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Artificial Intelligence tool developed to predict severity of pneumonia in patients, including COVID-19 patients

Predictive engine enables closer monitoring and treatment of patients with severe pneumonia for improved patient outcomes.

[1 October 2020] Changi General Hospital (CGH) and the Integrated Health Information System (IHiS) have developed a **Community Acquired Pneumonia and COVID-19 Artificial Intelligence (AI) Predictive Engine (CAPE)** that can determine the likelihood of whether the patient has mild or severe pneumonia, based on the chest X-ray image. This will help to alert doctors to patients who are likely to become critically ill, and enable prioritisation of treatment resources.

Why CAPE was developed

Pneumonia is one of the leading causes of death worldwide, and the main cause of deterioration in COVID-19. The ability to quickly predict the patient's expected severity of pneumonia would enable clinicians and administrators to efficiently allocate healthcare resources and treat patients, particularly in pandemic situations, where there may be an increased need for inpatient care and critical care support. As pneumonia severity correlates to the degree of Chest X-Ray (CXR) lung image abnormality, CGH's Respiratory and Critical Care Medicine and Radiology teams recognised the potential in leveraging artificial intelligence to predict the severity of pneumonia from CXR images, and worked with the IHiS Health Insights team to develop CAPE (ref to Annex A).

How CAPE works

Using more than 3,000 CXR images and 200,000 data points including lab results and clinical history, CAPE was trained to generate a score for (a) low-risk pneumonia with anticipated short inpatient hospitalisation; (b) the risk of mortality (death); and (c) the risk of requiring critical care support – indicators of pneumonia severity – from CXR images. This can serve as a decision support for doctors, so that patients who are likely to require critical care can be more closely monitored, and can receive treatment in a timely manner. Initial validation tests at CGH showed that CAPE has an approximate accuracy of 80% in predicting severe pneumonia. This is comparable to traditional pneumonia severity tools that are scored manually.

Dr Charlene Liew, Project Lead and Deputy Chief Medical Informatics Officer, CGH, and Director of Innovation, SingHealth Radiological Sciences Academic Clinical Programme (RADSC ACP) said, "One main advantage of using artificial intelligence as a predictive tool is that the risk of

patients requiring critical care can be calculated almost instantaneously. Emergency Department and ward doctors can receive an early warning for possible clinical deterioration and prescribe the appropriate interim measures to improve patient outcomes."

Beyond local healthcare settings, CAPE can potentially be calibrated to identify and predict the severity of respiratory infections globally. This would be crucial during pandemics such as COVID-19, where there could be an increased need for inpatient and critical care support. In areas where healthcare resources may be limited, CAPE can enable prioritisation of healthcare resources so that patients who are likely to develop severe pneumonia can receive appropriate and timely care, improving patient outcomes.

"Driven by the clinical care needs and resource demands of the pandemic, the CGH and IHiS teams saw the potential of AI to combat the critical needs of COVID-19," said Professor Ng Wai Hoe, Chief Executive Officer of CGH, "CAPE shows the value of interdisciplinary collaboration and that research and innovation can occur even in difficult times to provide practical solutions to improve patient care."

"Technology has been a crucial enabler in every stage of our fight against COVID-19 – prevention, detection, containment and patient care. CAPE is one of over 50 HealthTech solutions IHiS has engineered and we are happy to partner CGH in the use of AI to better predict the severity of pneumonia for better patient care. The accelerated launch and quick refinements were possible with an agile delivery approach and excellent partnership between the IHiS tech and CGH clinical teams," said Bruce Liang, Chief Executive Officer of IHiS.

Validated with prospective clinical data at CGH since May 2020, the team is looking to integrate data from electronic medical records, and further improve the accuracy of CAPE with clinical data from the SingHealth cluster including Singapore General Hospital and Sengkang General Hospital. The team is exploring collaborative models, including hosting it as a "freeware" collaborative tool on a research platform for interested researchers, so that CAPE can be generalised and eventually used internationally too.

An academic paper written on CAPE was accepted as poster paper in "Knowledge Discovery and Data Mining", a leading publication in data mining and analysis, and also presented at the Knowledge Discovery and Data Mining (KDD) conference on (24 August 2020). The KDD conference is a premier global interdisciplinary conference bringing together researchers and practitioners from around the world in the areas of data science, data mining, knowledge discovery, and large-scale data analytics.

Prof Ankur Teredesai, Health Day Chair at the KDD 2020 conference, as well as Chief Technology Officer and Co-Founder of KenSci and Professor of Computer Science & Systems at the School of Engineering & Technology, University of Washington Tacoma, said, "Operationalising machine learning models in healthcare is extremely challenging, particularly for triaging severity of illness at the point of admission for COVID-19 by integrating electronic medical record data with imaging data. I have spent over a decade in helping health systems

embed AI in workflows and was very impressed by the agility and comprehensiveness of the CAPE system as reported in the paper at KDD Health Day 2020 this August."

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About Changi General Hospital

Changi General Hospital (CGH) is an academic medical institution with over 1,000 beds serving a community of more than 1 million people in eastern Singapore. With a wide range of medical specialties and services, it is helmed by an experienced and skilled team of healthcare professionals who consistently deliver positive health outcomes and care for patients.

About IHiS

IHiS is a multi-award-winning healthcare IT leader that digitises, connects, and analyses Singapore's health ecosystem. Its ultimate aim is to improve the Singapore population's health and health administration by integrating intelligent, highly resilient and cost effective technologies with process and people.

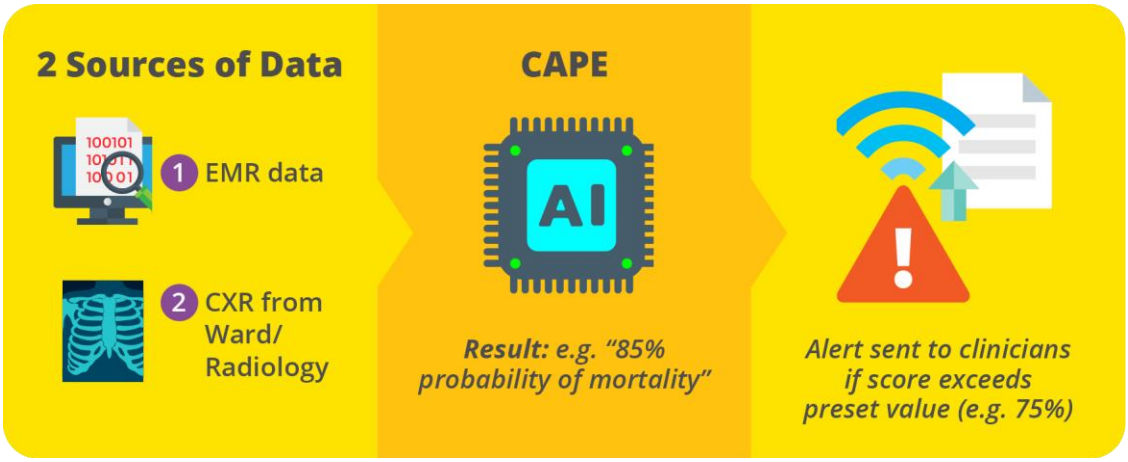
IHiS played a key role in helping all major public healthcare institutions become amongst the first in Asia Pacific to achieve HIMSS EMRAM Stage 7 and 7, international benchmarks for advanced technology used in patient care.

Transforming healthcare through smart technology, IHiS has garnered more than 80 awards for its innovations. It supports more than 50,000 healthcare users in Singapore's health ecosystem through the application of clinical informatics, computer science, data science, mechatronics, standards based IT that enables information exchange and cross boundary workflows, analysis, statistical and machine learning techniques to discover insights.

For more information, visit us at www.ihis.com.sg, connect with us on Facebook and follow us on LinkedIn to learn more about the latest healthcare IT news.

Annex A

How the Community Acquired Pneumonia and COVID-19 AI Predictive Engine (CAPE) works



Note: While CAPE has the capability to use electronic medical records (EMR) data, it has not been in use yet as more time is needed to incorporate EMA data into CAPE operationally.

Most assessment tools for pneumonia currently in the market rely on either radiology images or electronic medical record data. CAPE has the potential to utilise both in a machine learning model to generate a risk score for pneumonia severity.

Pair coding approach was used for model development where six data scientists from IHiS broke into two teams to do concurrent coding. Using different machine learning frameworks, the two teams set out to develop the same AI components for CAPE. The team ensured the robustness and consistency of the model by using different pair coding approaches and checking to see that they achieved the same results. A model of such complexity would normally take longer to develop. However, due to the urgency and potential impact it had on managing COVID-19, the team accelerated the project and adopted a rapid development approach onsite to complete it in two months."

To get the machine learning model to learn how to predict an accurate score, CGH and IHiS teams fed it with historical data – more than 3,000 Chest X-Ray (CXR) images and 200,000 data points including >10,000 lab results and patient clinical history from electronic medical records – carefully extracted and de-identified for developing the model. Leveraging past experience in implementing large scale machine learning application, IHIS and CGH conceptualised the end-to-end solution covering data mining, de-identification compliance, pre-processing, model development and redesign of workflow for clinical systems integration.

After two months of development, which included ensuring the viability of the predictive engine through many rounds of training, validating and testing the various permutations of data, three models were developed as indicators for pneumonia severity:

a) Low risk pneumonia with anticipated short inpatient hospitalisation
b) Patient at risk of mortality (death)
c) Patient at risk of requiring critical care support

These models are able to generate a score from CXR images to help clinicians to determine at admission, the likelihood of whether a patient will develop mild or severe pneumonia within 30 days. This knowledge provides an early alert to any deteriorating prognosis, and enables clinicians to better prioritise clinical worklists – when the AI predicts a high-risk prognosis, more medical attention can be channelled to these patients. Initial results have been promising – validation tests at CGH showed that CAPE has an approximate accuracy of 80% in predicting the future presence or absence of severe pneumonia. This is comparable to traditional pneumonia severity tools that are scored manually.

CAPE is implemented as a standalone desktop application that can be installed on radiology workstations. This helps to ensure ease of integration and use, as well as a shorter deployment time, as only minor changes need to be made to the existing system to incorporate CAPE.

Work is on-going to integrate more data-sets from clinical data from the SingHealth cluster including Singapore General Hospital and Sengkang General Hospital and other public health institutions in Singapore, which would likely make CAPE even more accurate. The team is also exploring collaborative models, including hosting it as a “freeware” collaborative tool on a research platform for interested researchers globally, so that CAPE can be generalised and eventually used internationally.

Case Study of CAPE Application

A 42-year old man with tested positive for COVID-19. CAPE predicted the need for critical care support to be at 80.6%. The patient was subsequently admitted to ICU for deteriorating oxygen levels.

A **B**

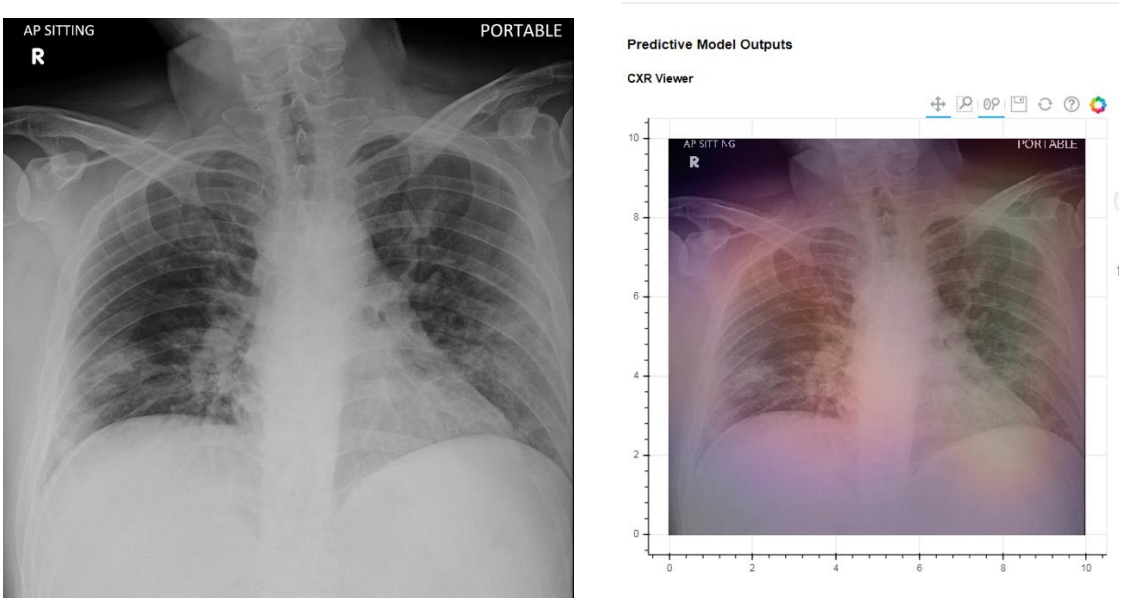
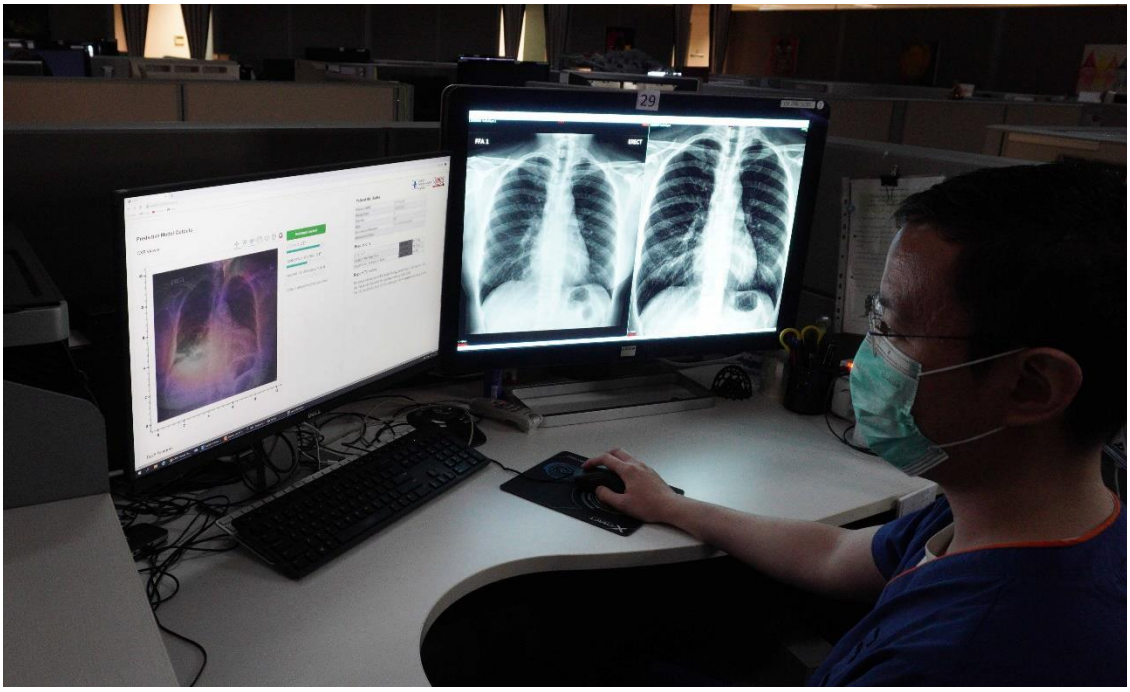
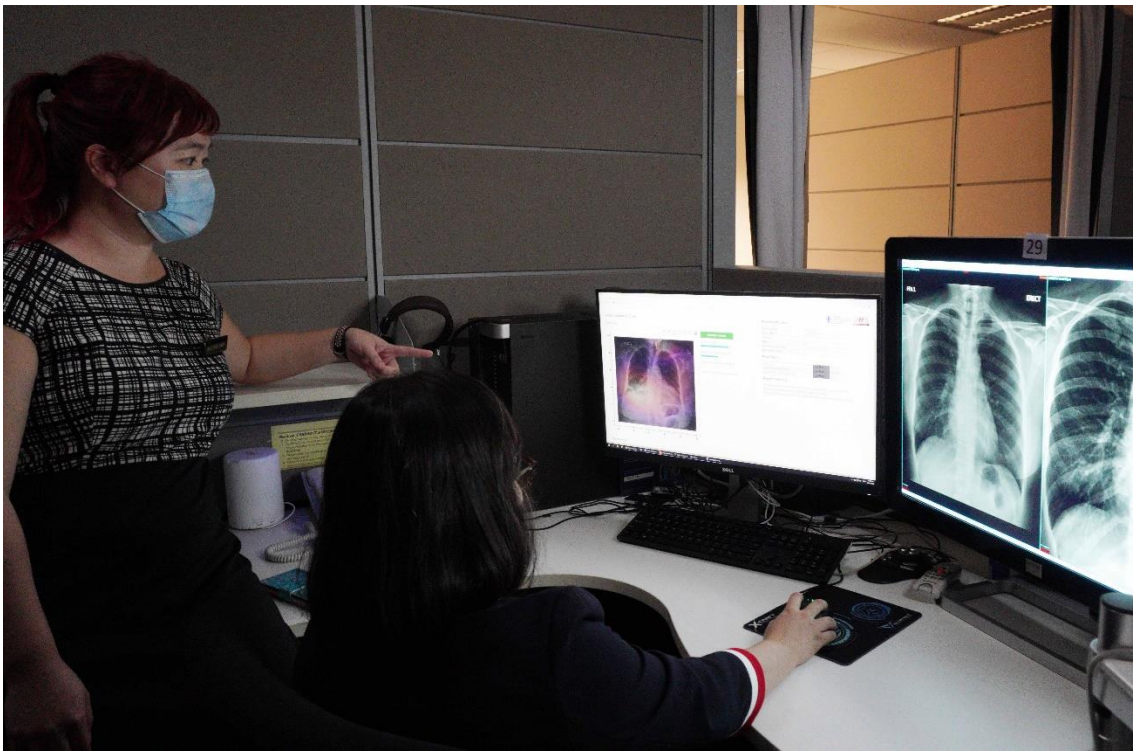


Figure 1. *A 42-year old man with a positive test for COVID-19 infection. (A) Frontal chest radiograph upon admission (B) The deep-learning model heatmap is overlaid over the image showing pneumonia-related features. The deep-learning model risk score for the subject requiring critical care support was 80.6%.*

Collaborators and researchers interested to work with CGH can contact the Centre for Innovation at innovation@cgh.com.sg or Centre for Healthcare Assistive & Robotics Technology (CHART) at chart@cgh.com.sg.



CAPE determines the likelihood of whether the patient has mild or severe pneumonia based on the chest X-ray image.



(From left) Dr Jessica Quah, Consultant, Respiratory & Critical Care Medicine, and Dr Charlene Liew, Consultant, Diagnostic Radiology, Changi General Hospital, were part of the team that developed CAPE

The CGH and IHiS team that developed CAPE
(From L to R) Jenny Zou, Dr Jessica Quah, Christine Ang, Dr Charlene Liew, Narayan Venkataraman, Andy Ta, Sandhiya Ramanathan, Dr Goh Han Leong