MEDINFO23
8 – 12 JULY 2023 | SYDNEY, AUSTRALIA

Dream Big : predicting Sepsis and building a healthcare AI framework for Queensland

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Clinical Excellence Queensland and Metro North Health

Acknowledgment

- Traditional Custodians
- Our vision is to use bigdata and AI research to help overcome inequity in health outcomes

Declaration

- Work funded by Qld Government
- *Enabled by the data of Queenslanders*

- Industry: Chief Medical Advisor for bdna, helped fund my attendance at this event

bdna
the dna of business™

Qld Sepsis AI Working Group

- There's no i in TEAM …
- Professor Ian Scott, Dr Anton Van Der Vegt, Rudolf Schnetler and Vikrant Kalke
- CBI eHealth – Cathi Ryan, Wil Wentholt
- Clinical Excellence Queensland – Michael Rice, Kirstine Sketcher-Baker
- Clinical Excellence Commission NSW
- Dr Amith Shetty, NSW Ministry Health

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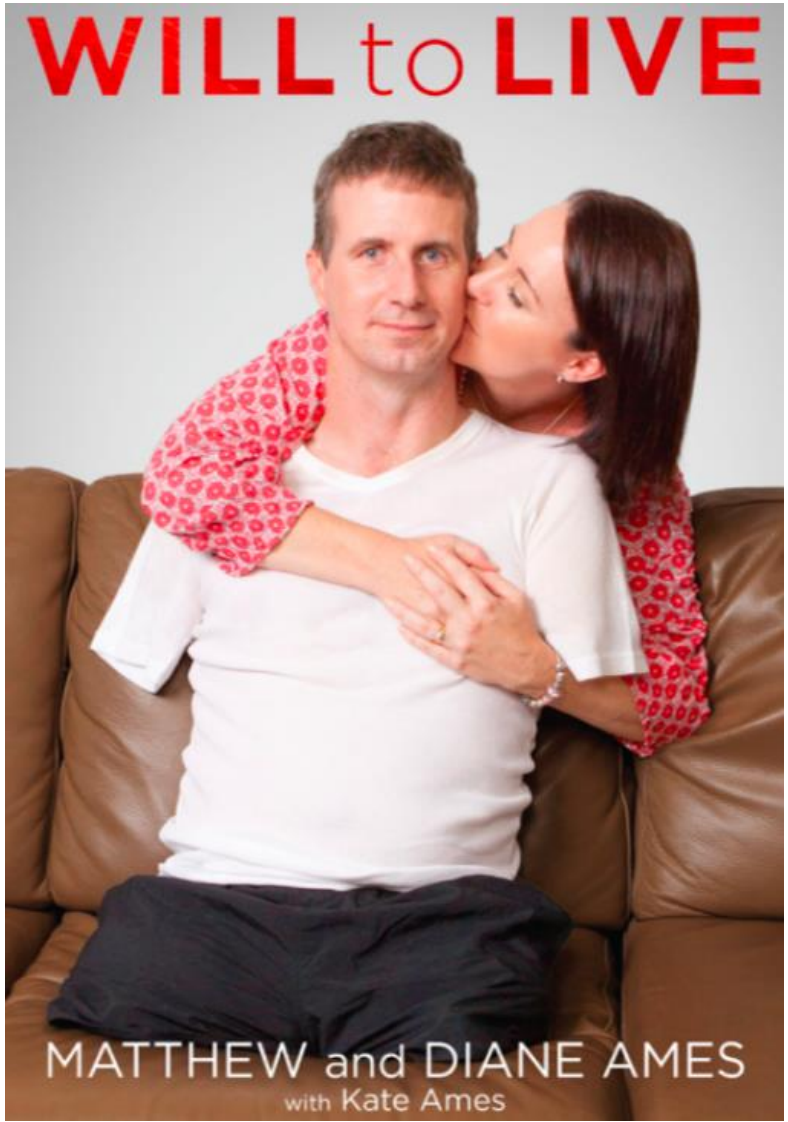
Sepsis

- Infection …
- and *'body shuts down'*

- Organ dysfunction – need machine support in an **ICU** – *'life support'*
- Genetic response – inbuilt in your body

- Global Health Emergency – 1 in 5 deaths worldwide
- 5000-10000 deaths/year Australia
- There is NO single test for diagnosis
- <1% of emergency dept presentations – *needle in haystack*



It turns out Sepsis is hard to diagnose…

Just ask Matthew if it's time critical…

Every minute counts!

Why?

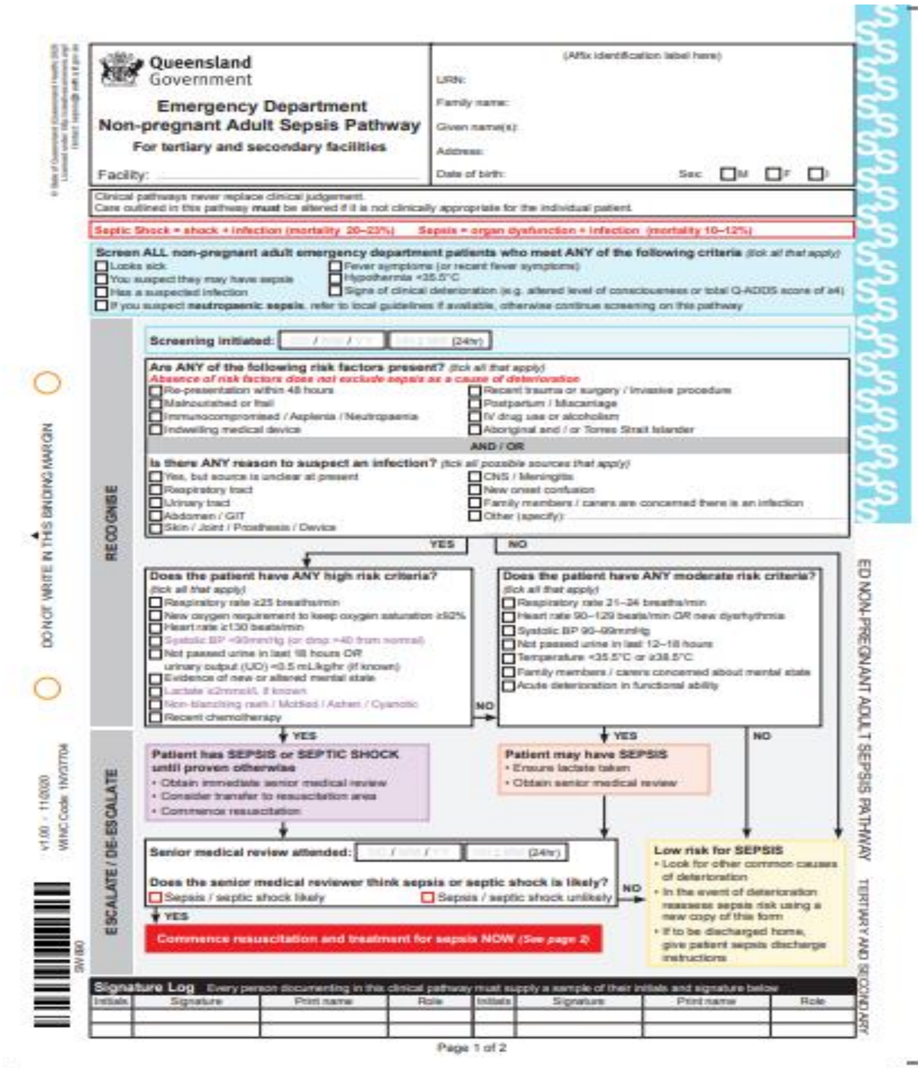
Impact of 1-hour and 3-hour sepsis time bundles on patient outcomes and antimicrobial use: A before and after cohort study

Balasubramanian Venkatesh • Luregn Schlapbach • Donna Mason • Kathryn Wilks • Robert Seaton • Paula Lister • Adam Irwin • Paul Lane • Lyndell Redpath • Kristen Gibbons • Endrias Ergetu • Michael Rice • Show less

Open Access • Published: November 01, 2021 • DOI: https://doi.org/10.1016/j.lanwpc.2021.100305

- Improved time to antibiotics
- Decrease need for ICU
- Reduces mortality

A fancy
Decision Tree …


Queensland Government

Emergency Department
Non-pregnant Adult Sepsis Pathway
For tertiary and secondary facilities

Facility:

(Affix identification label here)

URN:
Family name:
Given name(s):
Address:
Date of birth: Sex: M F I

Clinical pathways never replace clinical judgement.
Care outlined in this pathway **must** be altered if it is not clinically appropriate for the individual patient.

Septic Shock = shock + infection (mortality 20–23%) Sepsis = organ dysfunction + infection (mortality 10–12%)

Screen ALL non-pregnant adult emergency department patients who meet ANY of the following criteria *(tick all that apply)*
- Looks sick
- You suspect they may have sepsis
- Has a suspected infection
- Fever symptoms (or recent fever symptoms)
- Hypothermia <35.5°C
- Signs of clinical deterioration (e.g. altered level of consciousness or total Q-ADDS score of ≥4)
- If you suspect **neutropaenic sepsis**, refer to local guidelines if available, otherwise continue screening on this pathway

RECOGNISE

Screening initiated: DD / MM / YY HH:MM (24hr)

Are ANY of the following risk factors present? *(tick all that apply)*
Absence of risk factors does not exclude sepsis as a cause of deterioration
- Re-presentation within 48 hours
- Malnourished or frail
- Immunocompromised / Asplenia / Neutropaenia
- Indwelling medical device
- Recent trauma or surgery / invasive procedure
- Postpartum / Miscarriage
- IV drug use or alcoholism
- Aboriginal and / or Torres Strait Islander

AND / OR

Is there ANY reason to suspect an infection? *(tick all possible sources that apply)*
- Yes, but source is unclear at present
- Respiratory tract
- Urinary tract
- Abdomen / GIT
- Skin / Joint / Prosthesis / Device
- CNS / Meningitis
- New onset confusion
- Family members / carers are concerned there is an infection
- Other (specify):

YES NO

Does the patient have ANY high risk criteria? *(tick all that apply)*
- Respiratory rate ≥25 breaths/min
- New oxygen requirement to keep oxygen saturation ≥92%
- Heart rate ≥130 beats/min
- Systolic BP <90mmHg (or drop >40 from normal)
- Not passed urine in last 18 hours OR urinary output (UO) <0.5 mL/kg/hr (if known)
- Evidence of new or altered mental state
- Lactate ≥2mmol/L if known
- Non-blanching rash / Mottled / Ashen / Cyanotic
- Recent chemotherapy

NO

Does the patient have ANY moderate risk criteria? *(tick all that apply)*
- Respiratory rate 21–24 breaths/min
- Heart rate 90–129 beats/min OR new dysrhythmia
- Systolic BP 90–99mmHg
- Not passed urine in last 12–18 hours
- Temperature <35.5°C or ≥38.5°C
- Family members / carers concerned about mental state
- Acute deterioration in functional ability

YES YES NO

ESCALATE / DE-ESCALATE

Patient has SEPSIS or SEPTIC SHOCK until proven otherwise
- Obtain immediate senior medical review
- Consider transfer to resuscitation area
- Commence resuscitation

Patient may have SEPSIS
- Ensure lactate taken
- Obtain senior medical review

Senior medical review attended: DD / MM / YY HH:MM (24hr)

Does the senior medical reviewer think sepsis or septic shock is likely?
- Sepsis / septic shock likely
- Sepsis / septic shock unlikely

YES NO

Commence resuscitation and treatment for sepsis NOW *(See page 2)*

Low risk for SEPSIS
- Look for other common causes of deterioration
- In the event of deterioration reassess sepsis risk using a new copy of this form
- If to be discharged home, give patient sepsis discharge instructions

Signature Log Every person documenting in this clinical pathway must supply a sample of their initials and signature below

Initials	Signature	Print name	Role	Initials	Signature	Print name	Role

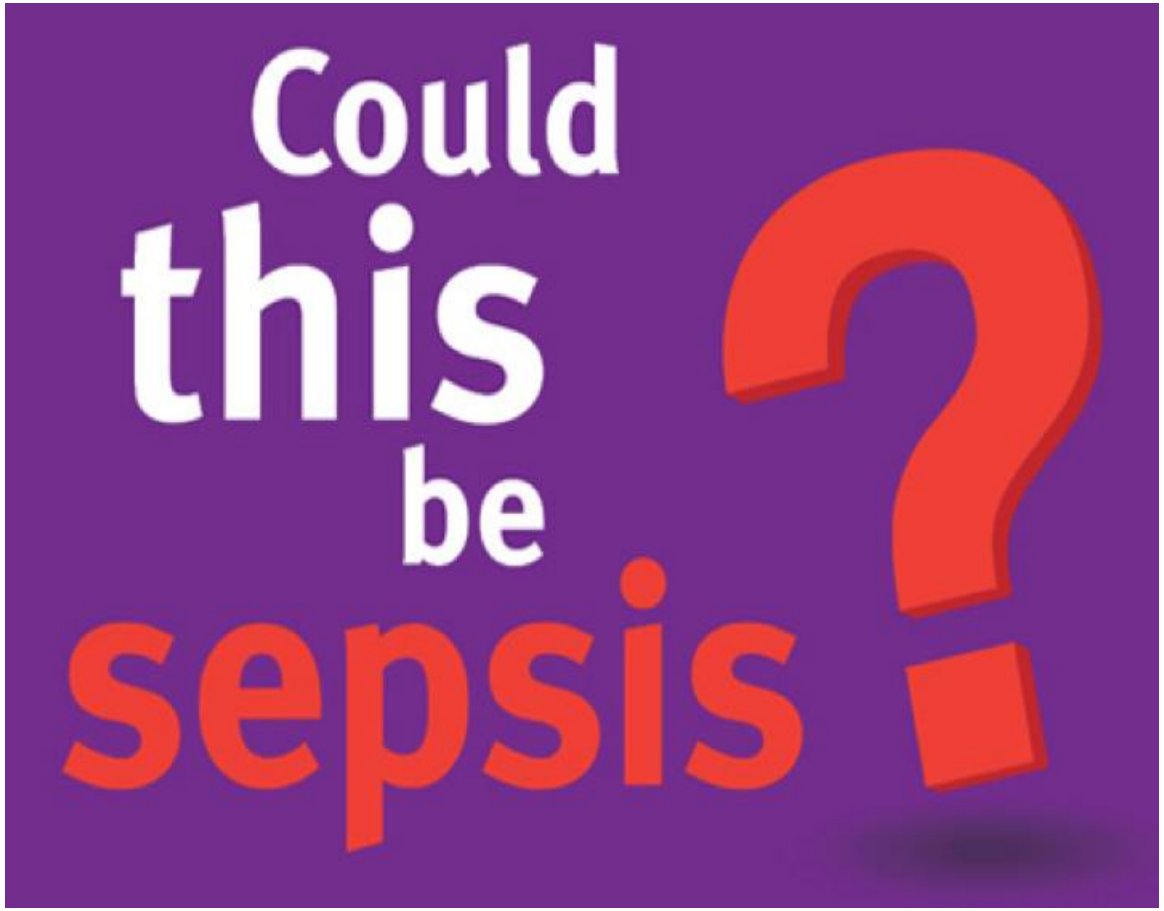
Page 1 of 2

DO NOT WRITE IN THIS BINDING MARGIN

v1.00 - 11/2020
SW180

ED NON-PREGNANT ADULT SEPSIS PATHWAY TERTIARY AND SECONDARY

The Problem

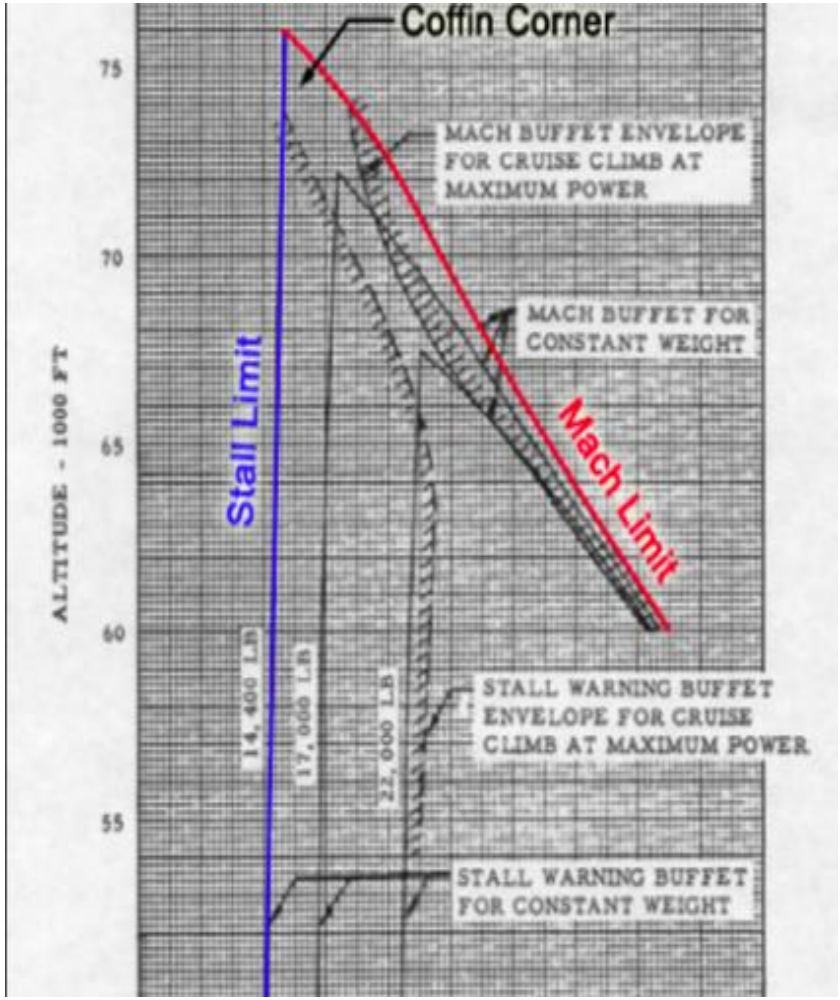


Why is Aviation so SAFE?? *"today I'll turn off the onboard augmented intelligence…"*

Coffin Corner…

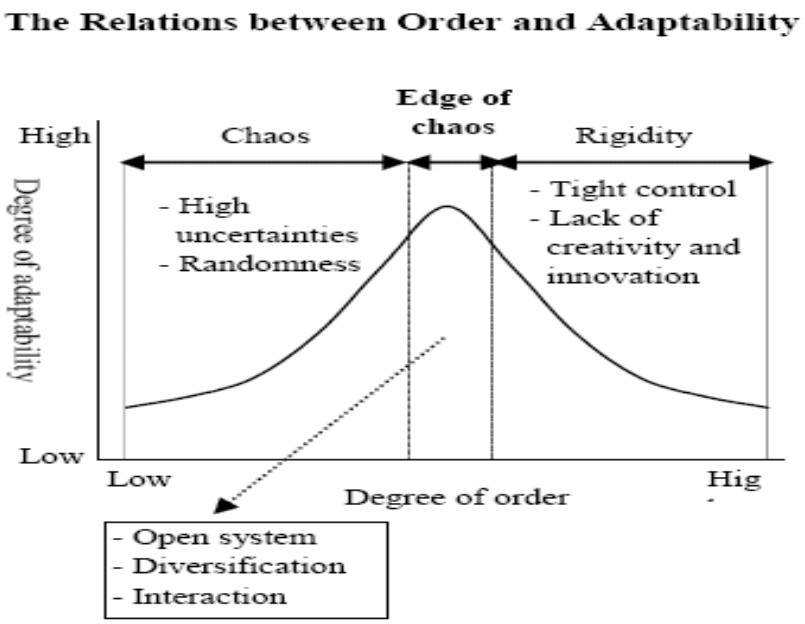
The Risk of Unstable Flight

- At high altitude the stall speed (plane falls from sky) is very near to critical Mach number (maximum speed) where lift is lost due to shock waves and drag is increased
- Both followed by structural failure as airplane falls
- Small margin for error



The 'Edge of Chaos' Problem

- *Clinicians working in the complexity of modern healthcare live on the edge of chaos where demand always exceeds capacity.*



How do we support busy clinical teams?

- We build and test Adult Sepsis predictive algorithms using Artificial Intelligence to provide timely clinician support to assist with the diagnosis of Sepsis

- *Paul, proceed until apprehended* *Prof Keith McNeil*

QLD Sepsis Algorithm Roadmap

Project Planning Start

Thank you NSW!

- **M1:** Funding Approval
- **M2:** Getting TUH Executives on board
- **M3:** CEC, NSW Collaboration –Transfer of Algorithm
- **M4:** Project initiation- Data requirements
- **M5:** Proposed Solution Data Collection- ieMR
- **M6:** Initial Model development
- **M7:** Model testing with stakeholders
- **M8:** Model iteration
- **M9:** Further model testing of iteration/s
- **M10:** Final Model delivery
- **M11:** Stakeholder acceptance Production deployment
- **M12:** Review Process with DAS
- **M13:** Strategies for production alerts being sent in live environment in the ieMR

Delay in Recruitment

Mar | April | May | June | * | Sept | Oct | Nov | Dec | Jan | Feb | Mar | April | May -July | Aug

Q1 Project Planning Funding Approval Recruitment

Q2 Research & Design Sprint Development

Q3 Testing

Q4 Implementation

Q5- Project closure report

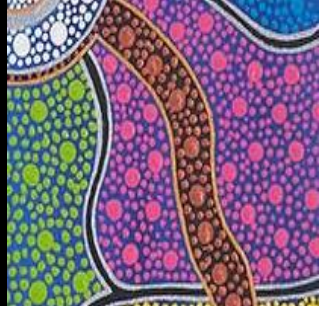
2020 | 2021

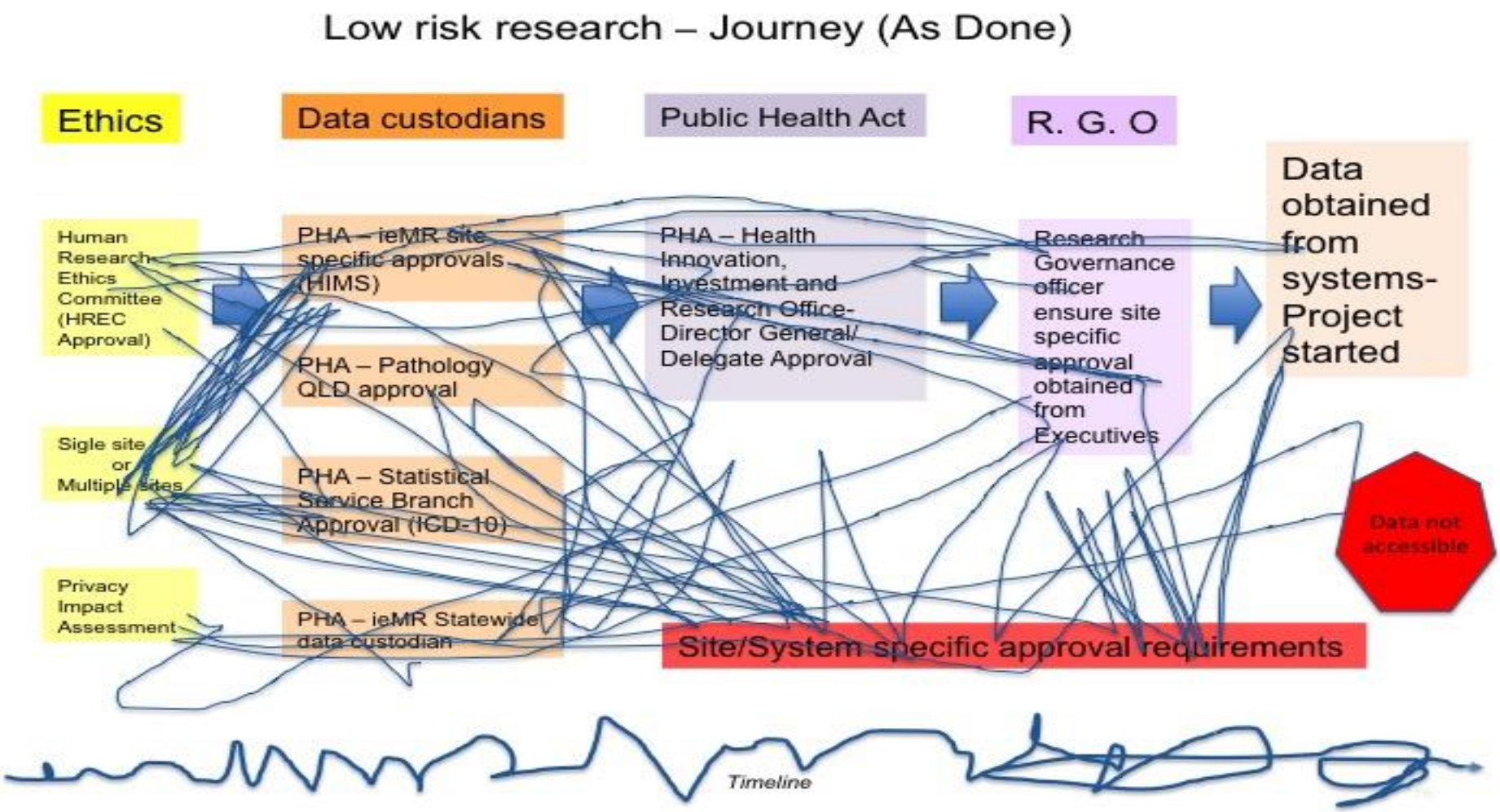
QLD SepAlgorithm_v2_Vik Kalke

Low risk research project – Journey (As Imagined)

Ethics	Data custodians	Public Health Act	R. G. O	
Human Research Ethics Committee (HREC Approval)	PHA – ieMR site specific approvals (HIMS)	PHA – Health Innovation, Investment and Research Office- Director General/ Delegate Approval	Research Governance officer ensure site specific approval obtained from Executives	Data obtained from systems- Project started
Sigle site or Multiple sites	PHA – Pathology QLD approval			
Privacy Impact Assessment	PHA – Statistical Service Branch Approval (ICD-10)			
	PHA – ieMR Statewide data custodian			

Timeline




Low risk research – Journey (As Done)
Ethics
Data custodians
Public Health Act
R. G. O
Data obtained from systems- Project started
Human Research Ethics Committee (HREC Approval)
Sigle site or Multiple sites
Privacy Impact Assessment
PHA – ieMR site specific approvals (HIMS)
PHA – Pathology QLD approval
PHA – Statistical Service Branch Approval (ICD-10)
PHA – ieMR Statewide data custodian
PHA – Health Innovation, Investment and Research Office- Director General/ Delegate Approval
Research Governance officer ensure site specific approval obtained from Executives
Data not accessible
Site/System specific approval requirements
Timeline

12 Digital Hospitals – **REAL EMR Data**

Merged 4 yrs EMR data: 524,000 patients with **1.13M** encounters

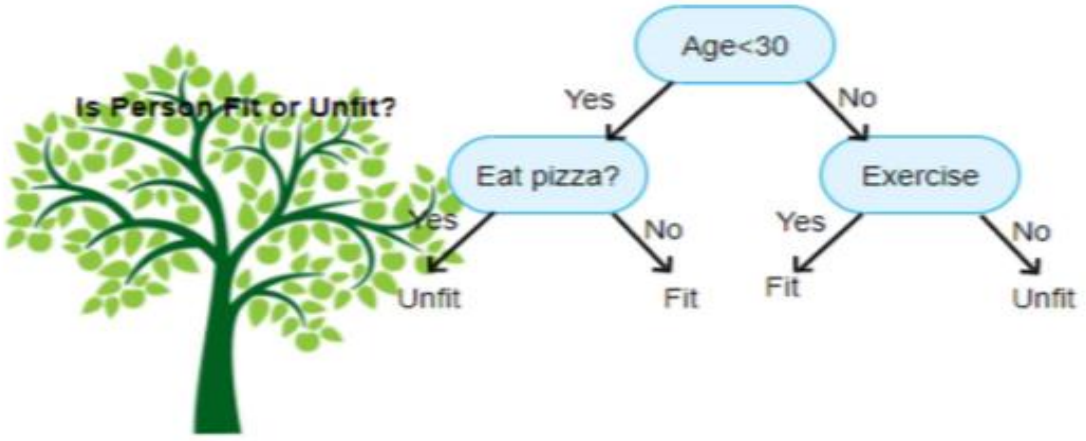
10,922 encounters coded sepsis (ICD-10)

26,753 sepsis encounters by an alternative Sepsis 3 classification

3.4 trillion bytes

Median age 64, mortality of 10%

Microsoft LightGBM



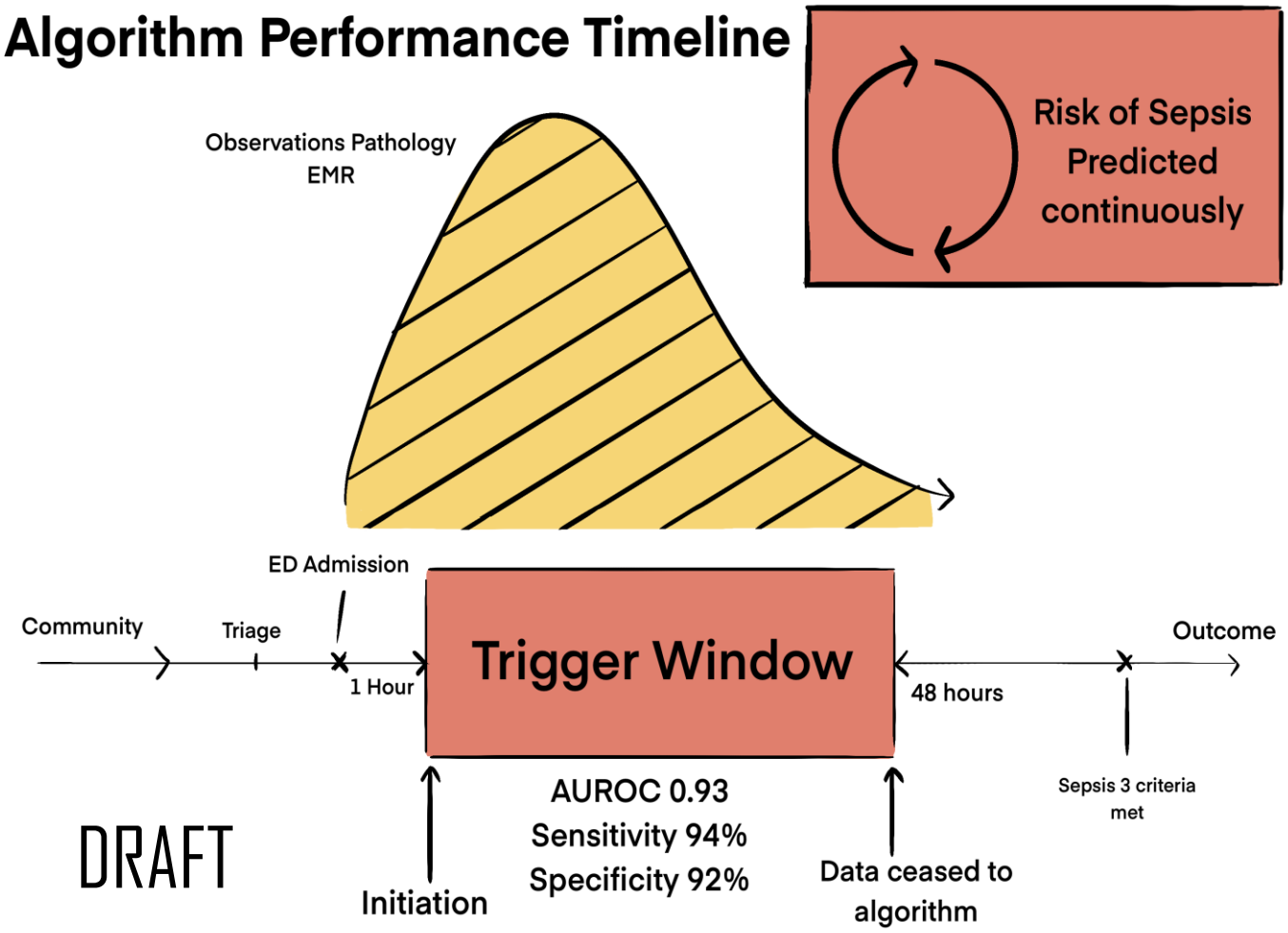

```
print('Create RepeatedStratifiedKFold splits...')
rskf = RepeatedStratifiedKFold(n_splits=10, n_repeats=3,random_state=42)

sen_list = []
spec_list = []
ppv_list = []
npv_list = []
auroc_list = []
acc_list = []
interval_list=[]
nsw_feature_importance = pd.DataFrame()

print('Start training across splits...')
for train_index, test_index in rskf.split(X, y):
    print("TRAIN:", train_index, "TEST:", test_index)
    X_train, X_test = X[train_index], X[test_index]
    y_train, y_test = y[train_index], y[test_index]

    print('Train Model...')
    train_data = lgb.Dataset(X_train,label=y_train)
    max_depth = 120
    param = {'max_depth':max_depth,'num_leaves': (2^max_depth), 'objective': 'binary',
    num_round = 500
    model = lgb.train(param,train_data,num_round)
    print('Predicting over test....')
    y_pred = model.predict(X_test).round(0)
    y_pred=y_pred.astype(int)
    nsw_feature_importance = nsw_feature_importance.append(pd.DataFrame({'Gain':model.
    sen_list.append(results(y_pred,y_test)['Sensitivity'])
    spec_list.append(results(y_pred,y_test)['Specificity'])
    ppv_list.append(results(y_pred,y_test)['PPV'])
    npv_list.append(results(y_pred,y_test)['NPV'])
    auroc_list.append(results(y_pred,y_test)['AUROC'])
    acc_list.append(accuracy_score(y_test,y_pred))
    acc = accuracy_score(y_test,y_pred)
    inter = z * sqrt((acc * (1-acc))/len(X_train))
    interval_list.append(inter)
print("Saving lightgmb data")
result = pd.DataFrame(data={'Algorithm':f'NSW LightGMB {h}',
                            'Sensitivity': [np.mean(sen_list)],
                            'Specificity': np.mean(spec_list),
                            'PPV':[np.mean(ppv_list)],
                            'NPV':[np.mean(npv_list)],
                            'AUROC':[np.mean(auroc_list)],
                            'Accuracy':[np.mean(acc_list)],
                            'Interval':[np.mean(interval_list)]
                           })
```

Machine Learning – lots of decision trees

The Algorithm learnt from the ‘weakest’ trees!

Explainable AI…

Algorithm Performance Timeline

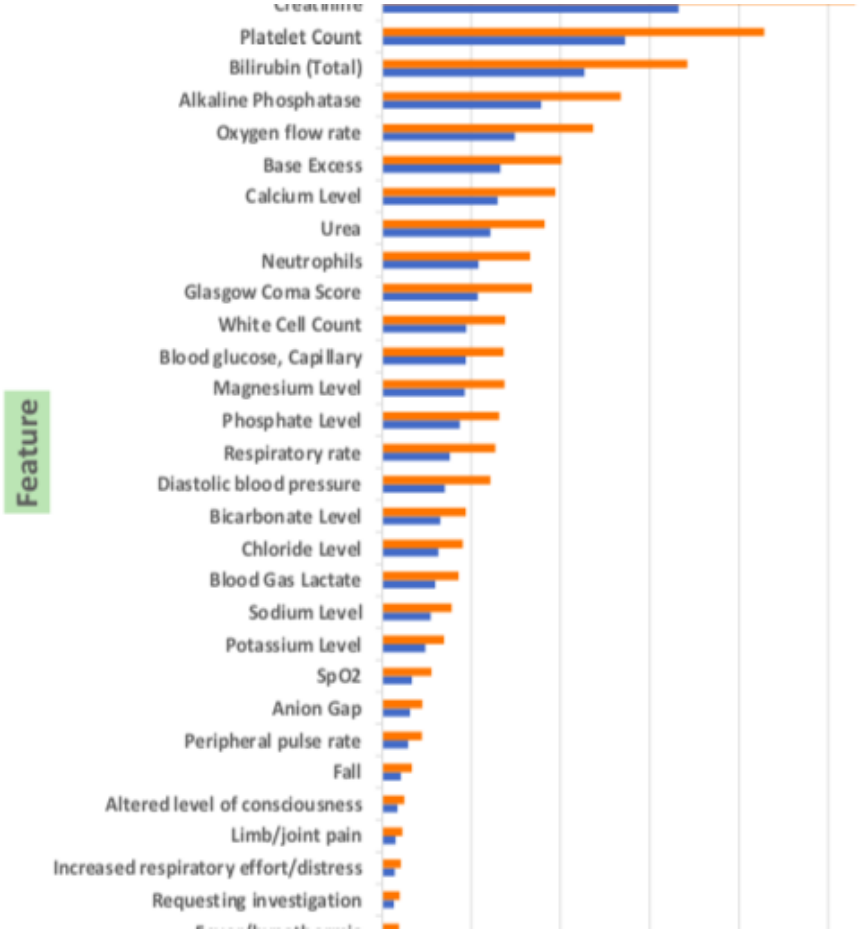


Algorithm	Sensitivity	Specificity	PPV	NPV	AUROC
QLD LightGBM 48	93.96	91.69	53.24	99.34	0.93
QLD Weighted LightGBM 48	80.23	94.03	68.10	96.77	0.87

Table 11 Machine learning Results with Additional Features

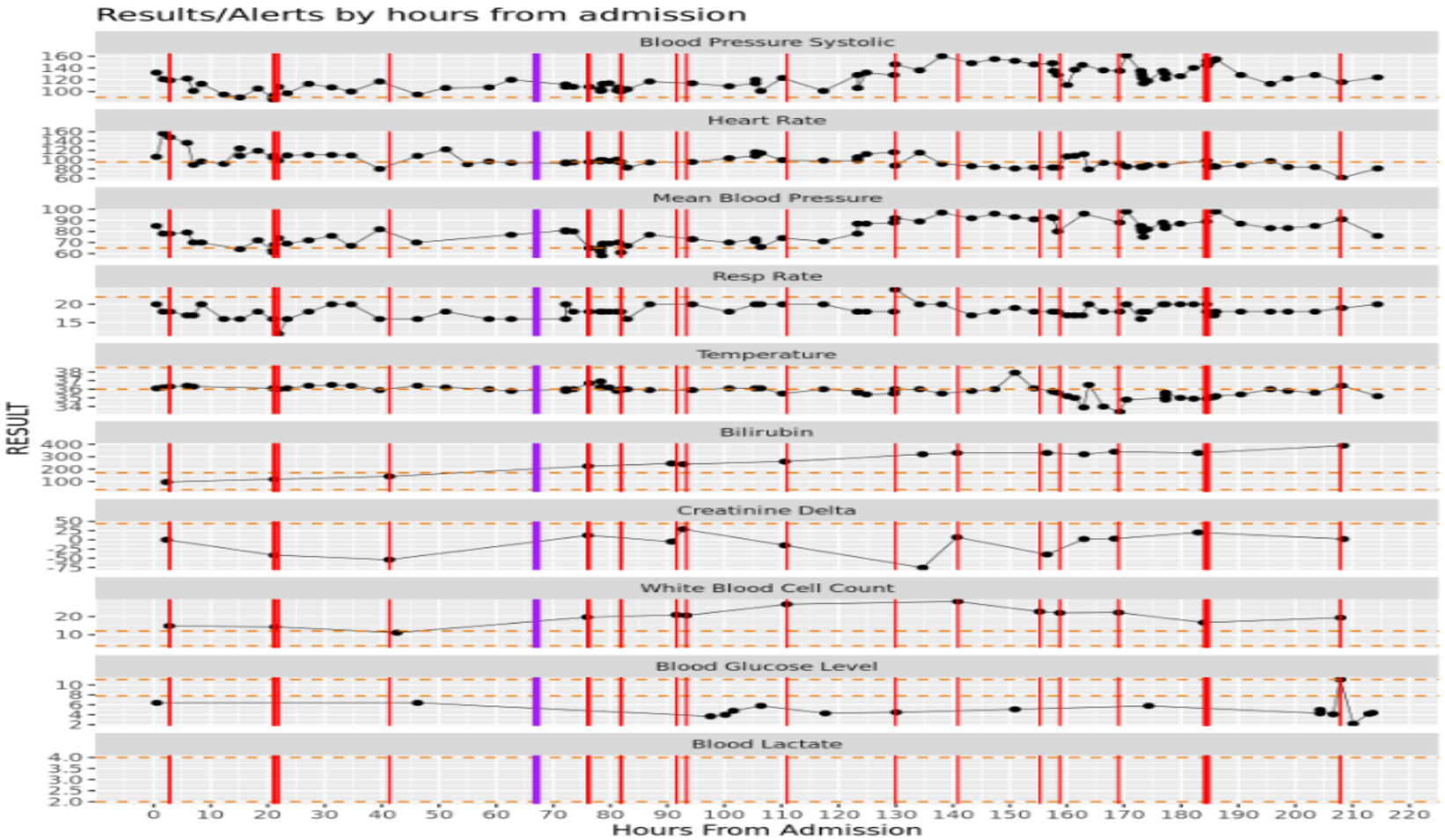
DRAFT

Weighted – removes bias of small sample



124 Features

...vs human Cognitive load...


Results/Alerts by hours from admission
Blood Pressure Systolic
Heart Rate
Mean Blood Pressure
Resp Rate
Temperature
Bilirubin
Creatinine Delta
White Blood Cell Count
Blood Glucose Level
Blood Lactate
RESULT
Hours From Admission
Legend
Result
Alert
Alert Threshold
Blood Culture Ordered

The road to hell is paved with good intentions …

JAMA Internal Medicine | Original Investigation

External Validation of a Widely Implemented Proprietary Sepsis Prediction Model in Hospitalized Patients

Andrew Wong, MD; Erkin Otles, MEng; John P. Donnelly, PhD; Andrew Krumm, PhD; Jeffrey McCullough, PhD; Olivia DeTroyer-Cooley, BSE; Justin Pestrue, MEcon; Marie Phillips, BA; Judy Konye, MSN, RN; Carleen Penoza, MHSA, RN; Muhammad Ghous, MBBS; Karandeep Singh, MD, MMSc

The need to overcome the bad stuff …

- Community suspicion, lack of trust
- Inequity
- Bias
- Consumer Privacy Fears
- Ethical Debt
- Fear of the unknown
- *Doctors are a suspicious bunch generally…*

Journal of the American Medical Informatics Association, 2023, 1–13
https://doi.org/10.1093/jamia/ocad088
Research and Applications

Research and Applications

Implementation frameworks for end-to-end clinical AI: derivation of the SALIENT framework

Anton H. van der Vegt [1], Ian A. Scott [2], Krishna Dermawan [3], Rudolf J. Schnetler [4], Vikrant R. Kalke [5], and Paul J. Lane [6]

[1]Centre for Health Services Research, The University of Queensland, Brisbane, Australia
[2]Department of Internal Medicine and Clinical Epidemiology, Princess Alexandra Hospital, Brisbane, Australia
[3]Centre for Information Resilience, The University of Queensland, St Lucia, Australia
[4]School of Information Technology and Electrical Engineering, The University of Queensland, St Lucia, Australia
[5]Patient Safety and Quality, Clinical Excellence Queensland, Queensland Health, Brisbane, Australia
[6]Safety Quality & Innovation, The Prince Charles Hospital, Queensland Health, Brisbane, Australia

Corresponding Author: Anton H. van der Vegt, PhD, BE, BSc, Centre for Health Services Research, The University of Queensland, Princess Alexandra Hospital, 34 Cornwall St, Woolloongabba, Brisbane, Queensland 4102, Australia; a.vandervegt@uq.edu.au

Staged Clinical AI Implementation Framework - SALIENT

- Full disclosure, honesty and transparency, rigor in evaluation
- Clinician lead, not for profit

The Elephant in the room …

- 15 000 AI papers in healthcare since 2020
- 45 published implementations
- *End to end implementation framework allowing for staged evaluation of the AI algorithms*
- Derived from various accepted AI research models – TRIPOD, DECIDE AI, CONSORT AI

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Journal of the American Medical Informatics Association, 00(0), 2023, 1–13
https://doi.org/10.1093/jamia/ocad075
Review

Review

Deployment of machine learning algorithms to predict sepsis: systematic review and application of the SALIENT clinical AI implementation framework

Anton H. van der Vegt [1], Ian A. Scott [2], Krishna Dermawan [3], Rudolf J. Schnetler [4], Vikrant R. Kalke [5], and Paul J. Lane [6]

[1]Queensland Digital Health Centre, The University of Queensland, Brisbane, Queensland, Australia, [2]Department of Internal Medicine and Clinical Epidemiology, Princess Alexandra Hospital, Brisbane, Australia, [3]Centre for Information Resilience, The University of Queensland, St Lucia, Australia, [4]School of Information Technology and Electrical Engineering, The University of Queensland, St Lucia, Australia, [5]Patient Safety and Quality, Clinical Excellence Queensland, Queensland Health, Brisbane, Australia, [6]Safety Quality & Innovation, The Prince Charles Hospital, Queensland Health, Brisbane, Australia

Corresponding Author: Anton H. van der Vegt, PhD, BE, BSc, Queensland Digital Health Centre, The University of Queensland, Princess Alexandra Hospital, 34 Cornwall St, Woolloongabba, Brisbane, QLD 4072, Australia; a.vandervegt@uq.edu.au

How does it perform?

Adding Rigor to the process...

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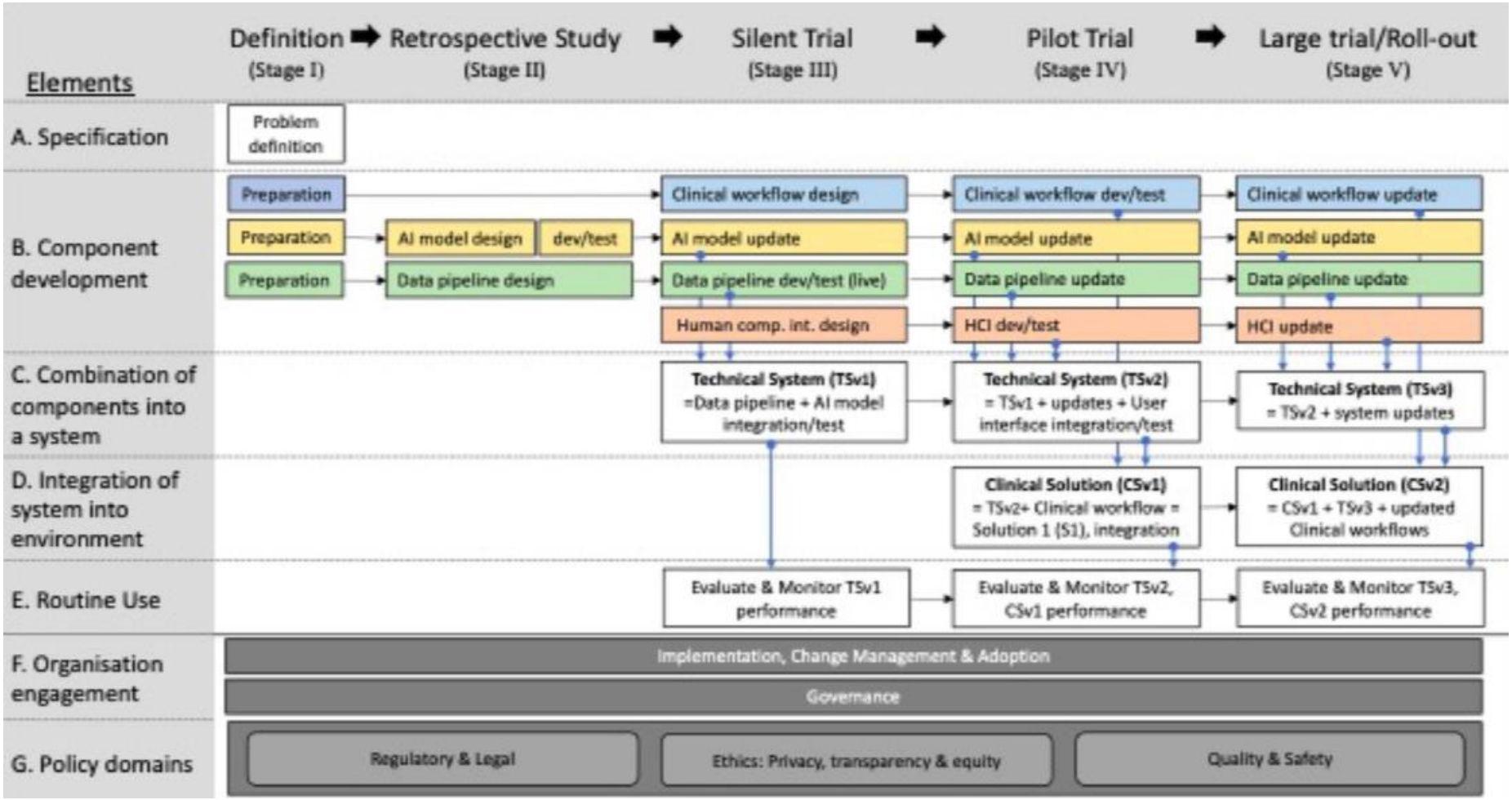

Silent Trial – Stage III

- Prospective Evaluation
- 5 large Qld Digital Hospitals
- Semi real-time data feed from Clinical Business Intelligence, Ehealth QLD
- Begin Aug-Sept 2023

Reflections

- Data governance is hard - a major blocker in Qld!
- De-identified real data will be essential for researchers/universities
- Once evaluated 'in-silico', presented to real time data for further evaluation – a staged approach, measured evaluation and rigor
- Building an end-to-end framework for the future
- Ethical Debt – the need to engage the community
- *Deteriorating Patient* work next… our false positives!
- First Nations QSA – burden of sepsis

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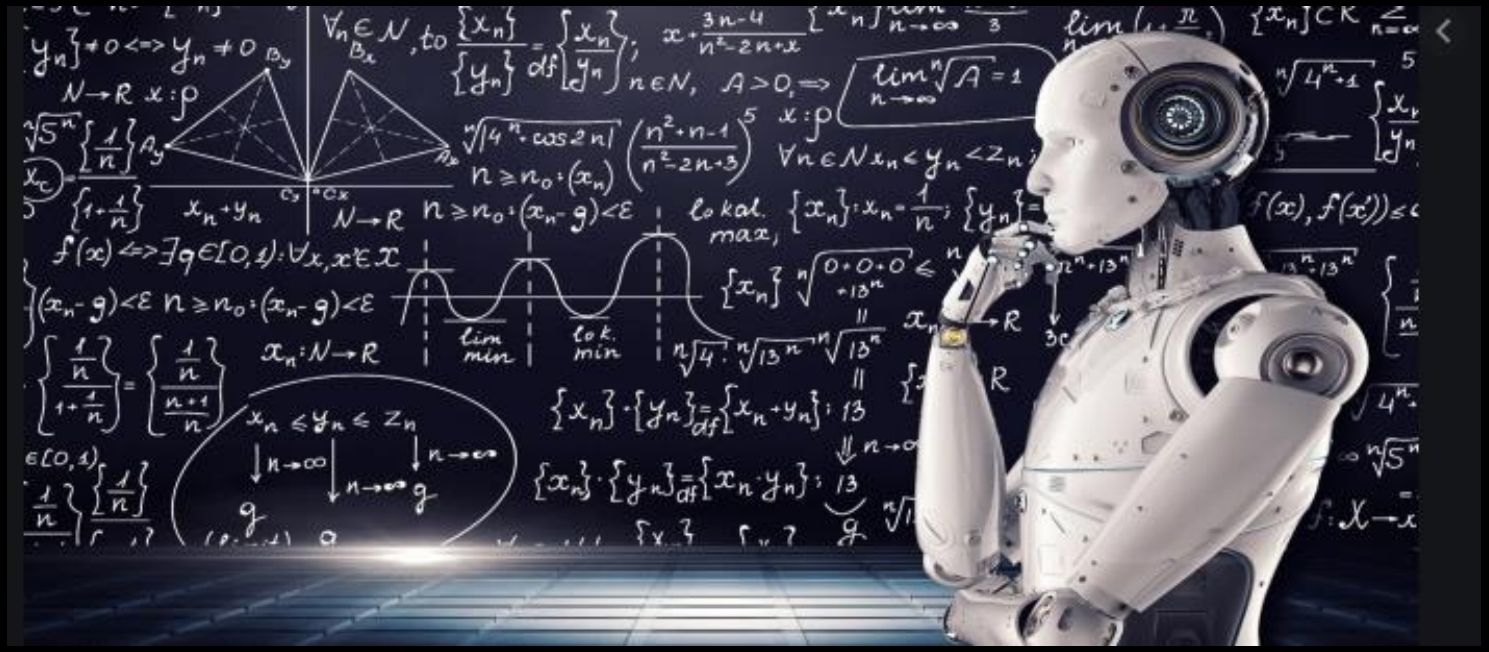

QUESTIONS?

AIDH IMIA