

Development and Application of a Data-driven COVID-19 Prognostication Tool in Hong Kong

新冠肺炎的病情預測工具: 香港研發及應用的大數據分析模型

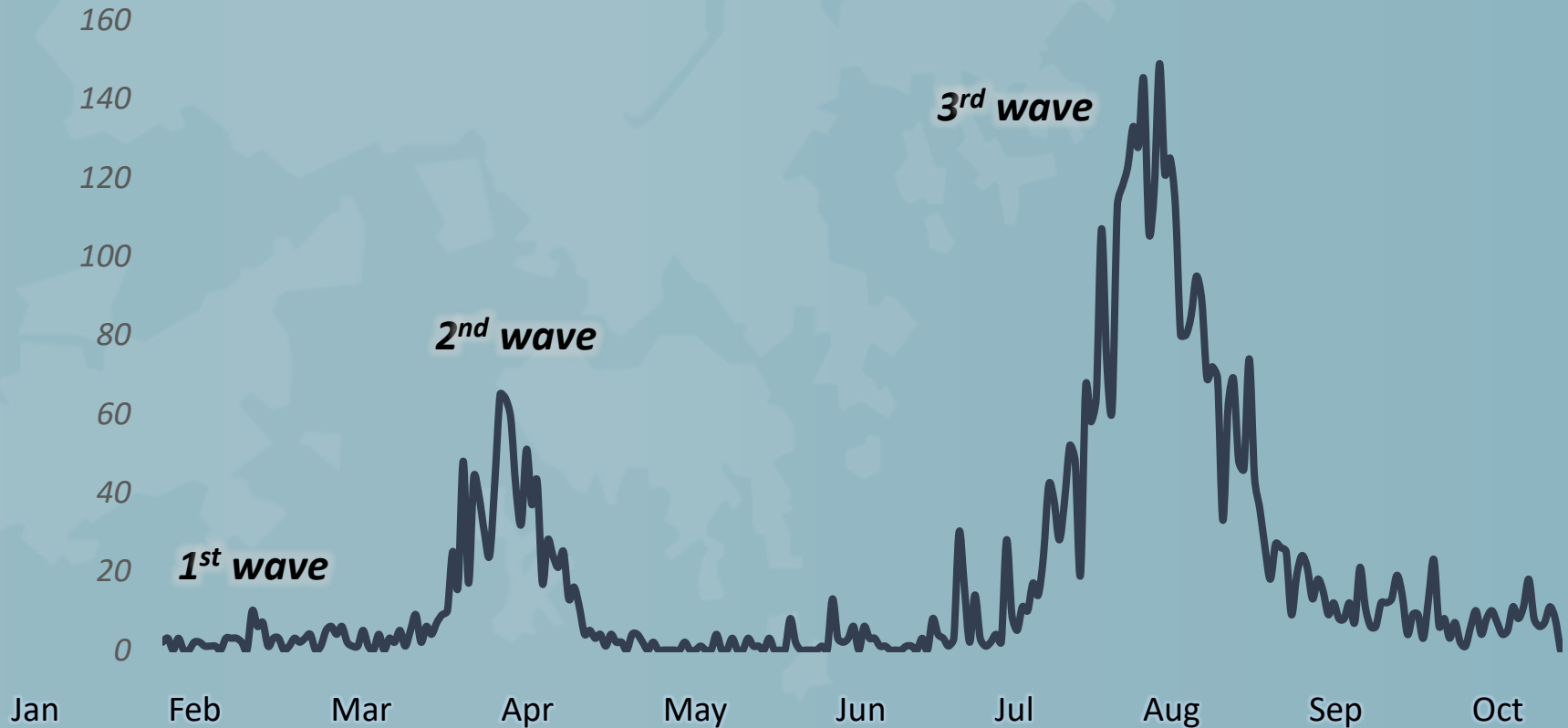
Eva Tsui

World Statistics Day

(20 Oct 2020)

COVID-19 Epidemic in Hong Kong

Daily no. of
new cases



HK Approach to Fight COVID-19



及早發現
Early
Identification

PCR Test
病毒核酸檢測

Mechanism 機制

including:

- Contact tracing 源頭追蹤
- Compulsory test 強制檢測
- Voluntary community testing programs 自願社區檢測計劃, etc...



及早圍堵
Early
Isolation

Home quarantine
家居檢疫

Community Isolation
Facility 社區檢疫設施
e.g. 駿洋村, 竹篙灣

Acute Hospitals
急症醫院
Confirmed: All Beds 隔離病床
Suspected (before test result):
All Beds or designated areas

All Facility = Airborne Infection Isolation Facility
負氣壓病房設施



及早治療
Early
Treatment

Acute Hospitals
急症醫院
(All Beds 隔離病床)

From Aug 2020 onwards
Community Treatment
Facility at AsiaWorld-Expo
亞博館社區治療設施



Hospital Authority (HA)
Airborne Infection Isolation (*AII*) bed capacity
limit will be exceeded with
a huge surge in new cases in HK

In mid-February, HA kicked start “Retrofit Ward” conversion capital works

醫管局擬改裝部分普通病房為負壓病房應對新型肺炎疫情

Started to operate from end March



HEPA filter designed by HA (right) and EMSD (left)



Provision of HEPA filter next to the window



Two additional exhaust fans are installed for every 6-bed cubicle of each ward



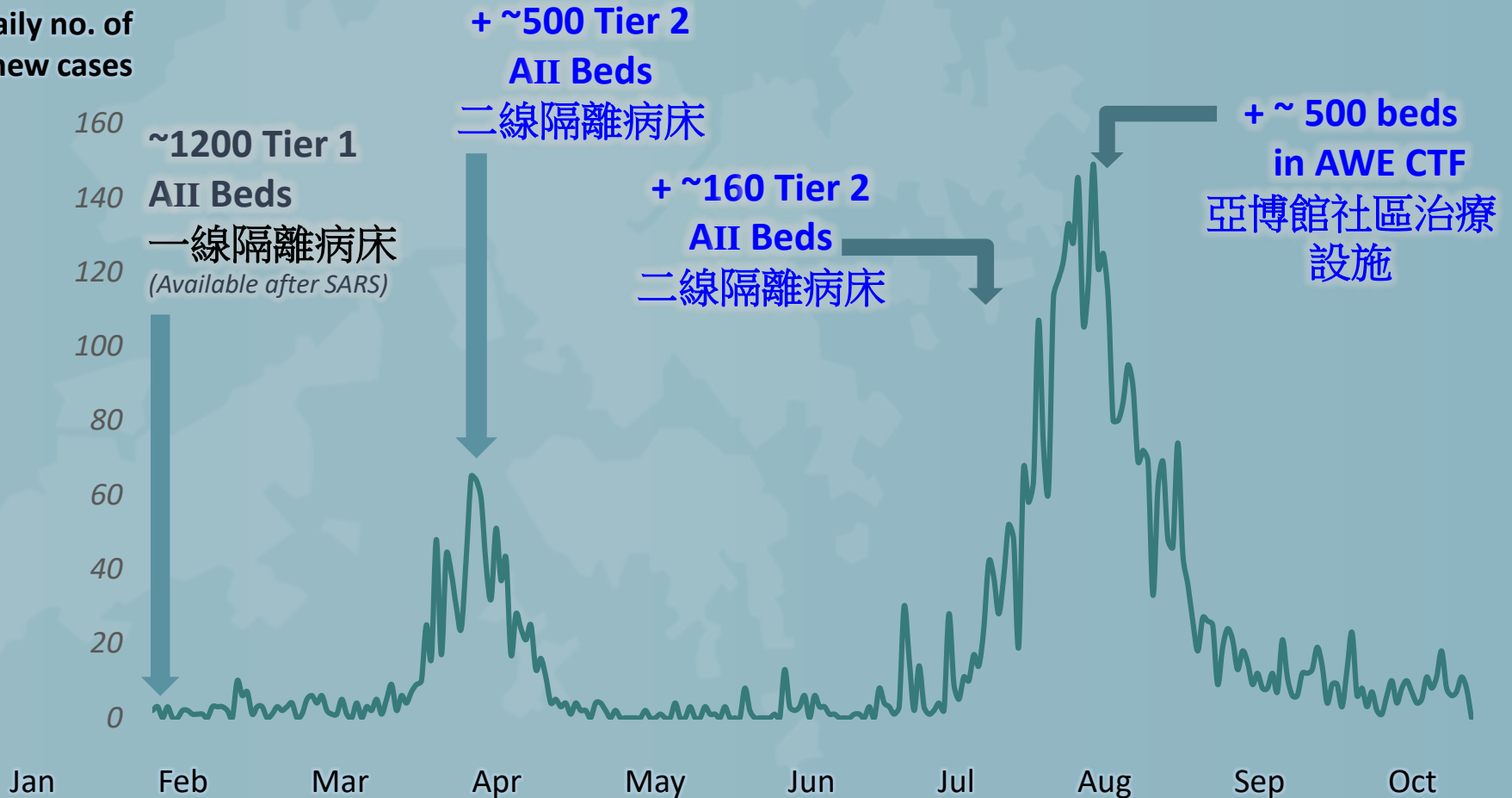
Additional door installed at the entrance of ward creates a buffer zone which helps stabilise the negative pressure inside the ward

HA Response in end March

醫管局預計今個星期啟用400張二線隔離病床，接收病徵輕微或正在康復的患者，以騰空一線隔離床給新確診患者。二線病床是「緊急救援」，會繼續和政府探討不同方案。

Additional Treatment Facilities to Cope with Epidemic

Daily no. of new cases





**How to apply Big Data Analytics
in support of Response Planning?**

**如何應用大數據工具
以支援應變措施的規劃?**

In mid-March

Kicked start engagement with a Clinical Expert Group



AIM

- To carry out some data analytics and modelling to **inform**, on a scientific basis, **triage and step-down care**

A Data-driven Tool put into practice



Apr

May

Jun

Jul

Aug

Sep

Oct

Model
development
& validation

- mid-March to mid-May
- based on COVID patients up to end April

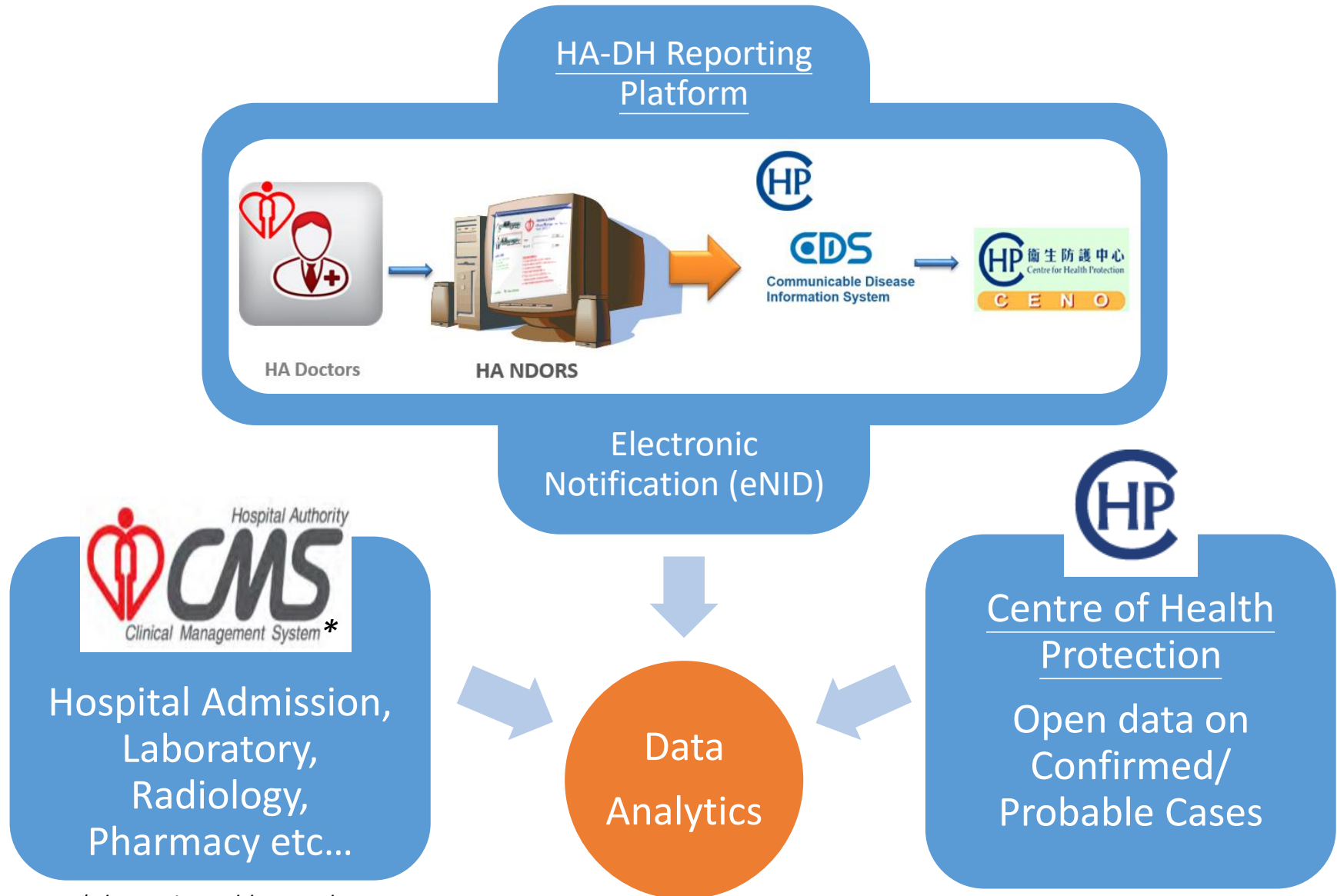
Model
simplification
& validation

- mid-May to mid-July
- Further validated based on new COVID patients from May onwards

Model
application

- Early August
- 1st application at Community Treatment Centre at AWE

Data Sources



*Electronic Health Record

Diagnosis 診斷

A judgment about what a particular illness or problem is, made after examination(s)

Prognosis 預斷

A judgment of the likely or expected development of a disease

COVID-19 in Hong Kong

Confirmed after two consecutive PCR positive test results

Clinical condition(s)
[Critical/Serious/Stable/Satisfactory]
during the clinical course
&
Clinical outcome
[Discharged after fulfilling discharge criteria, incl negative PCR results / Diseased]

4 Defined Clinical Conditions of Covid-19 patients - Assessed by Doctors on a daily basis

Condition	Definition
Critical	intubated, OR require ECMO OR in shock
Serious	require O2 supplement of 3L/min or more
Stable	mild influenza-like illness (ILI) symptoms
Satisfactory	progressing well and likely to be discharged soon

Classification into 3 Clinical Outcome Groups in Data Analytics

- Group 1 – Ever Critical / Serious



- Group 2 – Stable +/- Satisfactory



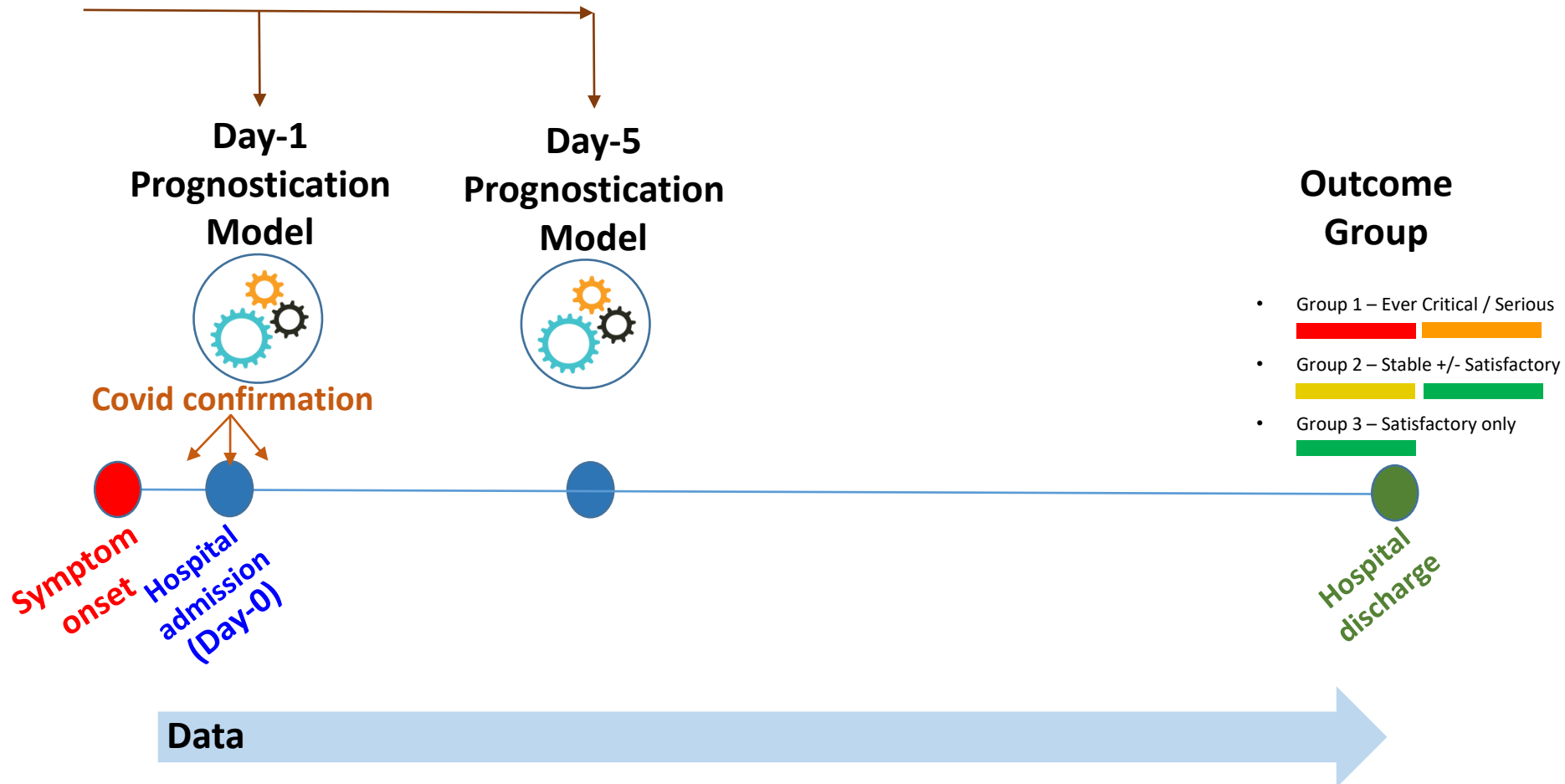
- Group 3 – Satisfactory only



Condition	Definition
Critical	intubated, OR require ECMO OR in shock
Serious	require O2 supplement of 3L/min or more
Stable	mild influenza-like illness (ILI) symptoms
Satisfactory	progressing well and likely to be discharged soon

Translate Data into a Model

Risk & Prognostic factors
up to Day-1 & Day-5 of admission

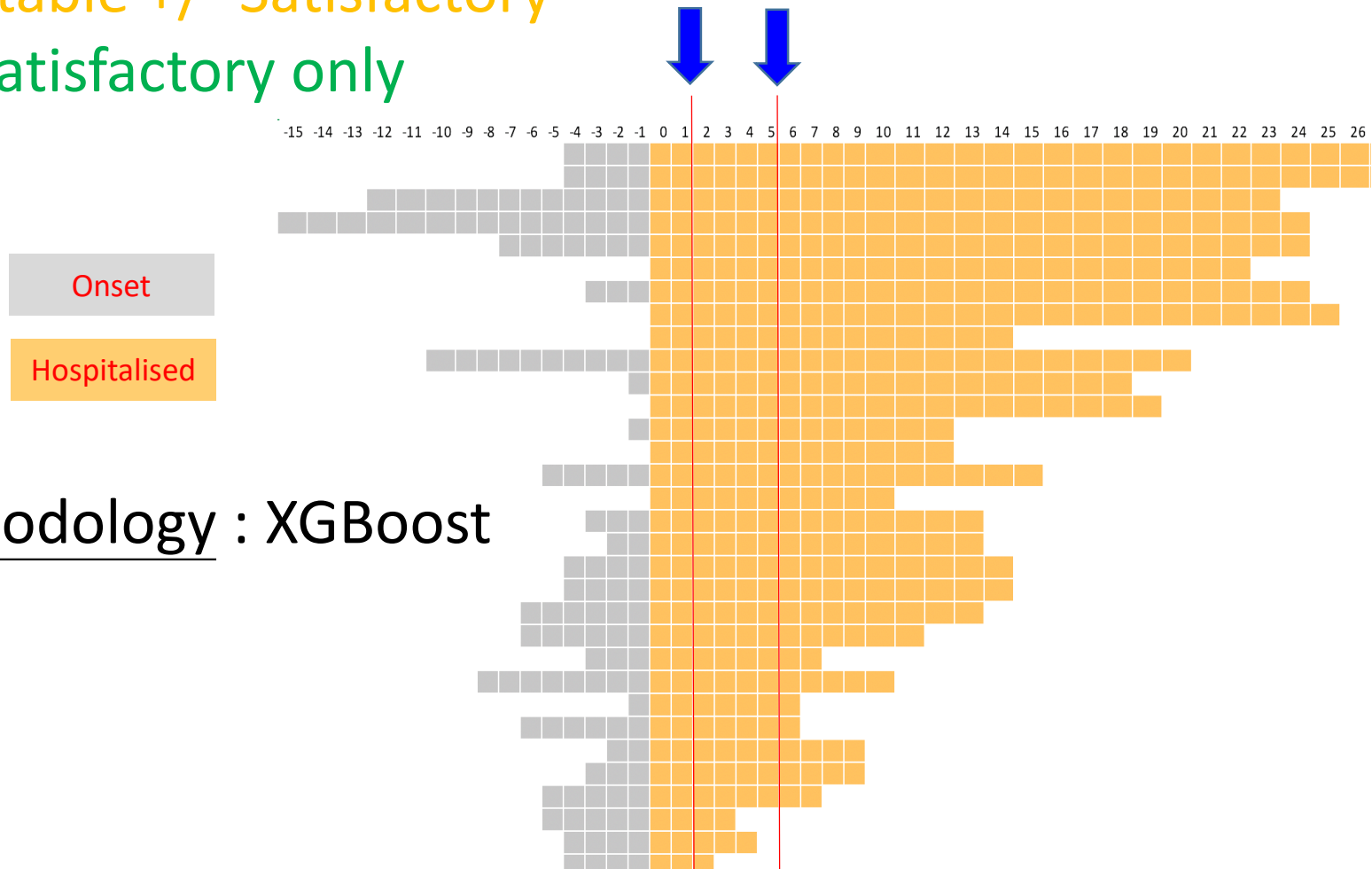




Predict and Classify patient into one of 3 outcome groups along the whole clinical course

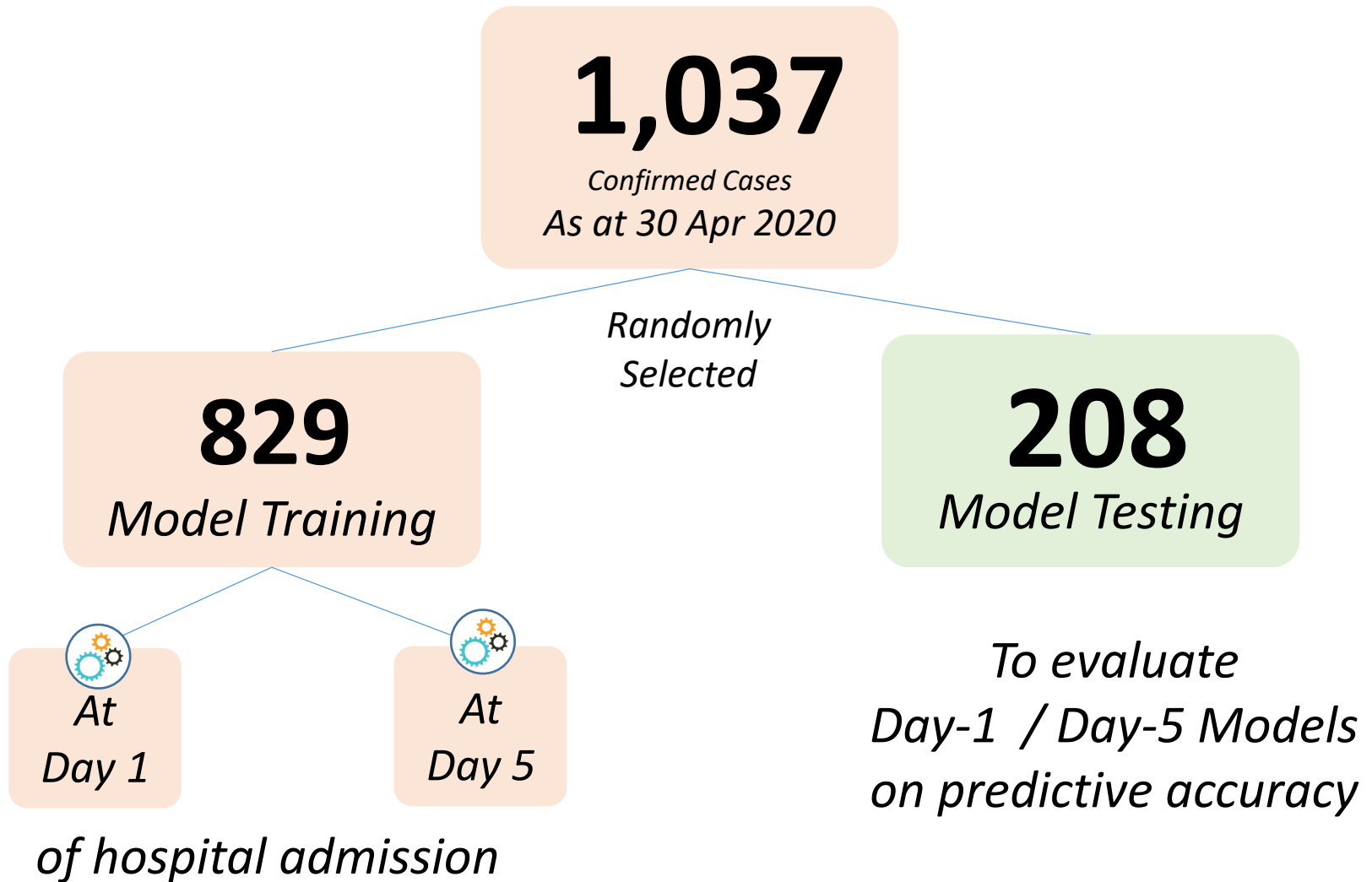
- 1) Ever Critical / Serious
- 2) Stable +/- Satisfactory
- 3) Satisfactory only

at Day 1 & Day 5 from admission



Methodology : XGBoost

Prognostic Modelling



Evaluation of Model Performance

1,037

*Confirmed Cases
As at 30 Apr 2020*

Randomly Selected

829

Model Training



*At
Day 1*



*At
Day 5*

of hospital admission

208

Model Testing

638*

Model Testing

*Confirmed cases on or
after 1 July 2020*

**as at 19 July 2020*

***Both cohorts achieved a
very high predictive
accuracy under
Day-1 / Day-5 Models***

COVID Dashboard to Visualize a host of Risk & Prognostic factors

COVID Case No
XXXX

Sex
Age
Source...

NOT HA User (2010 to 2019)
No "3 High" (based on 2019 and latest info)

List of Chronic Disease (based on Virtual Reg up to 2018):
None

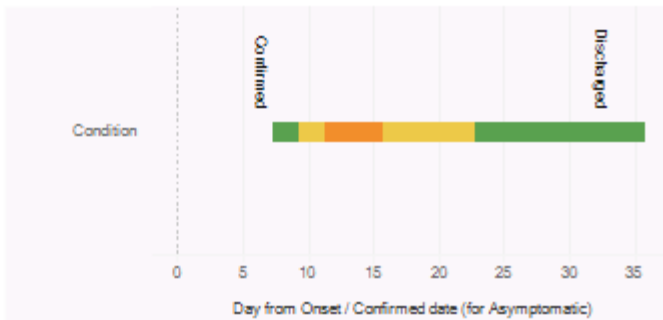
Onset: DDMMYY
Adm: DDMMYY
Cfm: DDMMYY
D/C: DDMMYY

(admitted on Day 8 from symptom onset)

Ever:
Intubation = NO
Critical = NO
Serious = YES

Symptomatic

Cough / Dyspnea / Fatigue /
Fever / Myalgia / Pneumonia /
Sore Throat



Condition
2 Serious (orange) 3 Stable (yellow) 4 Satisfactory (green)

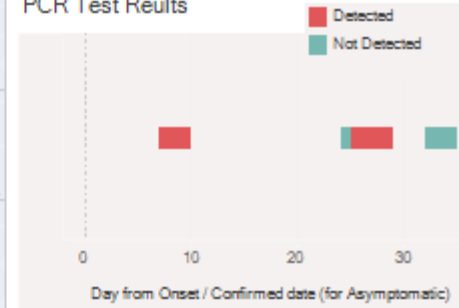


Legend
Yes (blue)
No (grey)

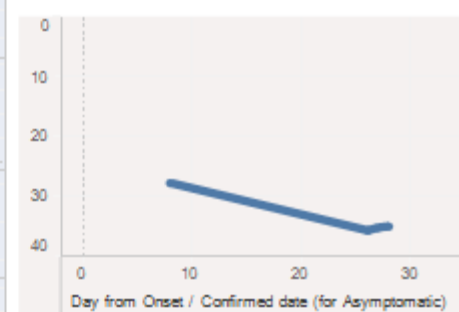


Lab Tests
Upper normal ref. (brown bar)
Lower normal ref. (teal bar)
Lab Value (blue line)

PCR Test Results



Daily Ct Value



**Predicted Probability
by XGBOOST**

Model at Day5 & Adm

Ever critical / serious	0.9932
Stable +/- satisfactory	0.0058
Satisfactory only	0.0010

Full Model: 30 Predictors considered

Pre-disposing factor

- Age at admission
- Gender
- Chronic diseases¹ history

Symptom onset

- Day from onset to admission
- 11 presenting symptoms

Clinical condition

- Worst condition²

Lab Results³

- CT value of RT-PCR test
- C-reactive protein
- Albumin-globulin ratio
- Total protein
- Neutrophil-lymphocyte ratio
- White blood cell count
- Bilirubin
- Potassium
- Creatinine
- LDH
- ALP
- ALT
- Platelet
- MPV

Notes:

1. Chronic diseases indicator , include diabetes, hypertension, hyperlipidemia, COPD, stroke, coronary heart disease, chronic heart failure, chronic kidney disease (stage 3A-5), glaucoma, hip fracture, dementia, depression, hepatitis B, Parkinsonism, lymphoma, cancer of female breast, colorectum, prostate, liver, lung, cervix, corpus, ovary, nasopharynx, stomach.
2. up to Day 1/ Day 5
3. latest values of the lab results up to Day 1/Day 5

Full Model : Prediction at Day 1 & 5 of admission

(208 cases confirmed **on or before 30 April**)

Day 1



		Model Prediction at Day 1			
		Critical / Serious	Stable	Satisfactory	
Actual (upon discharge)	Critical / Serious	6	0	4	Sensitivity: 0.83 Specificity: 0.96
	Stable	6	86	5	
	Satisfactory	1	0	100	

Model Accuracy: $192 / 208 = 92.3\%$ (based on testing data)

Day 5



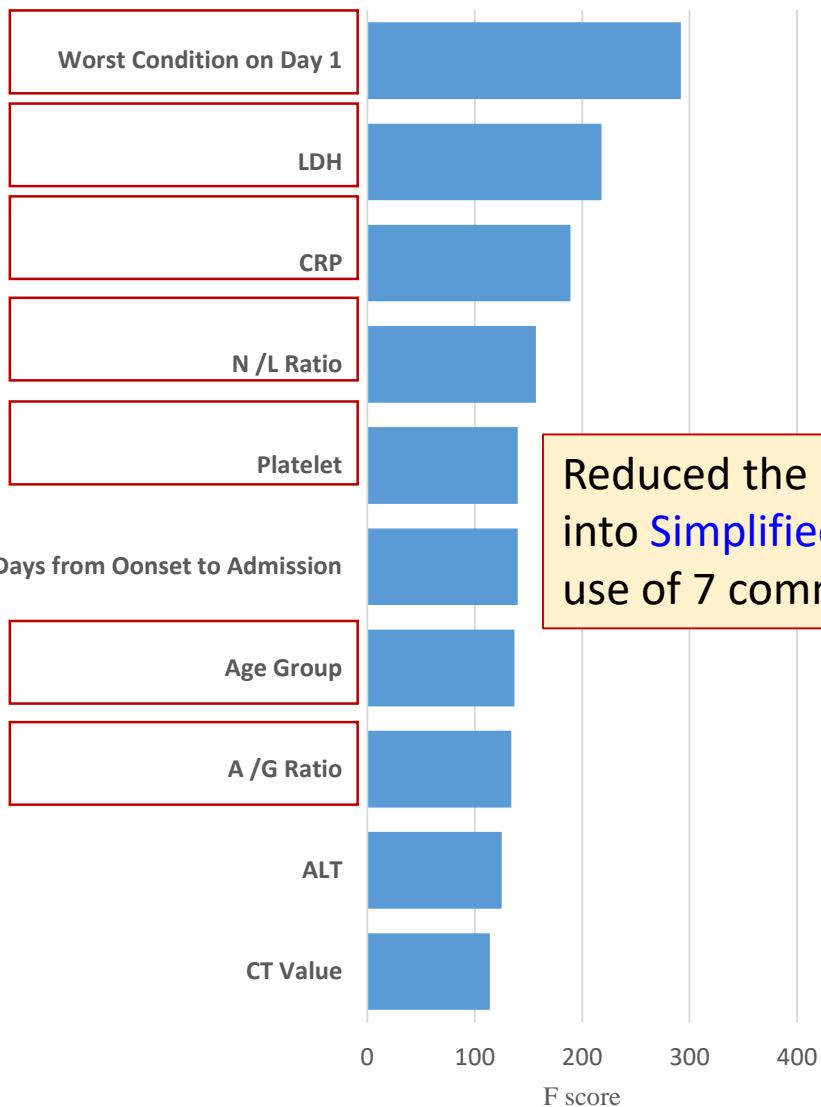
		Model Prediction at Day 5			
		Critical / Serious	Stable	Satisfactory	
Actual (upon discharge)	Critical / Serious	10	0	0	Sensitivity: 0.997 Specificity: 0.995
	Stable	0	96	1	
	Satisfactory	0	0	101	

The Day-5 Model can entirely predict "Critical/Serious"

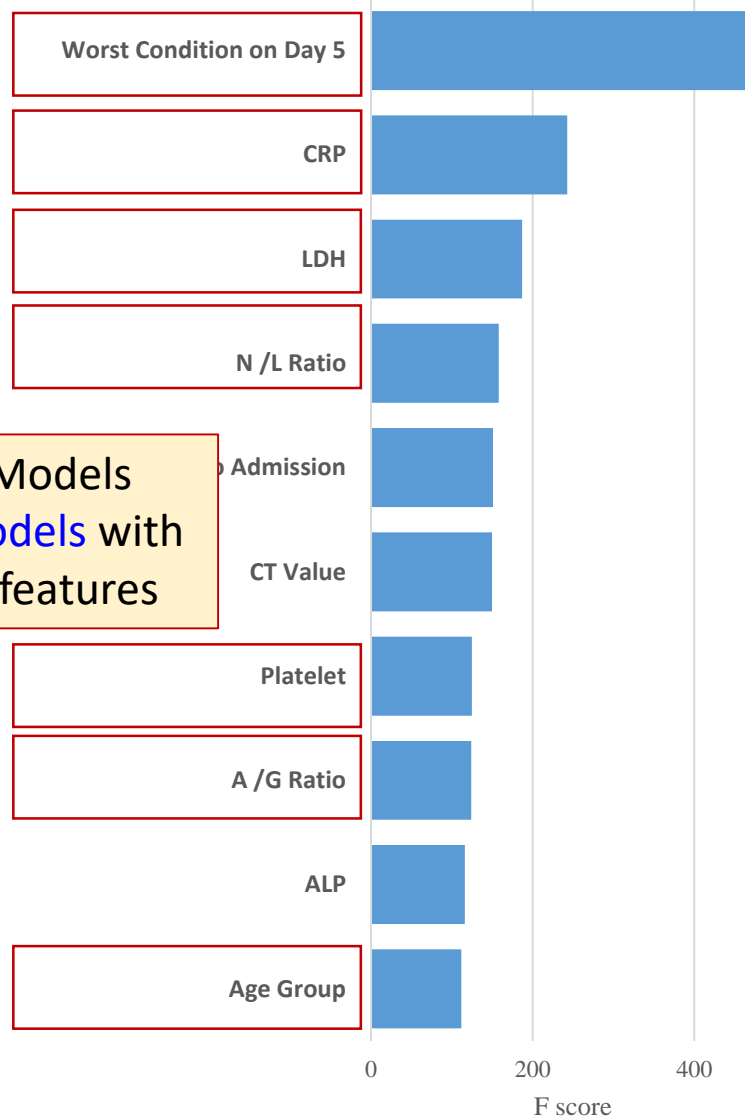
Model Accuracy: $207 / 208 = 99.5\%$ (based on testing data)

Top 10 Important Model Features (Out of 30)

Day-1 Model



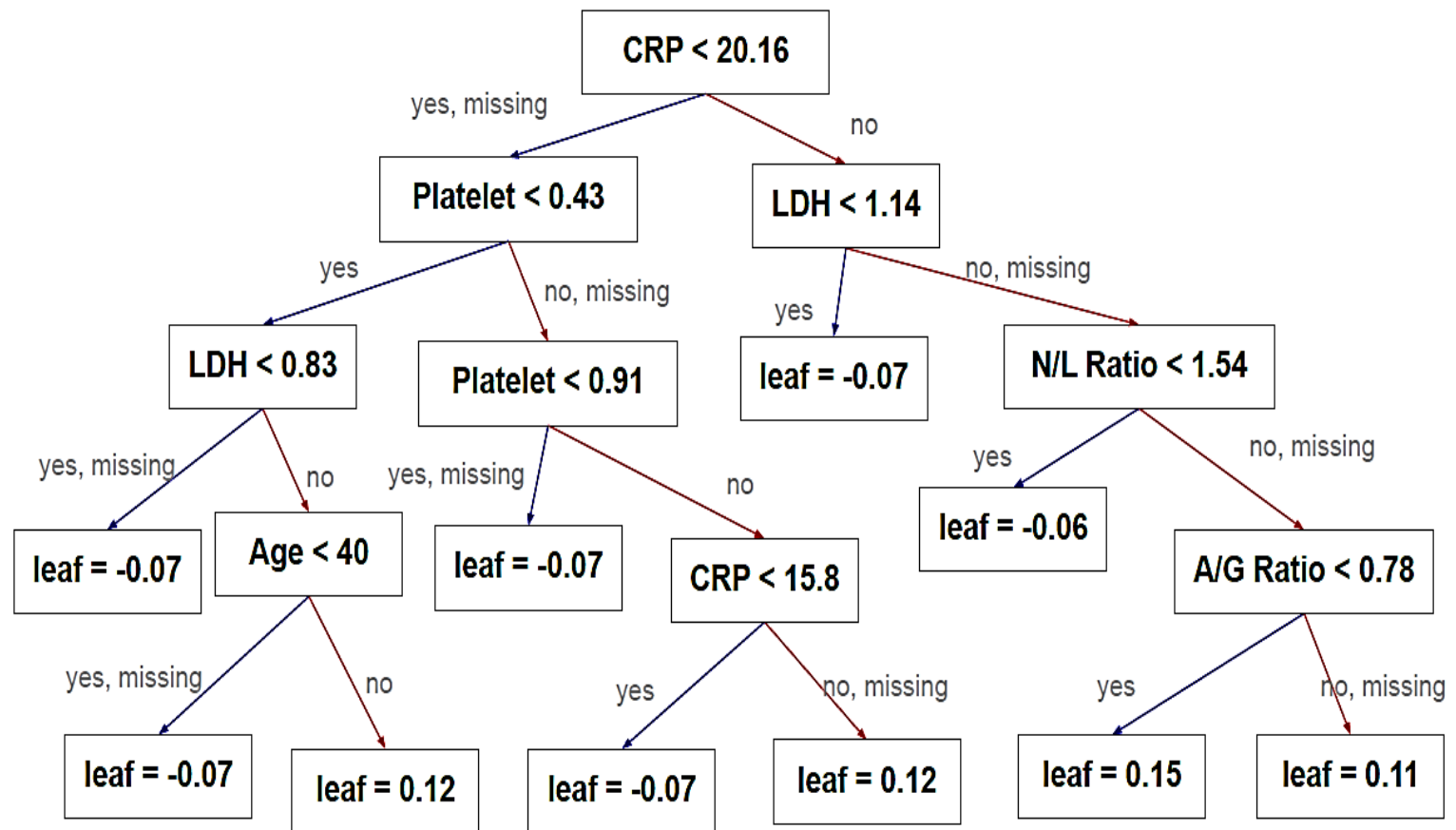
Day-5 Model



Reduced the Full Models into **Simplified Models** with use of 7 common features

Illustration :

One of Ensemble Decision Trees
to Classify wrt **Outcome Group = Critical / Serious**



Simplified Model : Prediction at Day 1 & 5 of admission

(Test set 1: 208 cases confirmed **on or before 30 April**)

Day 1



		Model Prediction at Day 1		
		Critical / Serious	Stable	Satisfactory
Actual (upon discharge)	Critical / Serious	7	1	2
	Stable	7	86	4
	Satisfactory	4	0	97

Sensitivity: 0.85
Specificity: 0.96

Model Accuracy: 190/ 208 = **91.3%** (based on testing data)

Day 5



		Model Prediction at Day 5		
		Critical / Serious	Stable	Satisfactory
Actual (upon discharge)	Critical / Serious	10	0	0
	Stable	9	87	1
	Satisfactory	2	0	99

Sensitivity: 0.96
Specificity: 0.98

Model Accuracy: 196/ 208 = **94.2%** (based on testing data)

Simplified Model : Prediction at Day 1 & 5 of admission

(Test set 2: 638 cases confirmed **on or after 1 July**)

Day 1



		Model Prediction at Day 1		
		Critical / Serious	Stable	Satisfactory
Actual (as of 19 July)	Critical / Serious	39	1	3
	Stable	25	299	14
	Satisfactory	0	0	257

Sensitivity: 0.93
Specificity: 0.97

Model Accuracy: $595 / 638 = 93.3\%$ (based on testing data)

Day 5



		Model Prediction at Day 5		
		Critical / Serious	Stable	Satisfactory
Actual (as of 19 July)	Critical / Serious	43	0	0
	Stable	9	324	5
	Satisfactory	2	0	255

Sensitivity: 0.97
Specificity: 0.99

Model Accuracy: $622 / 638 = 97.5\%$ (based on testing data)

Detailed Research Findings



Development of a data-driven COVID-19 prognostication tool to inform triage and step-down care for hospitalised patients in Hong Kong: A population based cohort study

Eva L.H. TSUI, Carrie Lui, Pauline P.S. Woo, Alan T.L. CHEUNG, Peggo K.W. Lam, T.W. Tang, C.F. YIU, C.H. Wan, Libby H.Y. Lee

doi: <https://doi.org/10.1101/2020.07.13.20152348>

Online access :

<https://www.medrxiv.org/content/10.1101/2020.07.13.20152348v2>

A Calculator Tool was developed & shared online

-for applications locally and open access globally

Day 1 calculator

Day 5 calculator

Link to download the calculator:

https://github.com/ha-covid19/covid19-prognostication-tool/blob/master/covid_risk_calculator.xlsm

COVID-2019 Criticality Calculator¹ : To predict the clinical outcome

1. Input the required fields below and press "Calculate"
2. Press "Reset" to clear all input and output

Day 1 of Admission					
	Critical / serious	Stable	Satisfactory		
Probability in each class (sum of 3 classes =1)	0.801	0.141	0.058		
As compared to a random chance of 0.333 in each class					
	Values on Day 1	Unit			
Age	80 - 89				
Worst Condition	Stable				
LDH		U / L	or	Ratio (LDH / LDH - Upper Reference)	5
LDH - Upper Reference		U / L			
Platelet	0.25	x10 ⁹ / L			
Albumin		g / L	or	Ratio (Albumin / Globulin)	2
Globulin		g / L			
CRP	100	mg/L			
Neutrophil		x10 ⁹ / L	or	Ratio (Neutrophil / Lymphocyte)	5
Lymphocyte		x10 ⁹ / L			
Calculate (Day 1 Probabilities)			Reset		

1st Application at Service Settings

as a clinical **reference** tool
at point of care



to support daily consultation and triage
at Community Treatment Centre
(set up at **AsiaWorld Expo** on 1st Aug)



大數據分析模型助亞博分流

Big data analytics model supports triage at AWE

AWE Community Treatment Centre

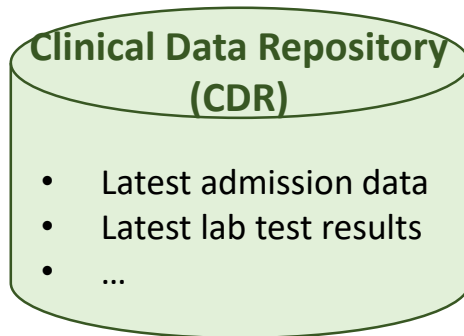
亞博館社區治療設施

- Triage and management (during Aug – Sep)
 - Triage for confirmed cases from community
 - Manage **stable cases aged 18-60** until fulfilling discharge criteria, excluding those with chronic diseases or have developed worst symptoms
 - Monitor at AWE by on-site medical teams with blood tests and radiological examinations
 - Transfer to hospital **if deteriorate**

Daily Automation of Model Predictions



Download electronic health records to CDR during midnight



For all staying COVID cases at AWE



Model is run **daily** at 7:00AM based on **latest figures**; allow for missing values

Prediction



Day 0
(upon admission to AWE Community Treatment Centre)

Day 1

Day 2

Day 3

Day 4

Day 5

Midnight





Automated List of Patients still staying at AWE

Generate the patient list with model predictions and latest value of model parameters

Rank in descending order according to the probability of “Critical/Serious”

Predictions

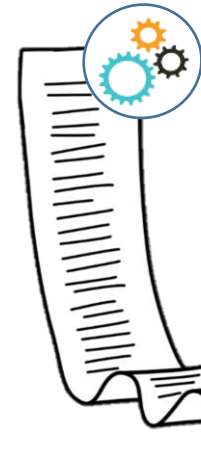
Latest conditions

Model Predictions on 2020MMDD by Statistics & Data Science Department, Strategy & Planning Division

Current Case No.	Current Hosp	Current Ward	Current Bed Number	Current Admission date	Age	Sex	Predicted Class	Prob. of Critical / Serious	Prob. of Stable	Prob. of Satisfactory	Latest Condition	LDH (U/L)	LDH Upper Ref (U/L)	Platelet ($\times 10^9 / L$)	Albumin (g/L)	Globulin (g/L)	CRP (mg /L)	Neutrophil ($\times 10^9 / L$)	Lymphocyte ($\times 10^9 / L$)	CT Ref Date	CT Value
HNXXXXXXXX	NLT	XXYY	YYZZ	2020MMDD	XY	F	Critical / Serious	0.560	0.085	0.355	Satisfactory	350	246.4	0.5	39.2	42.8	50.0	3.4	1.4	2020MMDD	20
HNXXXXXXXX	NLT	XXZZ	YYXX	2020MMDD	XY	F	Satisfactory	0.150	0.087	0.764	Satisfactory	179	246.4	0.5	40.6	30.7	4.6	2.4	0.8	2020MMDD	26
HNXXXXXXXX	NLT	XXYY	YYZZ	2020MMDD	XY	M	Stable	0.058	0.867	0.075	Stable	173	247.4	0.7	46.0	29.2	0.4	5.2	2.5	2020MMDD	38
HNXXXXXXXX	NLT	XXZZ	YYXX	2020MMDD	XY	F	Satisfactory	0.057	0.305	0.638		166	247.0	0.5	43.3	33.7	0.4	4.2	2.6	2020MMDD	33
HNXXXXXXXX	NLT	XXZZ	YYZZ	2020MMDD	XY	M	Stable	0.057	0.870	0.073	Stable	158	247.4	0.7	43.7	31.1	2.0	3.5	2.9	2020MMDD	34

Clinical Assessment

- ➔ Identify potential deterioration cases
- ➔ Transfer such cases to acute hospital for treatment



*Automated List of
Patients at AWE
with model
predictions for
reference*

**Acute
Hospital**



**Infectious Diseases
Physician**



AsiaWorld-Expo
亞洲國際博覽館



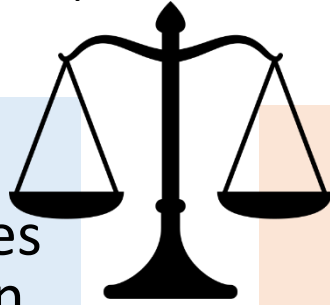
**On-site
Medical Team**

Application of Prognostic Tool





Positive = Model predicted as “critical/serious”



True Positive

Assist to identify cases for daily consultation with ID physicians;
Early transfer to hospital after clinical assessment

False Positive

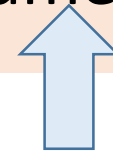
Occupy an *AII* bed if transfer to acute hospital

True Negative

Save an *AII* bed if transfer to acute hospital

False Negative

Assumed Nil



- Under clinical care of on-site clinicians & ID physicians taking into account the full spectrum of lab data, CXR & patients' conditions

Additional Facilities Capacity in pipeline

增7病例 連續3日無源頭不明個案

醫管局行政總裁高拔陞昨指，當局審視乎未來1、2周情況，才能於10月詳細交代恢復公立醫院探病安排。
(陳靜儀攝)



醫管局應對疫情重點

臨時醫院	增設 800 張病床處理需醫療設備的次嚴重病人
亞博館社區治療設施	1、2 號館共 800 張病床正處於備用狀態，其餘 8 個展館計劃興建 1,000 張負壓病床，用作處理輕症病人；預期至少會租用亞博館至明年冬季流感完結
居粵醫管局病人交港大深圳醫院覆診	預計最快 4 至 6 周後可提供跟進診症服務；港府將津貼部分覆診費用，病人承擔金額大致與在港覆診費用相若
公立醫院恢復探病安排	視乎未來一、兩周疫情，10 月後再公布
普通科門診派發樣本收集瓶	下周一起擴展至 46 間，包括南丫島、長洲及大嶼山等離島區，派發量由以往每日 2,000 個增至 4,000 個

資料來源：醫管局

亞博館治療設施完工 交醫管局

嚴陣以待

新冠肺炎疫情有反彈趨勢，醫管局嚴陣以待，港府近日完成大嶼山亞博館新社區治療設施外的工程，設 1,000 張病床部分備有負氣壓設施，昨日交醫管局以隨時啟用。

醫管局行政總裁高拔陞表示，亞博館 1 及 2 號展館早前已設有 900 張病床的社區治療設施，連同 8 至 11 號展館剛完成的新增治療設施，有助提升香港應對日後可能出現另一波疫情的能力，減低公立醫院的壓力。

內地助建臨時醫院 展地基工程

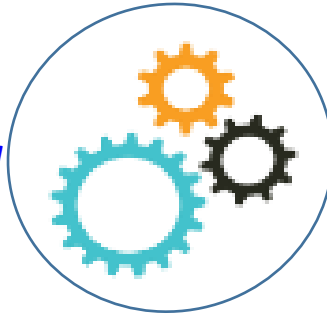
另外，中央政府支援在亞博館旁籌建的臨時醫院項目，建造工程團隊已於上月 19 日展開工作。承建商現正在工地進行地基工程，並同時在內地廠房生產項目的單元組件，整項工程預計會在 4 個月內完成，落成後可提供容納超過 800 張病床的負氣壓病房和相關醫療設施。

醫護的個人防護裝備方面，醫管局總行政經理（質素及標準）劉家獻昨天表示，公立醫院的個人防護裝備尚剩餘 6 個月用量，其中外科口罩量為 5,000 萬個、N95 呼吸器為 460 萬個、保護衣 620 萬件、面罩 1,090 萬個。

Potential Applications of the Tool

to cope with 4th wave

*Further enhanced
Prognostication Model*



*As a clinical reference
tool to inform triage
and step-down care*

16 Acute hospitals
(~1200 Tier I All beds;
~660 Tier II All beds)



Community Treatment centre
at AWE (~1800 beds)



a Temporary hospital
next to AWE (800 beds)



Acknowledgement

Hospital Authority

- Advice from the Expert Group on the data analytics & modelling work
- Efficient and hard work of Statistics & Data Science Department