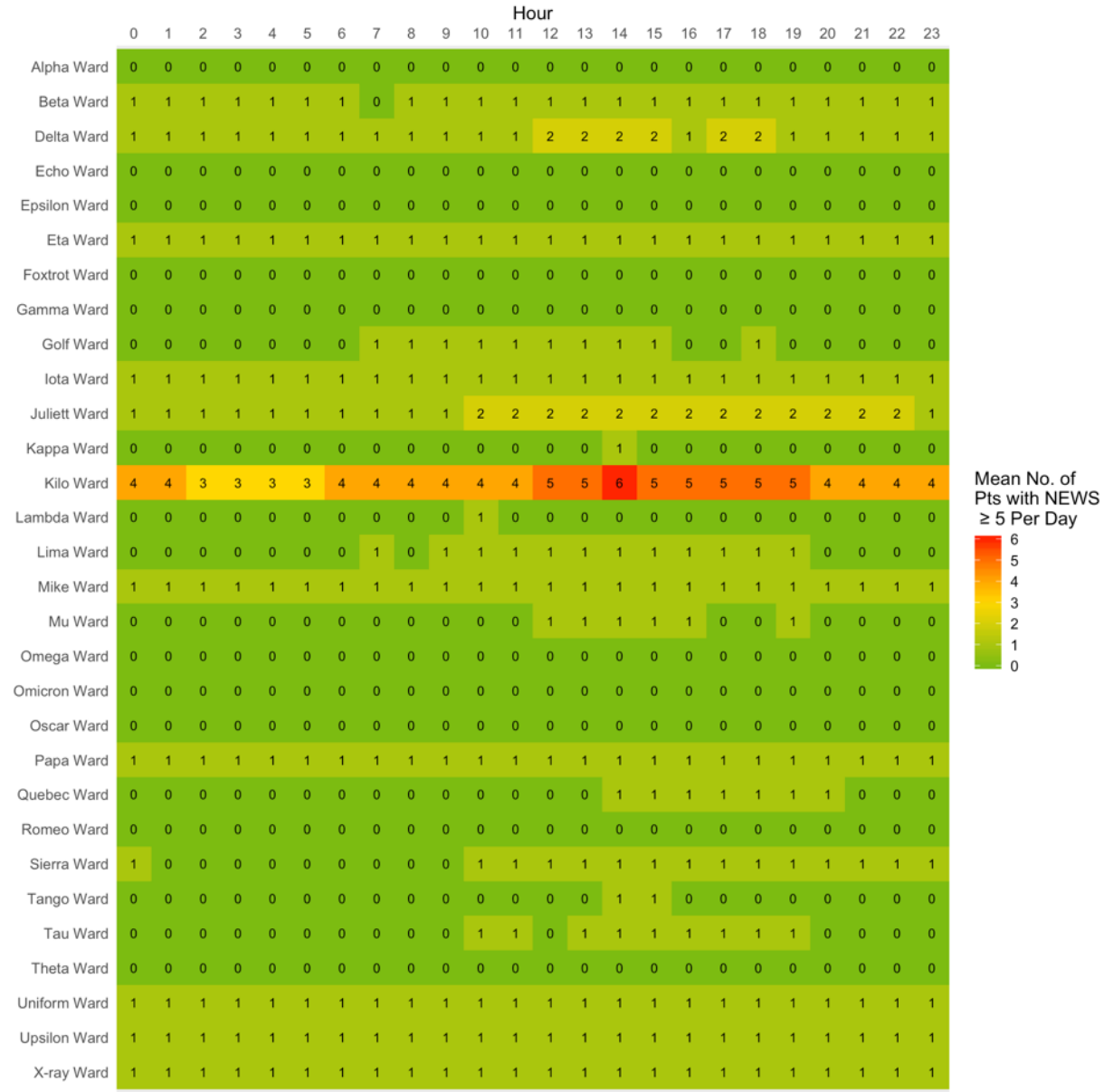
CLINICAL ISSUES

- Personalisation
- Confounding

PERSONALISATION

- Deterioration is predicted by deviations in vital signs from normality.

- Normal for which population?
  - PEWS


Hour
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
Alpha Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Beta Ward 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Delta Ward 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2 2 1 2 2 1 1 1 1 1
Echo Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Epsilon Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Eta Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Foxtrot Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Gamma Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Golf Ward 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 0 0 1 0 0 0 0 0
Iota Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Juliett Ward 1 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1
Kappa Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
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Lambda Ward 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0
Lima Ward 0 0 0 0 0 0 0 1 0 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0
Mike Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Mu Ward 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 1 0 0 0 0
Omega Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Omicron Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Oscar Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Papa Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Quebec Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0
Romeo Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Sierra Ward 1 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Tango Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0
Tau Ward 0 0 0 0 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 1 0 0 0 0
Theta Ward 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Uniform Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Upsilon Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
X-ray Ward 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Mean No. of Pts with NEWS ≥ 5 Per Day
6
5
4
3
2
1
0

Physiological parameter	Score 3	2	1	0	1	2	3
Respiration rate (per minute)	≤8		9–11	12–20		21–24	≥25
SpO_2 Scale 1 (%)	≤91	92–93	94–95	≥96			
SpO_2 Scale 2 (%)	≤83	84–85	86–87	88–92 ≥93 on air	93–94 on oxygen	95–96 on oxygen	≥97 on oxygen
Air or oxygen?		Oxygen		Air			
Systolic blood pressure (mmHg)	≤90	91–100	101–110	111–219			≥220
Pulse (per minute)	≤40		41–50	51–90	91–110	111–130	≥131
Consciousness				Alert			CVPU
Temperature (°C)	≤35.0		35.1–36.0	36.1–38.0	38.1–39.0	≥39.1	

CONFOUNDING

- Deterioration is predicted by deviations in vital signs from normality.

- But what is the observed physiology?
- Not natural disease

CONFOUNDING

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