The Australian e-Health Research Centre

Annual Report 2019-2020

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

Queensland Government

CSIRO

Contents

The Australian e-Health Research Centre

The Australian e-Health Research Centre is an unincorporated joint venture between the Queensland Government and CSIRO's national digital health research program. With over 100 scientists and engineers and a further 30 higher degree research students across Brisbane, Sydney, Melbourne, Canberra and Perth, the AEHRC is the largest digital health research program in Australia.

Established in 2003 with initial funding from the Department of State Development and CSIRO, the partnership was extended in 2007 for a further five years with funding from CSIRO, Queensland Health and the Department of Employment, Economic Development and Innovation. In 2012 the partnership was extended for a further five years with an additional contribution of $15 million from CSIRO and Queensland Health, supplemented by in-kind contributions from the partners, as well as funding from grants, research consulting and commercialisation. The partnership was further extended in 2017 for an additional five years with a further contribution of $15 million from CSIRO and Queensland Health.

The AEHRC is a full health and biomedical informatics research program, undertaking:

- applied research in biomedical informatics, including genomics and medical imaging
- health informatics, including clinical informatics and data interoperability
- health services research.

Through additional investment from CSIRO and funding from state health departments and federal health agencies, the AEHRC supports the digital transformation of healthcare around Australia. Through its research program, the AEHRC develops and deploys leading edge information and communication technology innovations in healthcare to:

- improve service delivery in the Queensland and Australian health systems
- generate commercialisation revenue
- increase the pool of world-class e-health expertise in Australia.

The current AEHRC strategy aims to use the research capability of our five research groups – health informatics, health system analytics, biomedical informatics, transformational bioinformatics and health services research – to continue to tackle Australia's healthcare system challenges and expand the impact of our research. The challenges set out in this strategy are to:

- increase our science outcomes to be recognised in the top three e-Health research centres in the world
- increase our impact through increased adoption of our technologies
- develop new areas of impact in Indigenous health, precision medicine, big data medical research, healthy ageing and a learning healthcare system
- increase our commercial outcomes, and
- continue the growth of the AEHRC around Australia.

Our research program is informed through strong partnerships with the health industry, including clinicians, researchers, health service executives and the health IT vendor community. With more than half our staff based at the Royal Brisbane Women's Hospital campus in Brisbane, our scientists and engineers have strong relationships with Queensland Health administrators, clinicians and researchers.

Our growing teams in Sydney, Melbourne and Perth are building relationships into respective state health departments and we continue to work as a program across Australia. The AEHRC continues to deliver to national programs, with key projects with the Department of Health and the Australian Digital Health Agency. As CSIRO's digital health research program, the centre works with scientists from across CSIRO, contributing to projects in CSIRO research in Health and Nutrition, Biosecurity, Probing Biosystems and Precision Health.

Foreword by the Chair and CEO

The past 12 months has been a challenging time for all with the COVID-19 pandemic. Despite the disruption our staff have continued to work with our stakeholders and customers to deliver our projects, while the pandemic provided new challenges and opportunities.

We encountered several opportunities to employ AEHRC science to support Australia's COVID-19 response – particularly with our joint venture partners, CSIRO and Queensland Health. Working with CSIRO Health and Biosecurity and CSIRO's Australian Centre for Disease Preparedness, our bioinformatics researchers were involved in studying the genomic sequence of the COVID-19 virus to inform the animal studies of potential vaccines. Our health data researchers contributed with a COVID-19 dashboard that is still being used around Australia, and worked with numerous health agencies on modelling the impact of the pandemic. Our team is still working with Queensland Health on their "COVID Barometer" project.

The AEHRC was also involved in numerous projects to support remote delivery of healthcare during the pandemic. Of note was the recent launch of the MoTHER project, an implementation trial of mobile health for women with gestational diabetes with Metro South Brisbane and Mater Mothers' Hospital. We have also been supporting the delivery of education remotely, working with the University of Queensland Medical School to introduce a digital version of Case-Based Learning for the medical students. It was pleasing to see that the AEHRC was well positioned to help in so many ways.

Our five research groups have delivered some amazing science over the past year, which this report presents. Our teams have delivered or been involved in trials which include enabling families of premature babies to see their baby in hospital; using sensors to support aged Australians living alone; patient risk stratification algorithms for discharge planning and reducing hospitalisations; and using imaging software to provide more efficient, higher quality prostate cancer radiotherapy, and to analyse the brain MRI images of more than 500 premature babies as part of a trial for early interventions for cerebral palsy.

Our teams have also delivered technologies for data interoperability through projects in Germany, the UK and in Australia; and technology for analysis of whole genome sequences and for sharing of genomic data using cloud computing. And our teams have undertaken analytics progress across a wide range of healthcare, validating a new blood based biomarker for Alzheimer's disease; analysing patient flow through different parts of hospitals and health systems in Queensland and Western Australia; and analysing genomic test data and electronic medical records for large genomics trials.

We have also increased collaboration with the Indigenous community to identify how digital health can be used to reduce the gap in Indigenous health outcomes.

We have seen increased opportunities to work with different parts of Queensland Health. eHealth Queensland is using our terminology server for a new Queensland Clinical Terminology Service; we are undertaking a number of projects with the Jamieson Trauma Institute and Metro North HHS; and we are collaborating with many hospitals around Queensland. We also worked with CSIRO's Data61 on a new fore-sighting project for Queensland Health.

Nationally the AEHRC has continued our successful collaboration with The Australian Digital Health Agency in the National Clinical Terminology Service and developed a national community for GP data standards with funding from the Commonwealth Department of Health. We have extended our collaboration with the WA Department of Health with our Perth based tele-health team and continued to work with the Department of Health and Human Services in Victoria on digital health projects. This year has also seen us work with the new Commission on Excellence and Innovation for Healthcare in South Australia and to undertake projects in New South Wales with e-Health NSW and NSW Health Pathology.

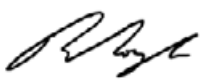
We have contributed to several NHMRC and Medical Research Future Fund projects, such as the MRFF OUTBREAK initiative for tackling antimicrobial resistance across human and animal health, and have continued involvement in the NHMRC-funded Australian Genomics Health Alliance and the NHMRC Centre for Research Excellence in Digital Health, among many others.

Internationally the AEHRC has had a very successful year. Our research groups have contributed to several international initiatives, such as the Global Alliance for Genomics and Health and the Project MinE initiative to understand and cure Motor Neurone Disease; they have given packed out (real and virtual!) seminars at the FHIR Dev Days events; developed projects with the Asian Development Bank; and are developing a new relationship with Harvard University.

We are using the CSIRO Digital Transformation Program to increase the quality and impact of our science. As part of this program we undertook a pilot of the Digital Academy, developing a workforce strategy for developing our staff. We are also at the forefront of the CSIRO Cloud Right program, transforming the way we do and deliver our science with cloud services.

The AEHRC continued to grow over the past year, welcoming new staff across our research groups. However, we were devastated by the sudden death of long-standing staff member John O'Dwyer in April. John has been a valued staff member of the AEHRC since January 2005 and contributed to projects across the centre. Our hearts go out to his wife Marilla and their family and friends.

We all hope that during the next year there is success in dealing with the COVID-19 pandemic and life returns gradually to normal. However, the pandemic has brought renewed focus on health systems around the world and the opportunities for digital health research and development have only increased. We look forward to reporting in 12 months' time on a successful 2020/21 year.



Richard Royle
Chair
The AEHRC

David Hansen
Chief Executive Officer
The AEHRC

Board of Directors

Richard Royle

Chair, the Australian e-Health Research Centre

Richard has over 30 years of senior executive experience in the public, for profit and not for profit private hospital sectors in Australia and is the immediate past President of the Australian Private Hospitals Association.

Richard oversaw the successful implementation of Australia's first fully integrated digital hospital in Hervey Bay as the group CEO of UnitingCare Health in 2014. In 2016 he was asked to be the startup CEO of the newly established Australian Digital Health Agency – putting into practice one of his recommendations from a landmark review he was asked to lead in 2013 for the Federal Government on digital health in Australia.

Damian Green

Damian Green is the Deputy Director-General of eHealth Queensland, and Chief Information Officer of Queensland Health. He leads the ongoing transformation of Queensland's public health service through the delivery of an innovative and customer-focused ICT platform and service. eHealth Queensland enables the delivery of health services to the community, supporting the information technology needs of the state's 16 Hospital and Health Services and the Department of Health. Damian is an Adjunct Professor in the School of Business Strategy and Innovation, Griffith University.

Professor Keith McNeil

Professor Keith McNeil is Acting Deputy Director-General, Chief Medical Officer (Prevention Division) and Chief Clinical Information Officer, Queensland Health. He plays a key role in the clinical leadership of the state-wide eHealth program, and works closely with key clinical stakeholders to maximise the clinical and patient safety benefits associated with technology in the healthcare setting.

Prof McNeil has previously worked within Queensland Health as the Head of Transplant Services at The Prince Charles Hospital, Chief Executive Officer at Royal Brisbane and Women's Hospital, and Chief Executive Metro North Hospital and Health Service.

More recently, Prof McNeil was Chief Clinical Information Officer and Head of IT for the NHS in England following roles as Chief Executive Officer at Addenbooke's Hospital and Cambridge University Hospital Foundation Trust.

Rob Grenfell

Dr Rob Grenfell, a public health physician, is the Director of CSIRO's Health and Biosecurity business unit. He leads a broad portfolio covering nutrition, e-health, medtech and diagnostics, and biosecurity from weeds to Ebola.

Rob has broad-ranging public health experience including:

- National Medical Director at BUPA Australia New Zealand
- National Director Cardiovascular Health at the Heart Foundation
- Strategic Health Advisor to Parks Victoria
- Senior Medical Advisor at the Department of Health Victoria
- Physician in charge of travel health BHP
- General Practice.

He was a member of the Safety and Quality Outcomes Committee of the Hospital Innovation Reform Council, a member of the Victorian Quality Council, Chair of General Practice Victoria, and member of the Health Advisory Committee of the National Health and Medical Research Council.

Adrian Turner

From: 2016 to August 2019

Adrian Turner was the CEO of Data61 at CSIRO from 2016 to September 2019. Data61 is the datascience arm of CSIRO and is focused on solving Australia's largest data-driven challenges. Adrian was previously Managing Director and Co-Founder of Borondi Group, a holding company focused on the intersection of pervasive computing, platform economics and traditionally conservative industries and was co-founder and CEO of smart phone and Internet of Things security company Mocana Corporation. Prior to this Adrian had profit and loss responsibility for Philips Electronics connected devices infrastructure, and was Chairman of the Board for Australia's expat network, Advance.org.

Adrian is a UTS graduate and has completed the Executive Program for Managing Growth Companies at Stanford University, having spent 18 years in Silicon Valley.

Richard Symonds

Minutes Secretary

Kelly Tighe

Finance Manager, CSIRO

Meetings

Board Meetings for 2019/2020 were held:

- 19 August 2019
- 19 November 2019
- 20 March 2020
- 4 June 2020

Research and Investment Advisory Committee

Reporting to the Board of the Australian e-Health Research Centre, the Research and Investment Advisory Committee (RIAC) performs an advisory function for the Centre's research activities, and assists the Board to carry out the functions of the AEHRC.

For a variety of reasons the Research and Investment Advisory Committee has not met over the past 12 months. However interactions between the AEHRC and Queensland Health continue to increase, as evidenced throughout this report with numerous projects between the AEHRC and QLD Health HHS and agencies funded through joint venture contributions and matching funds, as well as a variety of other grants and initiatives.

To ensure alignment between the research undertaken by the AEHRC and the digital health direction of Queensland Health, our staff have held several meetings with Queensland Health HHS and entities over the past 12 months. This includes ongoing meetings and workshops with multiple teams in e-Health Queensland, Clinical Excellence Queensland, Metro North HHS, Metro South HHS, Queensland Children's Hospital, Mt Isa Hospital, Townsville Hospital and many others.

Our leadership is working with Queensland Health board members to ensure ongoing alignment to Queensland Health strategy.

Management and leadership

Dr David Hansen

CEO and Research Director,
Australian e-Health Research Centre

Dr David Hansen is CEO and Research Director of the Australian e-Health Research Centre. David leads the research program of over 100 scientists and engineers developing information and communication technologies to improve the safety, quality and efficiency of healthcare.

David is a member of the Australian Digital Health Agency Clinical and Technical Advisory Committee, Co-Chair of the National Clinical Terminology Service, member of the National Steering Committee for the Australian Genomics Health Alliance and Vice-Chair of the board of the Australian Institute of Digital Health (AIDH).

David is passionate about the role of information and communication technologies in health care and the role of digital health in developing a safe, efficient and sustainable healthcare system in Australia.

Dr Jill Freyne

Deputy Research Director

Dr Jill Freyne is the Deputy Research Director of the Australian e-Health Research Centre at CSIRO.

Jill has significant research experience in the development and validation of digital health services, lifestyle interventions and recommender systems. Jill has worked with Australian and international industry partners to devise engaging and sustainable health technology solutions, aimed specifically at encouraging individuals to change the way that they engage with their health. Through clinical trials the technologies have been evaluated to understand and quantify their impact on individuals, care teams and carers, thus contributing to the body of evidence required to see large scale adoption and innovation in digital health service delivery.

Dr Michael Lawley

Group Leader, Health Informatics

Dr Michael Lawley is Senior Principal Research Scientist and Group Leader with the Australian e-Health Research Centre. Michael leads the Health Informatics group with teams in health data semantics, health informatics and modelling, and software engineering.

Michael has extensive expertise in clinical terminology, specifically large-scale ontologies such as SNOMED CT. Work developed by Michael and his team has produced technologies that have been licensed nationally and internationally by standards bodies, government organisations and SMEs. In 2018, he received the SNOMED International Award for Excellence recognising his many contributions to the evolution of SNOMED CT.

Dr Jurgen Fripp

Group Leader, Biomedical Informatics

Dr Jurgen Fripp leads the Australian e-Health Research Centre's Biomedical Informatics group, with teams covering genomics, biostatistics, medical image analysis and clinical imaging. The group's focus is on using medical imaging biomarkers, machine learning and statistical techniques that enable precision health (prediction, staging, prevention and treatment), including when combined with various omics, neuropsychology, smart sensing and clinical phenotypes.

The group's techniques are deployed in hospitals and on the AEHRC's cloud informatics platform for use in a wide range of large observational and randomised control trials across the human lifespan (from conception to senescence) and disease spectrum (including osteoarthritis, cerebral palsy, cancer and dementia). Jurgen has deep expertise in medical imaging, including Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), and Computed Tomography (CT).

Dr Denis Bauer

Group Leader, Transformational Bioinformatics

Dr Denis Bauer is the Principal Research Scientist in transformational bioinformatics and an internationally recognised expert in machine learning and cloud-based genomics. Denis is frequently invited to speak at international medical and IT conferences including the Amazon Web Services Summit, Alibaba Infinity and Open Data Science Conference.

Her revolutionary achievements have been featured in international media outlets such as GenomeWeb, ZDNet, Computer World and CIO Magazine and her work was listed as ComputerWeekly's Top 10 IT stories of 2017.

Denis holds a Bachelor of Science from Germany, a PhD in Bioinformatics from the University of Queensland and a Certificate in Executive Management and Development from the University of New South Wales Business School. Her achievements include developing open-source machine learning cloud services that accelerate disease research, which is used by 10,000 researchers annually. In 2020, she was involved in Australia's response to COVID-19 through her genomics work.

Dr Mohan Karunanithi

Group Leader, Health Services

Dr Mohanraj Karunanithi leads the Australian e-Health Research Centre's Health Services group. Mohan has a doctorate in Biomedical Engineering from the University of New South Wales, over 10 years of cardiac research experience and five years of medical industries experience.

At the AEHRC, Mohan manages and coordinates research and teams developing and validating innovative solutions to manage chronic disease and aged care.

Dr Rajiv Jayasena

Group Leader, Health System Analytics and Victorian Lead

Dr Rajiv Jayasena is the Group Leader for Health System Analytics and Victorian Lead for the Australian e-Health Research Centre. Rajiv has extensive experience in medical research, commercial industry and project leadership, and in recent years has worked on primary and acute healthcare reform and in new models of care for chronic disease management in the community.

Rajiv leads the AEHRC's Health Systems Analytics group, comprising research teams specialising in hospital patient flow, operational research, simulation and modelling, risk stratification for hospital avoidance and measuring implementation outcomes of new and improved models of health care. Rajiv also manages clinical trials in primary healthcare reform nationally and leads new areas of science in response to research opportunities and stakeholder priorities.

Dr Janet Fox

Business Development Manager

Dr Janet Fox is CSIRO's Digital Health Business Development Manager and is embedded within the Australian e-Health Research Centre, where she provides commercial advice and leadership to the team. Janet especially enjoys working at the interface of discovery, implementation and business strategy to translate digital health research technologies into sustainable commercial products, delivering impact both in Australia and overseas.

Annual e-Health Research Colloquium

Over 300 people attended this year's 16th Annual e-Health Research Colloquium, hosted by the Australian e-Health Research Centre at the RBWH Education Centre in Brisbane on 4 March 2020.

The AEHRC colloquium occurred earlier than usual this year, which was just as well since it turned out to be one of the last days a 300-person event could be held before COVID-19 social distancing rules came into effect!

This year a clear theme from the talks was the need for research to underpin the implementation of digital health – and we had some fantastic examples for delegates to discuss.

eHealth Queensland CEO Damian Green started the day with an update on the Queensland Health Digital Plan, which is building a sustainable digital health capability to deliver transformational digital health for Queensland. It was great to see so many of the areas that the AEHRC works in as part of the plan and we look forward to supporting Queensland Health in delivering on this promise into the future.

We then had six short talks highlighting projects the AEHRC has delivered with our collaborators over the past 12 months:

- Liesel Higgins from our Health Services group provided initial results from our 200-home trial of the Smarter Safer Homes platform, funded through the Australian Government Dementia and Aged Care Services (DACS) Fund
- Jason Dowling from our Biomedical Informatics group gave an update on how we are using AI to improve outcomes of prostate cancer radiotherapy planning with the Calvary Mater Newcastle Hospital
- Dr Yoga Kandasamy, Neonatologist at Townsville University Hospital, described how our Perth based tele-health teams developed BabyCam technology to provide families with a link to their newborn premature babies
- Dr Ben Barry from the University of Queensland (UQ) Medical School gave an overview of the Digital Case-Based Learning Tool that our Health Informatics group built to make medical education more interactive for UQ medical students
- Dr Andrew Mallet, Nephrologist at the Royal Brisbane and Women's Hospital, gave an update on the Australian Genomics KidGen project, including some data analysis undertaken by our Data Interoperability team
- Jill Freyne, our Deputy Research Director, described some of the great outcomes from the mobile health for orthopaedics project that the AEHRC has been undertaking with Johnson and Johnson Medical Devices.

After those quickfire talks it was time to hear about some further projects in depth:

- RACGP's Dr Nathan Pinskier and Kate Ebrill from the AEHRC described the FHIR community process we have been leading to develop data standards for the GP community, with consultation across peak GP and industry bodies, the vendor community and the research community. With FHIR implementation guides and SNOMED CT value sets the future of data interoperability in Australia's GP sector is looking brighter!
- The University of Melbourne's Professor Wendy Chapman described some of the projects which will link the primary care system to the secondary care system, with patients receiving integrated healthcare across the continuum of care
- Clare Naughtin from CSIRO's Data61 presented the megatrends which will influence healthcare in Queensland over the next 20 years – with the emerging COVID-19 pandemic providing a mega-shock to the megatrends!

We finished with a panel chaired by CSIRO Health and Biosecurity Director Dr Rob Grenfell. Our panel featured eHealth Queensland's Narelle Doss, Dr Louise Schaper from the Australasian Institute of Digital Health, Professor Wendy Chapman and Kate Ebrill, discussing how health services and biomedical research need to collaborate to improve health service delivery.

Project updates and sneak peeks from our researchers are always one of the highlights at our Colloquiums, and this year was no exception:

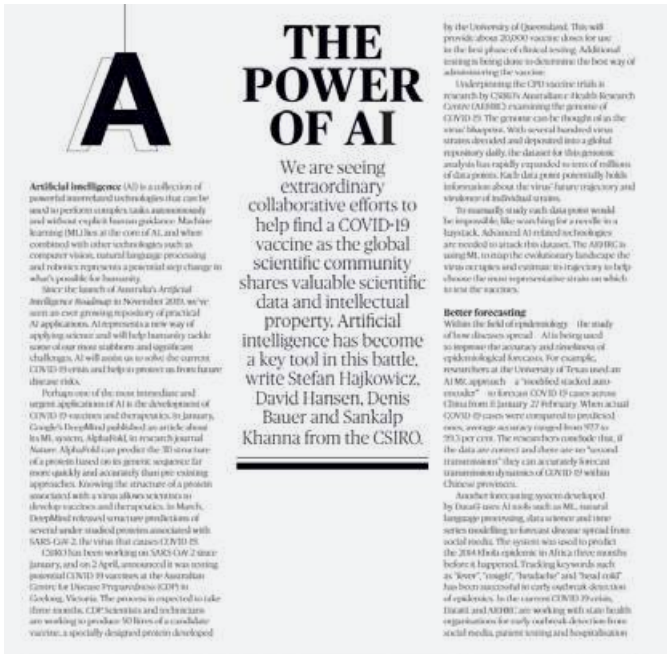
- Dr Peter Rizzo from Prince Charles Hospital and Anthony Nguyen from the AEHRC presented technology to use natural language processing to reduce antimicrobial resistance and increase clinical efficiency
- The AEHRC's David Ireland presented the iAward-winning Pain RoadMap project – a mobile platform to support relief for chronic pain
- Vincent Dore presented the AEHRC's work on using PET imaging for early diagnosis of Alzheimer's disease
- The AEHRC's Suzanne Scott gave a glimpse of the future when presenting on the use of gene therapy for treating cancer
- John Grimes and Kylynn Loi provided an overview of some of the new technologies coming out of the AEHRC to support data interoperability using FHIR and SNOMED across healthcare.

Attendees used the tea and lunch breaks to view posters and talk to our scientists. It was great to have so many of our partners and stakeholders together.

The AEHRC in the news

Our research and collaborations continued to make headlines this year, reaching key stakeholders around Australia through coverage in mainstream media and industry publications.
We also continued to raise awareness of our work through key engagements with partners and government.

VariantSpark and its publication through AWS Marketplace was featured in The Financial Review.



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THE POWER OF AI

We are seeing extraordinary collaborative efforts to help find a COVID-19 vaccine as the global scientific community shares valuable scientific data and intellectual property. Artificial intelligence has become a key tool in this battle, write Stefan Hajkowicz, David Hansen, Denis Bauer and Sankalp Khanna from the CSIRO.

Artificial intelligence (AI) is a collection of powerful interrelated technologies that can be used to perform complex tasks autonomously and without explicit human guidance. Machine learning (ML) lies at the core of AI, and when combined with other technologies such as computer vision, natural language processing and robotics represents a potential step change in what's possible for humanity.

Since the launch of Australia's *Artificial Intelligence Roadmap* in November 2019, we've seen an ever growing repository of practical AI applications. AI represents a new way of applying science and will help humanity tackle some of our most stubborn and significant challenges. AI will assist us to solve the current COVID-19 crisis and help us prevent us from future disease risks.

Perhaps one of the most immediate and urgent applications of AI is the development of COVID-19 vaccines and therapeutics. In January, Google's DeepMind published an article about its ML system, AlphaFold, in research journal *Nature*. AlphaFold can predict the 3D structure of a protein based on its genetic sequence far more quickly and accurately than pre-existing approaches. Knowing the structure of a protein associated with a virus allows scientists to develop vaccines and therapeutics. In March, DeepMind released structure predictions of several under studied proteins associated with SARS-CoV-2, the virus that causes COVID-19.

CSIRO has been working on SARS-CoV-2 since January, and on 2 April, announced it was testing potential COVID-19 vaccines at the Australian Centre for Disease Preparedness (CDP) in Geelong, Victoria. The process is expected to take three months. CDP scientists and technicians are working to produce 50 litres of a candidate vaccine, a specially designed protein developed by the University of Queensland. This will provide about 20,000 vaccine doses for use in the first phase of clinical testing. Additional testing is being done to determine the best way of administering the vaccine.

Underpinning the CDP vaccine trials is research by CSIRO's Australian e-Health Research Centre (AEHRC) examining the genome of COVID-19. The genome can be thought of as the virus' blueprint. With several hundred virus strains decoded and deposited into a global repository daily, the dataset for this genome analysis has rapidly expanded to tens of millions of data points. Each data point potentially holds information about the virus' future trajectory and virulence of individual strains.

To manually study each data point would be impossible, like searching for a needle in a haystack. Advanced AI-related technologies are needed to attack this dataset. The AEHRC is using ML to map the evolutionary landscape the virus occupies and estimate its trajectory to help choose the most representative strain on which to test the vaccines.

Better forecasting

Within the field of epidemiology – the study of how diseases spread – AI is being used to improve the accuracy and timeliness of epidemiological forecasts. For example, researchers at the University of Texas used an AI ML approach – a "modified stacked auto-encoder" – to forecast COVID-19 cases across China from 11 January–27 February. When actual COVID-19 cases were compared to predicted ones, average accuracy ranged from 97.7 to 99.3 per cent. The researchers conclude that, if the data are correct and there are no "second transmissions" they can accurately forecast transmission dynamics of COVID-19 within Chinese provinces.

Another forecasting system developed by Data61 uses AI tools such as ML, natural language processing, data science and time series modelling to forecast disease spread from social media. The system was used to predict the 2014 Ebola epidemic in Africa three months before it happened. Tracking keywords such as "fever", "cough", "headache" and "head cold" has been successful in early outbreak detection of epidemics. In the current COVID-19 crisis, Data61 and AEHRC are working with state health organisations for early outbreak detection from social media, patient testing and hospitalisation

Our AI work was featured in Company Director Magazine.

News coverage highlights

- News of our contribution to research on how the SARS-CoV-2 virus is evolving, and what it means for vaccine development and evaluation, reached 2.4M people through a targeted media campaign. Highlights included stories in the Daily Telegraph and the Herald Sun, coverage across ABC News and on commercial radio.
- The AEHRC and Dr David Hansen, Dr Sankalp Khanna and Dr Denis Bauer were featured in a Company Director Magazine story on using AI to combat COVID-19.
- Dr Denis Bauer provided expert commentary about new strains of the SARS-CoV-2 virus, and was quoted in numerous stories including in The Sydney Morning Herald, the Daily Mail and The Australian.
- Dr David Silvera was interviewed on ABC News 24, ABC Drive radio and ABC Compass about his work with socially assistive robots.
- Our VariantSpark technology's publication on AWS Marketplace was featured in the Financial Review.
- Our work with the Primary Care Data Quality Foundations project was featured in a story in industry news site PulseIT.
- Dr Mohan Karunanithi was interviewed by SBS Korean radio on digital healthcare partnerships between Australia and Korea.

Dr David Silvera was interviewed by ABC News about socially assistive robots.

Dr Qing Zhang with Minister Karen Andrews in Canberra.

Government and partner engagement highlights

- Dr Qing Zhang represented the AEHRC at the Techtonic AI Summit at Old Parliament House in Canberra, and was featured in tweets by the Federal Minister for Industry, Science and Technology Karen Andrews and the Department of Industry.
- Dr Sankalp Khanna participated in Science Meets Parliament in Canberra, featuring our predictive risk algorithms.
- Our mobile health scoping collaboration with Queensland Indigenous communities was featured twice in the Queensland Aboriginal and Islander Health Council's Sector Leader magazine.
- We reached key stakeholders through eHealth Queensland's National Digital Health Update newsletters, with stories on our COVID-19 dashboard, contribution to the OUTBREAK project and more.
- The Hear to Help project was featured in the Autism CRC's eNews.

Awards

Our teams were successful in winning and placing in a number of awards again this year.

- Our BabyCam streaming app for the families of premature babies, created by our Perth team with Townsville Hospital, won Queensland's Health 2019 Innovation Award and the Minister's Award for Outstanding Achievement. The Board congratulates those involved.
- David Ireland & collaborators from Metro North Hospital and Health Service obtained two merit recipient awards at the National iAwards (R&D of the Year & Data Insights) for the Pain ROADMAP project.
- The RISK team was shortlisted for the inaugural HISA Enterprise Achievement Award.
- David Ireland was shortlisted for the Branko award at the 2019 Health Informatics Conference in Melbourne.
- Suzanne Scott's poster received acclaim at the Westmead Research Showcase.
- Thanh Vu and Anthony Nguyen's co-authored paper with the Royal Brisbane and Women's Hospital, "Identifying Patients with Pain in Emergency Departments using Conventional Machine Learning and Deep Learning", received acclaim at the 17th Annual Workshop of the Australasian Language Technology Association in 2019.

David Ireland and MNHHS collaborators were recognised at the National iAwards for Pain ROADMAP.

CSIRO recognition

Our work received significant recognition amongst our peers at CSIRO this year.

- H&B Customer Value Award: David Rolls, Sankalp Khanna and the project team for the Rauland Australia project at Barwon Health Victoria.
- H&B Special Customer Value Award: Pippa Niven for coordinating the Healthlinks project with the Victorian Department of Health and Hospital Services.
- H&B Digital+Domain: Justin Boyle, Sankalp Khanna and the project team for the Fiona Stanley Hospital project in WA.
- H&B Outstanding Collaboration Award: Lynne Cobiac, Hugo Leroux and the team (including Jurgen Fripp and Jason Dowling).

AEHRC research supporting the response to COVID-19

The Australian e-Health Research Centre was involved directly in many aspects of the Australian response to the emergence of the COVID-19 pandemic.

Understanding the genomic sequence of COVID-19

Our Transformational Bioinformatics team was quick to respond to the publication of the first COVID-19 virus sequence. As more strains of the virus were sequenced and made publicly available the team developed a new k-mer based analysis tool to "fingerprint" the virus and compare the sequences of the different strains. This new measure for similarity complements the traditional phylogenetic approach and was the first publication from CSIRO in COVID-19.

They then worked with the CSIRO Health and Biosecurity team at CSIRO's Australian Centre for Disease Preparedness in Geelong to determine which strain of the virus would be best for the animal trials of COVID-19 vaccine candidates. This was undertaken as part of CSIRO's work funded by the Coalition for Epidemic Preparedness Innovations (CEPI).

The team is now working with the Health Informatics group to help GISAID, the largest repository of COVID-19 virus genomic information, design interoperable standardised data collection approaches.

The team used their specialist knowledge in genomes and cloud computing to then develop several tools which have informed the diagnostics, monitoring and tracking of the virus. More about these tools can be found in the Transformational Bioinformatics group section.

Understanding the outbreak's impact on our health services

We have been active in the development of data analysis methodologies and tools for understanding the outbreak, working with most health departments around Australia and the Commonwealth Department of Health.

The most visible part of our response has been the COVID-19 dashboard which we continue to maintain and is used widely by state and federal health and related agencies. The dashboard contains three views: data on the status of the outbreak in Australia, a worldwide view and an advanced analytics view of the data.

We also worked with several state health agencies to support their work in developing models of the impact of COVID-19 on their health services. We worked closely with Queensland Health on several versions of a Queensland Health forecasting model, and we're now working with them on a number of models to support surveillance, monitoring, disease forecasting and decision making as restrictions are eased and efforts are being made to return to normal. We also worked with New South Wales Health to provide expert advice on their forecasting models, and with SA Health to develop syndromic surveillance algorithms for early detection of future outbreaks and other pandemics.

We worked with experts from CSIRO's Data61 and other universities in some of these projects. Further information can be found in the Health System Analytics and Health Informatics group sections.

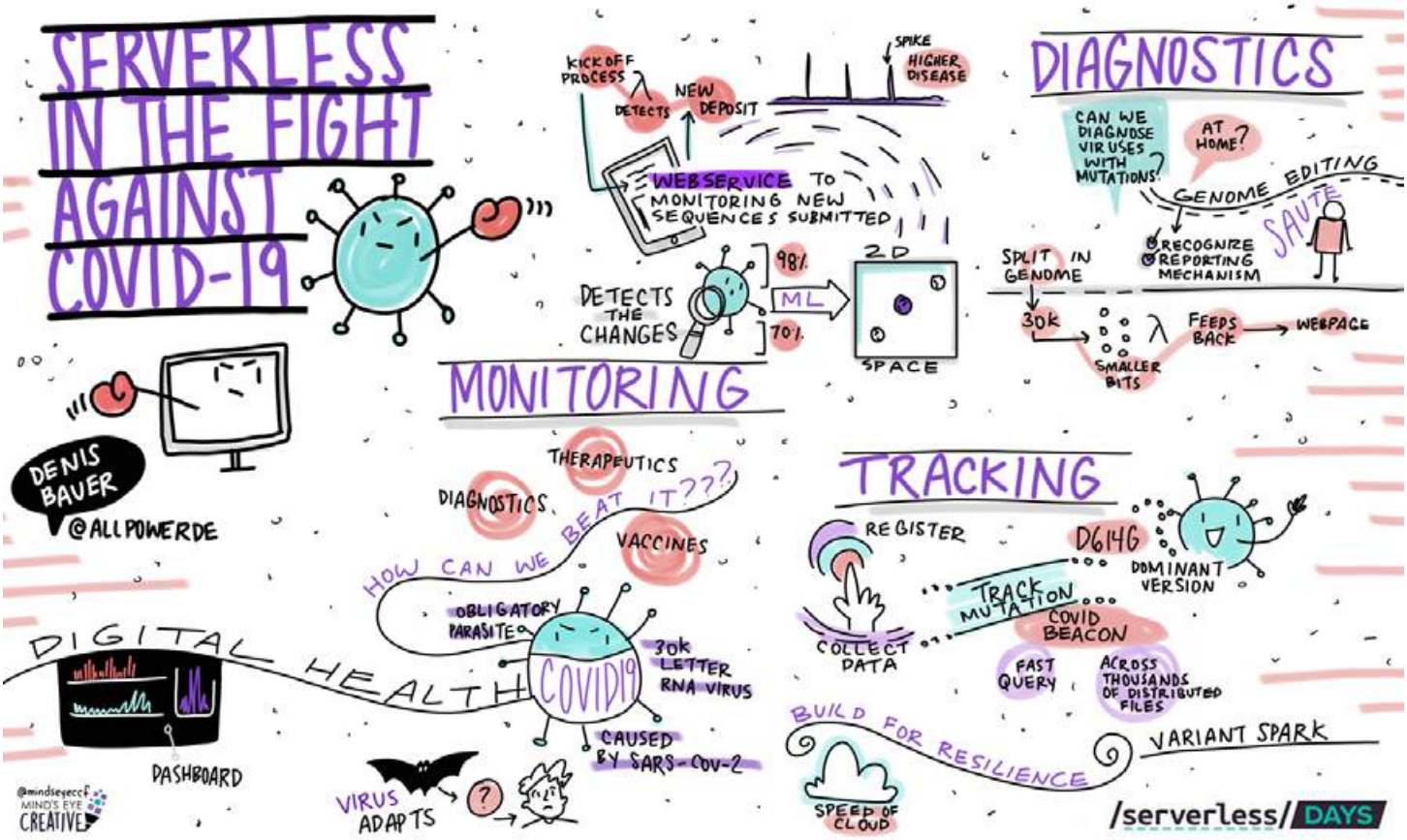


Image: Twitter user @MindsEyeCCF.

The move to virtual care – and other business continuity support

Our expertise in virtual care across mobile health, telehealth and aged care services were of considerable interest – with several service providers getting in touch with our scientists to accelerate potential projects.

The project we accelerated most was our trial of mobile health for women with gestational diabetes. This South Brisbane-wide trial finally got underway in June with the Mater Mother's Hospital, followed by Queensland Health Hospitals shortly thereafter. Other hospitals in Queensland and around Australia have requested to become part of the trial. The aim is to keep women away from hospitals and manage them remotely from their own home, especially during the current pandemic.

Our ongoing trials in aged care were impacted by the national pandemic restrictions, with the halting of recruitment to ensure the safety of CSIRO staff and potential trial participants. However, for participants where the Smarter Safer Homes platform had already been installed the trial continued, and we look forward to capturing the benefits of this technology.

We developed a COVID-19 dashboard to support the pandemic response.

Another project that came in a timely manner was our Case-Based Learning project with the University of Queensland Medical School. This project introduced a digital, EMR-like platform for the delivery of clinical cases to students, replacing the traditional document-based approach. The first 19 cases were made available to over 500 students in mid-April, allowing them to undertake this part of their education from home.

Further information on these projects can be found in the Health Services and Health Informatics group sections.

NHMRC and MRFF grants

Scientists at the Australian e-Health Research Centre are Chief and Associate Investigators on many grants from Australia's foremost medical research grant bodies, such as the National Health and Medical Research Council and the Medical Research Future Fund.

Updates on these projects are given in the group sections to follow, but here we give a short description of the aim of each of these projects.

Medical Research Future Fund (MRFF)

MRFF Future Frontier Stage 1: OUTBREAK: A One Health Approach to AMR

Years funded: 2019-2020

Chief Investigators: Dr Branwen Morgan, University of Technology, Sydney; Dr Paul De Barro, CSIRO Health and Biosecurity

AEHRC Investigators: Dr David Hansen, Dr Denis Bauer

OUTBREAK is a world-first surveillance system designed to combat the growing threat of antimicrobial resistance in Australia and across the world. Powered by artificial intelligence, OUTBREAK will use new sensor technologies and huge data sets to track, trace and tackle antibiotic-resistant infections, helping us to save lives.

MRFF Clinical Trials Activity 2019 Rare Cancers, Rare Diseases and Unmet Need: Ataxia-telangiectasia: treating mitochondrial dysfunction with a novel form of anaplerosis

Years funded: 2020-2023

Chief Investigator: Professor David Coman, University of Queensland

AEHRC Investigators: Dr Jason Dowling

There is no effective therapy for ataxia-telangiectasia and life expectancy is approximately 25 years. This trial involves a new treatment for the correction of mitochondrial dysfunction and cell death in respiratory epithelial cells associated with the disease, and endpoints include non-invasive monitoring of lung disease status (through MRI).

MRFF Emerging Priorities and Consumer Drive Research (Ovarian Cancer): A new radio-imaging agent to guide targeted therapy for epithelial ovarian cancer

Years funded: 2020-2024

Chief Investigator: Professor Paul Thomas, University of Queensland/Royal Brisbane Hospital

AEHRC Investigators: Dr Simon Puttick, Professor Stephen Rose

While epithelial ovarian cancer (EOC) is generally responsive to first-line treatments, most patients will eventually progress to increasingly treatment-refractory disease with narrowing options for control and symptom management. We have developed a novel antibody theranostic for EOC called 10D7 that is suitable for human use. To validate 10D7 we will perform a first-in-human study in 15 patients with histology-confirmed advanced EOC.

National Health and Medical Research Council (NHMRC)

NHMRC: Nanomedicine strategies for early detection and treatment of brain metastases

Years funded: 2019-2021

Chief Investigator: Professor Sunil Lakhani, University of Queensland

AEHRC Investigators: Dr Simon Puttick, Professor Stephen Rose

The development of brain metastases is a serious complication of cancer associated with very high morbidity and virtually 100% mortality. This project will exploit brain tissue-associated adaptations of metastatic cancer cells - induction of the neuregulin receptor HER3, and its oncogenic dimerization partner HER2 - as molecular targets for theranostic nanoparticles (TNPs).

NHMRC: Developing insight into the molecular origins of familial and sporadic frontotemporal dementia and amyotrophic lateral sclerosis

Years funded: 2016-2020

Chief Investigator: Professor Ian Blair, Murdoch Children's Research Institute

AEHRC Investigators: Dr Denis Bauer

There is strong evidence that frontotemporal dementia (FTD) and amyotrophic lateral sclerosis (ALS) represent a spectrum of neurodegenerative disease with common origins. A combined study of FTD/ALS patient cohorts will provide greater power to identify these shared molecular origins. We aim to discover gene variants that cause, predispose or modify onset and progression of inherited and sporadic FTD/ALS, and validate and study our discoveries in new cell and animal models of these disorders.

NHMRC Australian Genomics Health Alliance

Years funded: 2016-2021

Chief Investigator: Professor Katherine North, Murdoch Children's Research Institute

AEHRC Investigators: Dr David Hansen, Dr Denis Bauer, Dr Alejandro Metke

The Australian Genomics Health Alliance (Australian Genomics) was launched in 2016 to address the challenges and to build the evidence to inform the integration of genomic medicine into mainstream healthcare.

NHMRC Dementia Research ADNET

Years funded: 2018-2023

Chief Investigator: Professor Chris Rowe

AEHRC Investigators: Dr Jurgen Fripp, Dr Vincent Dore, Dr Pierrick Bourgeat, Dr Parnesh Raniga, Dr James Doecke

The project (The Australian Dementia Network, ADNeT) seeks to continue and develop one of the worlds largest longitudinal studies into Alzheimer's disease (AIBL). By recruiting a large population based cohort of participants, the study will provide a registry for worldwide clinical trials, and an Australian network of leading clinicians to research the progression of the disease.

NHMRC Development Grant: MR hip intervention and planning system to enhance clinical and surgical outcomes

Years funded: 2018-2021

Chief Investigator: Professor Stuart Crozier

AEHRC Investigators: Dr Jurgen Fripp, Dr Ying Xia, Dr Jason Dowling

Degenerative hip disorders and osteoarthritis are a major cause of pain and disability. In this project, we are developing software tools to assist patient specific clinical interventions and surgical planning for degenerative hip diseases without ionising CT scans. Our MR Hip Intervention and Planning System (mrHIPS) will be the first tool to simultaneously develop 3D hip models of joint cartilage, bone and dynamic motion to provide a standardised and repeatable method to visualise, assess, monitor and plan treatments.

NHMRC Dementia Grant: Prospective imaging study of ageing: genes, brain and behaviour

Years funded: 2016-2021

Chief Investigator: Professor Michael Breakspear

AEHRC Investigators: Dr Jurgen Fripp, Dr Parnesh Raniga, Dr Ying Xia

The Prospective Imaging Study of Ageing: Genes, Brain and Behaviour will study the interplay between genetic, epigenetic and environmental factors for dementia, and also aims to identify risk factors that could be modified through intervention, such as lifestyle choices.

NHMRC Centre for Research Excellence in Digital Health

Years funded: 2018-2022

Chief Investigator: Professor Enrico Coiera, Macquarie University

AEHRC Investigators: Dr David Hansen

The Centre for Research Excellence (CRE) in Digital Health is a national research centre which brings together the major Australian centres of health informatics research. The CRE delivers an integrated research program to address critical evidence gaps that limit our national capacity to exploit digital technologies in healthcare.

NHMRC Centre for Research Excellence in Cerebral Palsy

Years funded: 2017-2022

Chief Investigator: Professor Ros Boyd, University of Queensland

AEHRC Investigators: Dr Dana Bradford

This Centre for Research Excellence (CRE) will improve the health outcomes of all infants/children with Cerebral Palsy (CP) by earlier detection and determining the best interventions to guide clinical practice. The main research objective is to improve early detection and develop and test new interventions to improve physical, cognitive, psychological and health outcomes in an Australasian CP clinical trials network.

NHMRC Dementia Research Fellowship: Early detection of Alzheimer's disease using ocular biomarkers

Years funded: 2016-2021

Chief Investigator: Dr Shaun Frost, the Australian e-Health Research Centre

There is a clear need for a non-invasive, simple and cost-effective test to detect Alzheimer's disease early, before the irreversible damage that precedes diagnosis. This fellowship was awarded to support the development of ocular imaging tests for early detection and monitoring of Alzheimer's pathology in the eye, which is more accessible for imaging than the brain.

NHMRC Project 2018: Novel Integration of New prostate radiation schedules with adJuvant Androgen deprivation (NINJA)

Years funded: 2019-2022 (Cancer Australia)

Chief Investigator: Professor Jarad Martin, University of Newcastle

AEHRC Investigators: Dr Jason Dowling

This national trial compares two emerging and practice-changing schedules of radiotherapy for localised prostate cancer that leverage state-of-the-art technology developments, including MRI-only planning.

NHMRC Project Grant: Elucidating the biomarker sequence of the natural history of progression of Alzheimer's disease

Years funded: 2019-2021

AEHRC Investigators/Chief Investigator A: Dr Samantha Burnham

The pathological processes and clinical/cognitive decline associated with Alzheimer's disease occur gradually, over decades, leading to the onset of dementia. Imaging and chemical biomarkers represent in vivo indicators of key features characterising Alzheimer's disease. It is paramount to understand the sequential ordering and progression of these various markers to effectively understand disease staging.

NHMRC Project Grant: Prediction of childhood brain outcomes in infants born preterm using neonatal MRI and concurrent clinical biomarkers

Years funded: 2019-2024

Chief Investigator: Ros Boyd

AEHRC Investigators: Dr Dana Bradford

The Predict-CP study will investigate the influence of brain structure, body composition, dietary intake, oropharyngeal swallowing, habitual physical activity, musculoskeletal development, and muscle performance on motor attainment, cognition, executive function, communication, participation, quality of life and related health resource use costs. The Predict-CP cohort provides further follow-up at 8-10 years of two overlapping preschool-age cohorts examined from 2-5 years.

NHMRC Boosting Dementia Research Grants: Holistic Approach in Primary care for Preventing Memory Impairment and Dementia (HAPPI MIND)

Years funded: 2019-2024

Chief Investigator: Dr Johnson George, Monash University, Melbourne

AEHRC Investigators: Dr Rajiv Jayasena, Dr Marlien Varnfield

To evaluate the efficacy and cost-effectiveness of the Holistic Approach in primary care for Preventing Memory Impairment and Dementia (HAPPI MIND) program in reducing the risk of dementia among middle-aged people attending Australian general practices.

NHMRC MRFF ICTC: The AUstralian-multidomain Approach to Reduce dementia Risk by prOtecting brain health With lifestyle intervention (AU-ARROW) study

Years funded: 2020-2024

Chief Investigator: Professor Ralph Martins, Macquarie University

AEHRC Investigators/Chief Investigator G: Dr Samantha Burnham

One of the greatest challenges faced by older Australians is to identify and implement strategies to optimise cognitive health and wellbeing, thereby prolonging their productivity and quality of life. The AUstralian-multidomain Approach to Reduce dementia Risk by prOtecting brain health With lifestyle intervention (AU-ARROW) study is a strategically innovative and an important proposal to validate the efficacy of a multidomain treatment plan that may benefit cognitive and brain health in Australia.

NHMRC Project Grant: Genetic and lifestyle susceptibility and resilience factors affecting rates of change in preclinical Alzheimer's disease

Years funded: 2019-2021

Chief Investigator A: Associate Professor Simon Laws, Edith Cowen University

AEHRC Investigators/Chief Investigator E: Dr Samantha Burnham

The overarching aim of this study is to combine genome wide genetic/epigenetic data with lifestyle factors to gain a thorough understanding of how they interact to impact rates of change. This will be achieved through the leverage of data from AIBL, a high quality and established longitudinal cohort and validation both nationally (Prospective Imaging Study of Ageing (PISA)) and internationally (Alzheimer's Disease Neuroimaging Initiative (ADNI), Lothian Birth Cohort (LBC) and pharmaceutical cohorts). We propose to undertake an integrated approach of combining genetic, epigenetic and lifestyle patterns in a large longitudinal study of ageing with respect to rates of change.

NHMRC/JPND Project Grant: Early Detection of Alzheimer's Disease Subtypes (E-DADS)

Years funded: 2020-2022

AEHRC Investigators/Chief Investigator A for NHMRC: Dr Samantha Burnham

Collaboration Lead for JPND: Professor Daniel C Alexander, UCL

E-DADS aims to untangle the heterogeneity of Alzheimer's disease (AD) by defining data-driven subtypes of the clinical manifestation of AD based on brain imaging, cognitive markers and fluid biomarkers that are robustly identifiable from predictive risk factors (genetics, co-morbidities, physiological and lifestyle factors) years before disease onset. To achieve this we develop a novel multi-view learning strategies that relates end-stage disease manifestations observable in clinical cohorts to features of early-stage or at-risk individuals in preclinical cohorts and the general pre-affected population from population or aging studies.

NHMRC Grant - GAME: Harnessing neuroplasticity to improve motor performance in infants with cerebral palsy

Years funded: 2019-2021

Chief Investigator: Iona Novak, Nadia Badawi, Cathy Morgan, Roslyn Boyd

AEHRC Investigators: Dr Dana Bradford

This new pragmatic, single blind randomised controlled trial (RCT) in 300 infants with cerebral palsy or at high risk of cerebral palsy aims to evaluate the effects of "GAME" (Goals Activity Motor Enrichment, an early training intervention) versus traditional passive early intervention on gross and fine motor skills at two years of age. We will also evaluate the secondary outcomes of neuroplasticity on MRI, cognitive skills and quality of life.

NHMRC Project Grant: ADIron

Years funded: 2015-2020

Chief Investigator: Professor Ashley Bush

AEHRC Investigators: Dr Jurgen Fripp, Dr Amir Fazlollahi

The AD-iron study aims at developing new imaging tests that assess levels of iron in the brain, which have been found to indicate the rate of deterioration caused by Alzheimer's disease.

NHMRC Project Grant: Deferiprone to Delay Dementia (The 3D Study)

Years funded: 2017-2021

Chief Investigator: Professor Ashley Bush

AEHRC Investigators: Dr Pierrick Bourgeat, Dr Amir Fazlollahi

New research has found that iron build-up in the brain might contribute to Alzheimer's disease. A Phase II trial of the anti-iron drug Deferiprone in a cohort of Alzheimer's patients is underway to test whether conservatively lowering brain iron slows or stops deterioration in the disease.

Australian Research Council

ARC Grant: Personalised learning for per-pixel prediction tasks in image analysis

Years funded: 2020-2022

Chief Investigator: Luping Zhou, University of Sydney

AEHRC Investigators: Dr Jurgen Fripp, Dr Pierrick Bourgeat

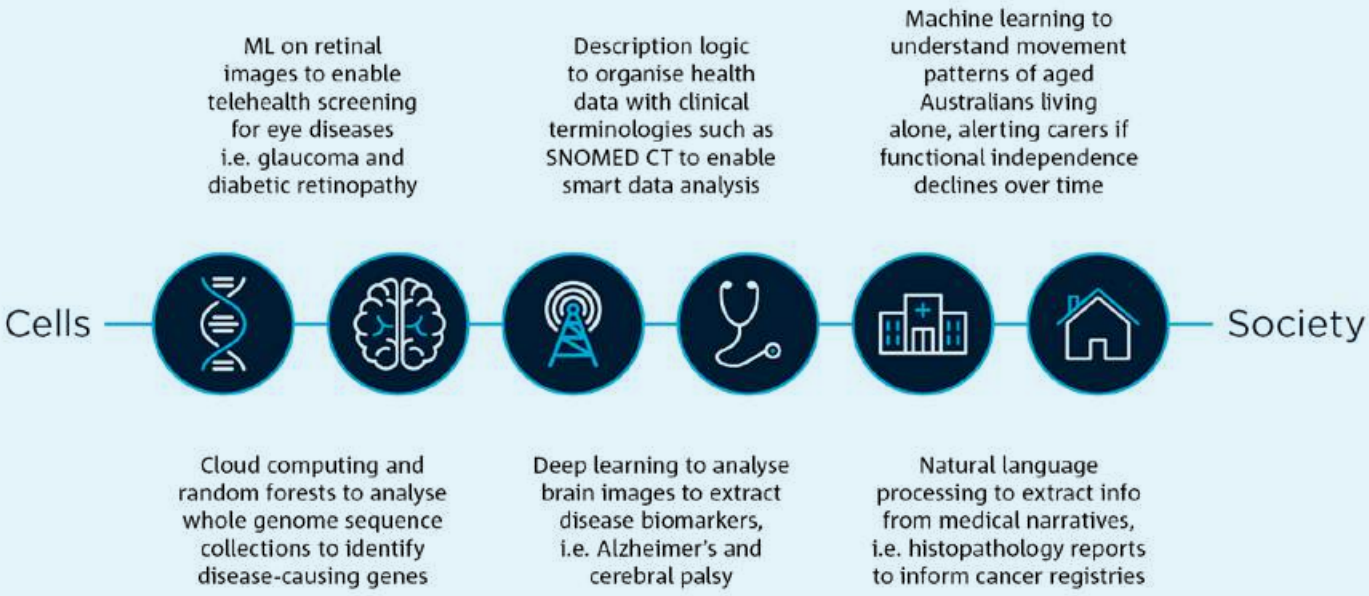
This project proposes a new paradigm of "personalised learning" for image analysis. It is argued that rather than learning a unified prediction model, each sample (including both the training and the test samples) is allowed to have a specific model that caters for its own characteristics. Catering for both the commonality and the particularity of samples, the proposed new paradigm and learning techniques are expected to help significantly advance the state-of-the-art methods for per-pixel prediction and provide better solutions tailored to individual samples.

Artificial intelligence in healthcare at AEHRC

Artificial intelligence (AI) and machine learning (ML) are technologies our scientists use widely in our digital health technologies. Recent advances in cloud computing along with increased data collection have resulted in increasing interest in and use of AI and ML technologies across our society, including in health.

The AEHRC contributes to a number of AI and ML initiatives, including CSIRO's ML/AI Future Science Platform and the Macquarie University-led Australian AI Alliance in Healthcare. Staff across the AEHRC contributed to many projects in these areas, and these are mentioned throughout this annual report.

To highlight our work in AI and ML, we recently released a report titled Exemplars of AI in Healthcare at AEHRC. Highlights are below, and you can read the full report at aehrc.com/ai.



From genomic engineering to independent living, the Australian e-Health Research Centre is using artificial intelligence techniques and machine learning approaches to overcome the challenges facing the healthcare system and improve health service delivery to Australians.

Examplars of AI in Healthcare at AEHRC

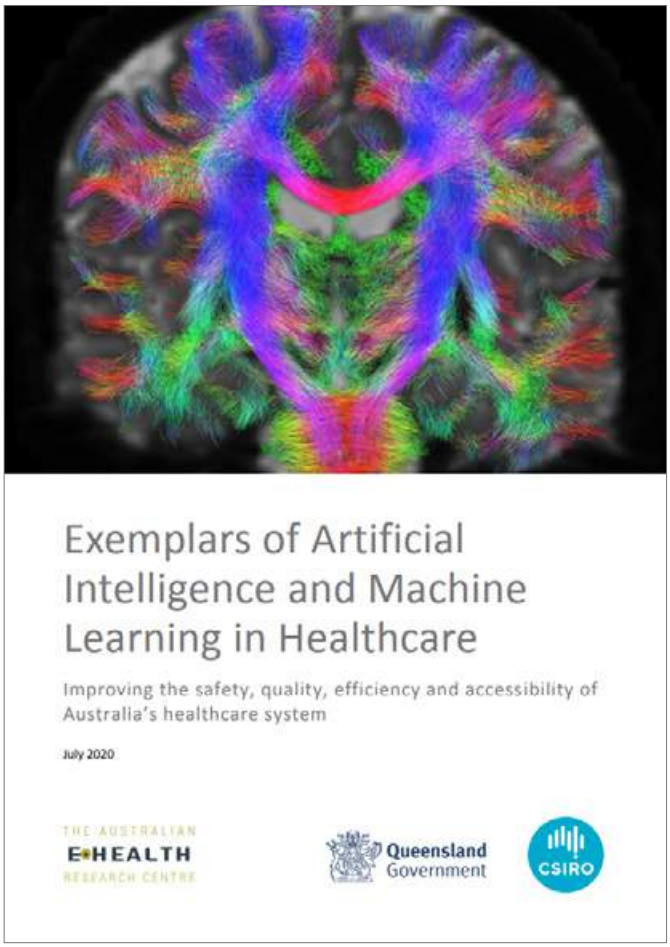
Our 100+ scientists and engineers collaborate closely with government and industry to tackle the key challenges of 21st century healthcare, and most of our solutions involve the skilled application of AI and ML techniques. AI depends on data, and the quality of the data used to train AI models or used in AI-based analysis directly affects the quality of downstream tasks.

In health, AI techniques are often described in these categories:

- Knowledge representation and reasoning: how we represent or classify information in a way that enables us to infer (new) knowledge.
- Imaging and vision: analysing images or videos for insights into the cause or impact of medical conditions.
- Human language understanding: extracting meaning from, searching, summarising and classifying natural communication.
- Predictive analytics and data-driven intelligence: extracting insights from existing, often large, datasets.

Just a few exemplars of our AI and ML used in healthcare:

- Improving prostate radiation therapy: We developed AI-based software to support prostate cancer radiation treatment planning.
- Reasoning on medical knowledge: We used AI to develop a Snorocket Description Logic classifier that can be used on ontologies such as SNOMED CT to 'reason' about medical knowledge.
- Supporting ageing in place: We used AI to develop a low-cost, non-invasive sensor, monitoring and support system to support older people living in individual homes or supported-living communities.
- Making genomic research faster: We developed VariantSpark, a new random forest algorithm, whose speed and higher sensitivity opens up the use of advanced, efficient ML algorithms on high dimensional genomic data.
- Understanding virus evolution: We used ML-based technology to make sense of a pathogen's evolutionary drift, by visualising the genomic fingerprint unique to virus isolates sequenced around the world. In 2020 this was used to analyse the virus that causes COVID-19.



Our new AI report shows how our AI techniques are powering digital health: from understanding whole genome sequences to enabling clinical decision support, determining patient risk prediction, understanding older people's functioning wellbeing and more.

CSIRO Future Science Platforms

CSIRO's Future Science Platforms (FSPs) are an investment in science that underpin innovation and have the potential to help reinvent and create new industries for Australia. FSPs combine science from across the organisation to grow the capability of a new generation of researchers and allow Australia to attract the best students and experts to work with us on future science.

The AEHRC is contributing to several Future Science Platforms, detailed below, with projects described throughout this Annual Report.

Precision Health FSP

Australia's current healthcare system is focused on treating illnesses, but to keep up with our ageing population and the rise of chronic conditions like obesity the focus needs to switch to keeping healthy people healthy. Through engagement with the community to understand their expectations and attitudes to a more tailored healthcare paradigm, and building on programs and developments already underway in the medical field, the Precision Health FSP will focus on creating an integrated platform that can be used to proactively manage a person's health throughout the course of their life through highly tailored food, nutrition and lifestyle interventions.

We are contributing to the Precision Health FSP by developing analytics technology able to predict disease risk from genomic information. This will help identify at-risk groups and start interventions such as improving lifestyle choices. We are also investigating approaches for integrating a patient's genomic data with clinical information. This allows a patient's current health status to be assessed in light of genomic risk and resilience factors and allows a personalised view of outcome and progression.

Probing Biosystems FSP

The Probing Biosystems FSP aims to usher in a revolution in healthcare through devices and systems to obtain real-time information from living organisms about their health and wellbeing. This will lead to the ability to provide health and medical interventions that are timely, customised and highly specific. Innovative autonomous sensing technologies also strengthen future biosecurity control for the nation.

We are leading the development of blood-based neural biomarkers that allow better understanding of brain injury and potential prediction of patient outcomes. Molecules released by neural cells, such as cell free DNA or exosomes, can be measured in peripheral blood samples. Together with CSIRO Nutrition and Health's Molecular Diagnostics Group, we are developing assays to identify DNA methylation patterns indicative of brain injury in neonates and adults following traumatic brain injury. This team is also collaborating with the Australian Institute for Bioengineering and Nanotechnology at The University of Queensland to examine the propensity of neural exosomes to have diagnostic application in the early detection of neural injury.

Machine Learning and Artificial Intelligence (ML/AI) FSP

The ML/AI FSP aims to develop capacity and platforms in key areas of artificial intelligence and machine learning. The FSP positions CSIRO at the forefront of the advancement in AI so we can create new industries and support the transition of the Australian economy. Working across all CSIRO business units, AI-driven solutions will target areas including food security and quality, health and wellbeing, sustainable energy and resources, resilient and valuable environments, and Australian and regional security.

We are contributing to three different FSP activities. In the 'Object Detection' FSP activity, we plan to combine image processing and natural language processing expertise to better search, classify and exploit mixed image/text health data. In the 'Decisions' activity, we aim to develop new 'human-on-the-loop' machine learning solutions for clinical decision support – ML solutions that give the clinician much more control over the ML process. In the 'Bioprediction' activity, we are using our VariantSpark tools to predict genomic traits in both humans and plants. As we continue to expand our AI program, other projects will benefit from working with the AIML FSP.

Space Technology FSP

The Space Technology FSP will identify and develop the science to leapfrog traditional technologies and find new areas for Australian industry to work in. It will initially focus on advanced technologies for Earth observation, and then address challenges such as space object tracking, resource utilisation in space, and developing manufacturing and life support systems for missions to the Moon and Mars.

We are working with the Space Technology FSP to assist with the development of capabilities in space medicine and space life sciences research which align with the Australian Space Agency's Moon to Mars initiative. We also support efforts to develop analogue environments for terrestrial validation of these technologies, and we have representation on the International Space Exploration Co-ordination Group.

Synthetic Biology FSP

The Synthetic Biology Future Science Platform is positioning Australia to play a role in one of the fastest growing areas of modern science so that we can understand global developments and contribute to advances in areas including manufacturing, industrial biotechnology, environmental remediation, biosecurity, agriculture, and healthcare research.

We are developing machine learning-based analytics tools for genome editing, which can be applied to a broad spectrum of synthetic biology applications. Specifically, we work with the Gene Therapy unit at the Children's Medical Research Institute to develop novel approaches for "genetic surgery", which one day will be able to treat a life-threatening hereditary liver disease. Here, we help design the delivery vector to move the genome editing machinery to the right tissue, as well as design the programmable element of the machinery to find and precisely correct the genetic misspelling. We also work with the FSP, other CSIRO business units and Macquarie University to investigate the application of genome engineering for biosecurity approaches to keep Australia's unique biodiversity safe, and protect its people and agricultural industry.

The Health Informatics group

Group Leader: Dr Michael Lawley

Australia's healthcare system faces many challenges. One significant challenge is the increasing demand for real-time clinical information to be shared between individual health practitioners, healthcare provider organisations and state and territory health departments.

Our Health Informatics researchers develop and apply innovative tools and techniques for evidence-based solutions and strategies to support improved health outcomes. Our goal is to improve the quality of, and unleash the value in, health data, including electronic health records and administrative data sets, to improve patient outcomes and health system performance and productivity.

We apply informatics, machine learning, natural language processing, and formal logic to problems involving decision support, systems modelling and integration, and reporting and analytics.

Health Informatics' science and impact highlights for 2019/20

- We continue to partner with the Australian Digital Health Agency in the National Clinical Terminology Service (NCTS). There are over 1300 registered users of the NCTS and over 70 companies and organisations have sublicenced our terminology server, Ontoserver, for implementation of state-of-the-art support for clinical terminology in their e-health products.
- The HiGHmed consortium consisting of eight German hospitals and various university partners has taken multiple Ontoserver licences to support their work in developing novel, interoperable, medical informatics solutions.
- Use of Ontoserver is one of the core elements of Defence's JP2060 Phase 4 procurement requirements, which looks to deliver their next generation EMR platform.
- Improvements to the Medtex (medical text analytics) tool is continuing to be integrated and deployed at Queensland Health to support the clinical coding of pathology and death certificates for cancer notifications reporting. Medtex processes and analyses live pathology feeds from public and private pathology laboratories across Queensland. A death certificate cause-of-death classification service is also deployed within the Medtex platform to supplement the cancer notifications reporting from pathology reports.

- We contributed to the OUTBREAK Medical Research Future Fund initiative to track, trace and tackle antimicrobial resistance (AMR). An AMR decision support prototype, leveraging the Medtex tool and in combination with interactive visual dashboard analytics, was deployed to demonstrate the tracking and tracing of person- and location-specific AMR across Australia. In addition, the prototype supports the microbiology test result review workflow in emergency departments to ensure correct antibiotics have been prescribed.
- Our COVID-19 dashboard, leveraging the AI and platform technology used in the OUTBREAK project, was developed to integrate, analyse and share national and international COVID-19 information for the health system during the crisis. It was used nationally in PM&C briefings, and by Australia's Chief Scientists and federal/state government agencies including the Australian Defence Force and Queensland Police to help respond to the pandemic.
- Our Data Interoperability team is contributing to the Australian, Queensland and Melbourne Genomics Health Alliances to capture accurate clinical phenotypes, vital to ensuring Australia will get full value from investments in genomics medicine. The standards developed as part of this work are in being published internationally through the Global Alliance for Genomics and Health.
- We are leading a national project for the Commonwealth Department of Health to develop a set of foundational standards for GP data. The GP Data Quality Foundations project is successfully collaborating with GP vendors and peak bodies to develop these standards.
- We continue to contribute to the National Health and Medical Research Council (NHMRC) Centre for Research Excellence in Digital Health in partnership with Macquarie University's Australian Institute for Health Innovation and the University of Melbourne.
- We have partnered with the University of Queensland to introduce a Health Informatics on FHIR course for third-year IT students. The course was led by CSIRO Distinguished Visiting Fellow Professor Mark Braunstein.

Clinical Terminology team

Team Leader: Kylynn Loi

The Clinical Terminology team is dedicated to improving the use and implementation of standard terminologies such as SNOMED CT to improve health data quality and data interoperability. The team does this by working with national and international groups to develop terminology content, develop and apply data analytic techniques to coded data, and provide advice around implementation and use of terminology in Australia.

Health Data and FHIR team

Team Leader: Jim Steel

The Health Data and FHIR team is a team of engineers with expertise in the use of FHIR to build and integrate digital health systems. We develop a range of tools aimed at accelerating and promoting the use of FHIR and related standards to build and integrate digital solutions in the health sector.

Health Data Engineering team

Team Leader: Derek Ireland

Our world-class Health Data Engineering team is a dedicated team of software engineers who work with scientists across the AEHRC in delivering solutions to our customers and partners.

Health Data Interoperability team

Team Leader: Dr Alejandro Metke

Data is captured about patients in a number of different formats and electronic repositories using many different terminologies. Our technologies are targeted at understanding the information in data, whether the data is captured in an electronic health record, coded in a clinical database, captured from sensors, described in medical free text reports or even captured using imaging technology.

Our team also works in genomics, specifically representing patient phenotype data using standards and terminologies. Our involvement in several genomics alliances in Australia and internationally has helped us position ourselves as leaders in this field.

Health Text Analytics team

Team Leader: Dr Anthony Nguyen

The Health Text Analytics team is focused on extracting value from structured and unstructured narrative electronic health data to deliver innovative technology that improves data quality and patient outcomes as well as health system performance and productivity. The team does this by developing and applying machine learning, natural language processing, information retrieval and clinical terminologies to deliver and support meaningful data interoperability and analysis for decision support, analytics, modelling and reporting.

Clinical Terminology Product Manager

Kate Ebrill

Our Product Manager is dedicated to the development of the strategic direction and roadmap for the clinical terminology and data interoperability platform technologies. This includes ensuring programme delivery, developing strategic partnerships and furthering commercial licensing opportunities nationally and globally.

Health Informatics: platform technologies

Our technologies are enabling interoperability, advanced and effective use of data captured in electronic medical records, through the development of products and services to support the use of clinical terminologies such as SNOMED CT and interoperability standards such as FHIR®.

Our technologies include:

- FHIR native terminology and classification tools: Ontoserver, Snapper, snoMAP, Snorocket, Shrimp
- OpenSource FHIR tools: RedMatch, Pathling
- Natural language processing tools: Medtex

Suite of FHIR native terminology tools

Widespread use of national terminologies by clinical systems provides considerable interoperability benefits and supports meaningful use of patient data for better health outcomes. However, rich and powerful clinical terminologies, such as SNOMED CT, are complex in nature.

This complexity makes implementation difficult and often costly, presenting a challenge to adoption. In order to address this challenge, we are developing new technologies that enable the advanced use of clinical terminologies such as SNOMED CT, LOINC and any FHIR-based CodeSystems.

Ontoserver

Ontoserver is a world-leading clinical terminology server implementing FHIR terminology services and supporting syndication–based content distribution. Read more in Health Informatics: Project Reports or visit ontoserver.csiro.au.

Snapper

Snapper: Author is a web browser-based app for authoring FHIR terminology resources and publishing them to a FHIR terminology server.

Snapper: Map is a web browser-based app that enables authoring maps from legacy terminology to standards-based terminologies. Together, these tools support migration to and use of standard terminologies, and the adoption of the national approach to interoperable digital health information.

snoMAP

snoMAP is a suite of SNOMED CT to ICD10-AM Mapping Products which enables diagnoses recorded using SNOMED CT-AU to be mapped to ICD10-AM codes. We have developed two products:

snoMAP Starter: a simple SNOMED CT-AU diagnosis to ICD-10AM Codes FHIR ConceptMap, to support the use and reuse of SNOMED CT for analytics and research activities.

snoMAP ED: a mapping service for emergency department non-admitted patient reporting purposes, thus supporting the use and re-use of the standard clinical terminology for ED funding activities.
Read more in Health Informatics: Project Updates.

Snorocket

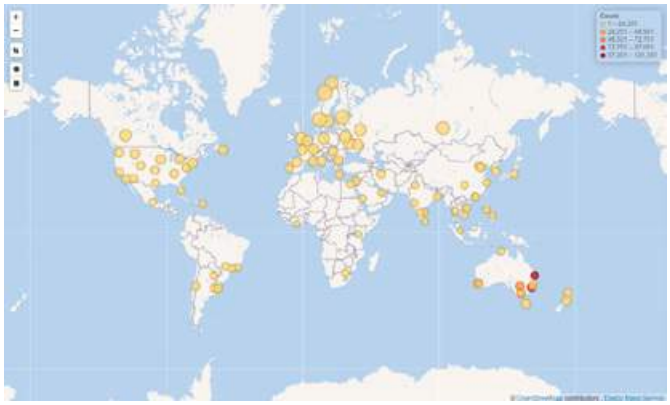
Snorocket is our classifier, which for the first time enabled semi-real-time authoring of very-large-scale clinical ontologies like SNOMED CT. Snorocket is available under an Apache 2.0 open source licence and as a Protégé plugin. It has also been licensed to SNOMED International and the Australian Digital Health Agency for their ongoing maintenance of SNOMED CT. Read more at github.com/aehrc/snorocket.

SHRIMP

SHRIMP is a widely used tool for browsing SNOMED CT, LOINC and other FHIR CodeSystems, powered by Ontoserver.

Supporting users around the world

Our clinical terminology and FHIR® enabled products are in use globally to support the advanced use of SNOMED CT, management of ValueSets and ConceptMaps and syndication of clinical terminologies. SHRIMP and our public testbed is in use worldwide. Ontoserver is also licenced commercially by users in Australia, New Zealand, Switzerland, Germany, England, Wales, with evaluation licences in use across the United States, ASEAN region and South America.



Supporting open source technology

In order to further our data interoperability research, we leverage and extend existing open-source products or develop and open-source new standards-based products. Key technologies we have leveraged include the HAPI FHIR Server and REDCap.

REDCap is one of the most popular tools currently used to capture research data. Two plugins have been developed to improve the quality of the data captured using REDCap:

1. The **FHIR Ontology External Module** is an open-source plugin that can be installed in REDCap and can be used to turn a text field into an autocomplete-style field backed by a FHIR terminology server. This module provides a significant improvement over the capabilities provided by REDCap out of the box, by enabling the use of all the functionality available in the FHIR terminology module including, for example, the definition of value sets, which constrain the search space and improve the quality of the autocomplete results.
2. The **Pedigree Editor External Module** leverages the open-source version of the pedigree drawing tool recently released by Phenotips to provide a mechanism to capture pedigrees electronically in REDCap and represent them in FHIR format. Before the plugin was available it was impossible to capture a diagram electronically and most users would instead upload scanned versions of pedigree drawings.

Read more in Health Informatics: Project Reports and Project Updates.

Redmatch

Redmatch is an open-source, rules-based transformation engine that allows exporting data in REDCap as FHIR resources.

In recent years, clinical trials and studies have increasingly started using electronic systems to capture data required to conduct a range of analysis, such as the effectiveness of a new treatment or its economic value. However, even though these tools allow creating electronic forms easily, they are not designed to capture clinical data, impose few constraints on what should be captured and also have limited data sharing capabilities. One of the most popular tools currently used to capture research data is REDCap, a web application created at Vanderbilt University. Redmatch allows defining rules that describe how the elements in forms should be represented as FHIR resources without having to write any code. This functionality can be used to standardise clinical data captured in different REDCap systems.

Read more in Health Informatics: Project Updates.

Leveraging HAPI FHIR Server

A number of projects across the AEHRC require a FHIR server to act as a repository for storing data. We use an extended version of the open-source HAPI platform for this purpose. These extensions implement support for specific security models for partitioning data (compartments), and advanced terminology support in the FHIR Search API through integration with Ontoserver.

Pathling

Pathling is a new CSIRO-developed open-source analytics server based on the HL7® FHIR® standard, implementing special functionality designed to ease the delivery of analytic-enabled apps and augment tasks related to health data analytics.

Health care is a complex domain, and health care information models reflect this complexity. Linking data with clinical terminology such as SNOMED CT adds a further degree of complexity, often requiring expert knowledge of coding systems and skill in the correct use of them within the analytic context. Generalised tools for data analytics and business intelligence do little to insulate their users from this complexity, as it is often impractical for them to cater for requirements unique to specialist areas such as health care.

Using FHIRPath, Pathling encapsulates a set of functionalities useful for health data analytics application development and workflow into a server implementation that natively understands FHIR on the way in and on the way out. This functionality is designed to service the following use cases:

- Exploratory data analysis – exploration of hypotheses, assessment of assumptions, and selection of appropriate statistical tools and techniques.
- Patient cohort selection – selection and retrieval of patient records based on complex inclusion and exclusion criteria.
- Data preparation – processing and re-shaping data in preparation for use with statistical and machine learning tools.

Leveraging the FHIR Terminology Services API and the ability to call a terminology server, such as Ontoserver, Pathling also allows you to work with the richness and power of SNOMED CT including the SNOMED expression constraint language.

Natural language processing

Even with the increasing adoption of electronic medical records and the move to more formalised structured content, clinical records will always contain sections of narrative or free text information which will contain rich, valuable information which needs to be queried.

Medtex

Medtex is a semantic medical text analysis software that analyses free-text clinical documents for informing clinical decision making.

Medtex works by learning what statements to look for and uses SNOMED CT, the internationally defined set of clinical terms, to unify and reason with the language across information sources. It incorporates domain knowledge to bridge the gap between natural language and the use of clinical terminology semantics for automatic medical text inference and reasoning.

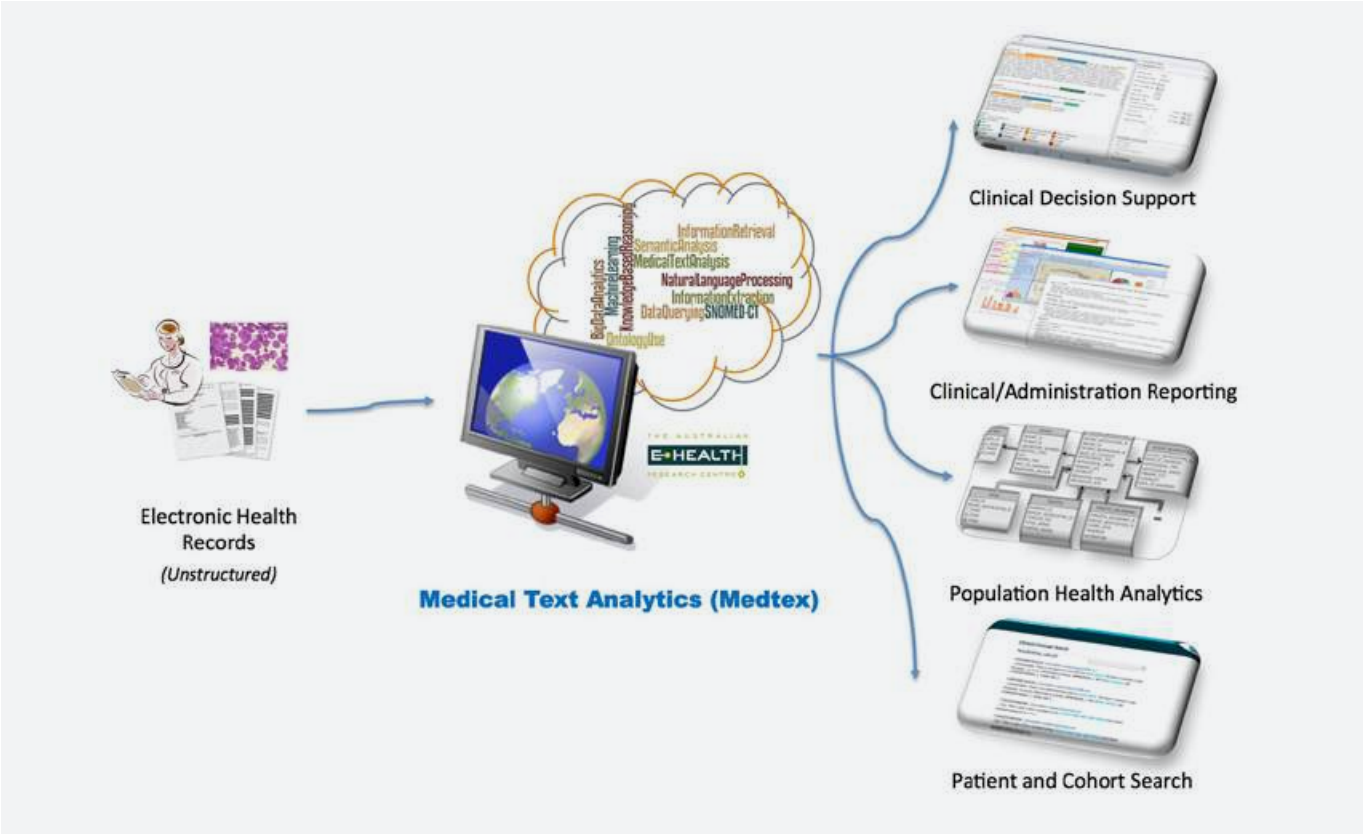
Analysis engines using the Medtex technology have been developed to:

- Standardise the free text by identifying medical concepts, abbreviations and acronyms, shorthand terms, dimensions and relevant legacy codes;
- Relate key medical concepts, terms and codes using contextual information and report substructure; and
- Use formal semantics to reason with the clinical concepts; inferring complex clinical notions relevant to a health application.

Medtex scales to large amounts of unstructured data and has been integrated within a highly distributed computational framework. It turns the medical narrative into structured data that can be easily stored, queried or rendered by most systems for use in their health application. Medtex has been used to deliver solutions to healthcare practitioners from cancer registries, and hospital radiology and emergency medicine departments including:

- The analysis of pathology and radiology reports and death certificates to timely assess the incidence of cancer and the associated mortality rates,
- The analysis of pathology test results and discharge summaries to support pending test result reviews within emergency departments,
- The analysis of medical reports to provide the capability for medical record searching and analytics.

Read more in Health Informatics: Project Reports.



Medtex software processes narrative medical reports and generates structured data to support meaningful data interoperability and analysis for decision support, analytics, modelling and reporting.

National Clinical Terminology Service

Collaborator: Australian Digital Health Agency

We continue to work with the Australian Digital Health Agency to deliver the National Clinical Terminology Service (NCTS). Our Ontoserver is a key component of the solution and is used to deliver this service through a nationally hosted service. Technology providers can also license Ontoserver free of charge for integration into their own health record solutions, with a syndication service keeping the standardised terminology content up to date. This is a pioneering approach to making standard clinical terminology readily available – going well beyond the traditional mechanism of providing files for download along with documentation.

Advantages to this approach include:

- Providing terminology server software ensures consistent interpretation of specifications and that state-of-the-art search algorithms are available to all implementers.
- Local terminology server instances allow for local autonomy, and local code systems and value sets can be supported using the same system supporting standard clinical terminology like SNOMED CT-AU.
- Syndication of content ensures that every terminology server instance can easily remain up to date with monthly SNOMED CT-AU releases without complex and manual update processes.
- Use of the simple and easily adopted HL7 FHIR API not only means there's no lock-in to one proprietary terminology server implementation, but it is both cloud and mobile friendly, and paves the way to broader adoption of what is promising to be a truly revolutionary standard for health IT.

Through 2019/20 the team delivered 14 new versions of Ontoserver and delivered Ontoserver 6, based on the first normative version of FHIR (R4). We have also closely engaged with the FHIR community to clarify, refine and improve details of the Terminology Services subsystem of the HL7 FHIR Specification, and engaged closely with state jurisdictions and the vendor community through a series of meetings and workshops to ensure the resulting service delivers what is needed.

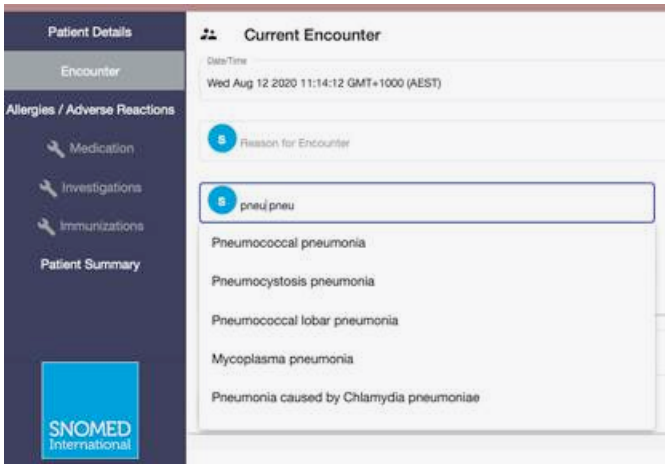
There are over 1300 registered users of the NCTS and 70 Ontoserver sub-licensees through the NCTS, including several health organisations, clinical colleges, research organisations and software vendors.

The NCTS Portal.

User interface for SNOMED CT

Collaborator: SNOMED International

We were contracted by SNOMED International, as part of their SNOMED International Innovation Framework, to create a prototype user interface (UI) to demonstrate different options for using SNOMED CT in a UI. The goal of this UI demonstrator is to promote best practice in user interfaces with regards to the use of SNOMED CT. The UI demonstrator was launched at the SNOMED International Expo in Kuala Lumpur in October 2019. It has since been extensively used to educate both users and vendors of health-related software of what is possible with SNOMED CT and how it can be incorporated properly into a UI. The UI demonstrator uses the FHIR Terminology Services API to connect to either our Ontoserver or Snowstorm, the SNOMED International open source terminology server. This provides opportunity for users to explore the different functionalities of the terminology servers.



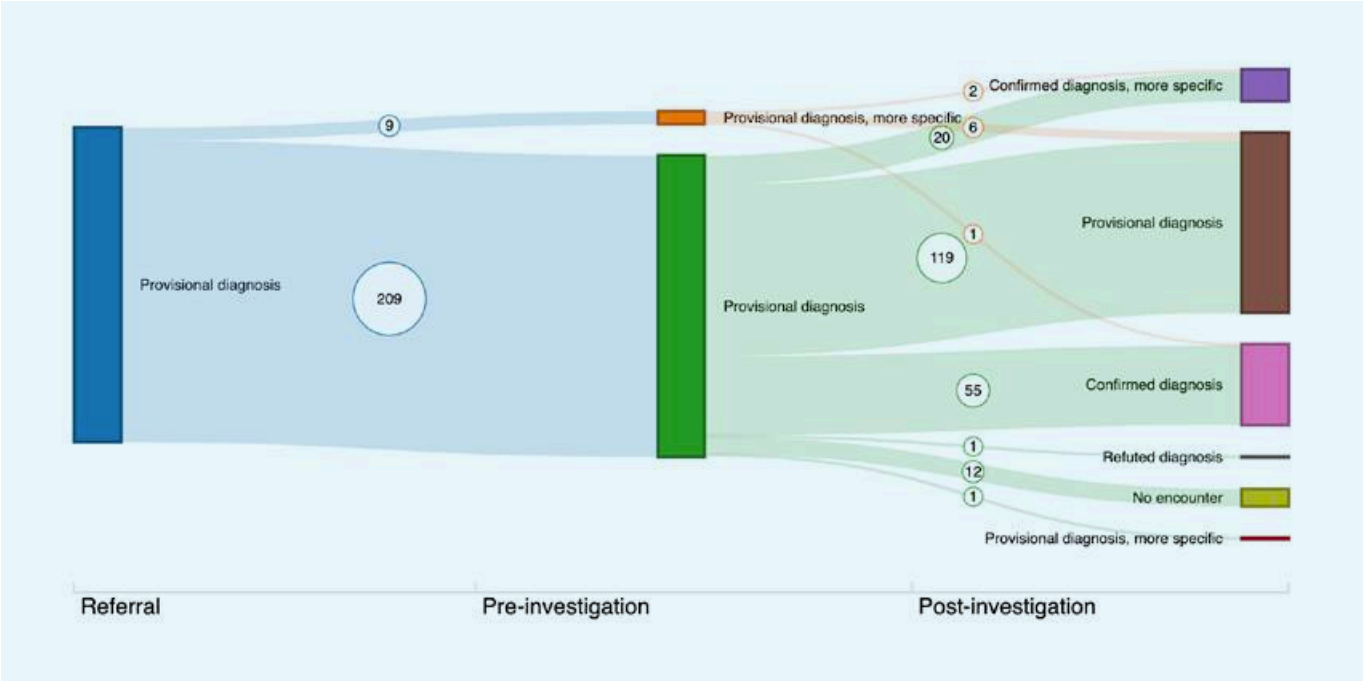
SNOMED International UI Demonstrator.

SNOMED International genomics pilots

Collaborators: SNOMED International and Australian Genomics Health Alliance

One of the current goals of SNOMED International is to support the needs of the global genomics community. As part of their strategy, we were contracted to run two pilot projects with the Australian Genomics Health Alliance to assess the value of SNOMED CT in real implementations.

The first pilot was conducted with the Renal Genetics Flagship, a project that builds upon the KidGen consortium to integrate genomic medicine into care for those with inherited kidney diseases. The main goal of the pilot was to use SNOMED CT in conjunction with a FHIR-based analytics platform to generate insights and help establish an evidence-based evaluation of the effectiveness of a multidisciplinary clinic model implemented by the flagship. The project included coding existing data using SNOMED CT, exporting the REDCap forms into FHIR, loading the data into the FHIR analytics platform and running queries on the platform to generate multiple visualisations of the data.



Sankey diagram created as part of the SNOMED CT genomics pilot with the Australian Genomics Renal Genetics Flagship. The diagram shows how the patients' diagnoses evolve as they are assessed at referral by a multi-disciplinary team, before having access to genomics results and after genomic results are available.

The pilot was successfully completed and the visualisations produced were presented at the National Australian Genomics Conference.

The second pilot was conducted with the Cardiovascular Flagship, whose main goal is enabling genomic testing for patients with genetic heart conditions such as inherited cardiomyopathy, primary arrhythmia and congenital heart disease. The main goal of the pilot was to assess the suitability of SNOMED CT to do deep phenotyping in this clinical area. The project included designing the REDCap forms in consultation with flagship clinicians, development of value sets to be used in the forms, and an analysis of any gaps or issues found in SNOMED CT.

The pilot was successfully completed and concluded that even though SNOMED CT has some content gaps, it does cover the majority of the content required in this clinical area and it is a good choice as an underlying terminology.

Case-based learning on FHIR

Collaborator: The University of Queensland

In 2018 we saw the successful prototyping of a case-based learning tool by final year Information Technology students studying Health Informatics at The University of Queensland (UQ), a joint program with CSIRO. In collaboration with Dr Ben Barry from UQ and Professor Mark Braunstein from Georgia Tech University, we have now built a case-based learning platform for medical students supporting in-class and at-home use. The platform has been built using FHIR, and includes:

- A case-authoring tool, which tutors can use to design case-based learning cases for medical students.
- A case player, which students use to navigate their way through cases by making decisions about how to treat the virtual patients, and to make notes to help their studies.
- A dashboard, which tutors can use to monitor how students are working through cases.

As an extra benefit, translating the static paper-based cases into an interactive form has involved a close examination of decision-making methods in the cases, leading to many updates to the cases and the way they are presented.

The cases also provide excellent opportunities for UQ third-year IT students undertaking the Digital Health on FHIR course to build a SMART on FHIR application that can support clinical decision making in a particular case.

Primary Care Data Quality Foundations

Collaborator: Australian Government Department of Health

In 2018 we were commissioned by the Australian Government Department of Health to undertake a series of projects known as the Primary Care Data Quality Foundations Programme. Phase 1 was delivered in 2018/2019 through collaboration with the clinical profession, software industry, and government agencies. The objectives of Phase 1 were to define foundation data standards in primary care to support better clinical outcomes, enhance the usefulness of information in the practice record, and improve interoperability of health information shared with other health care providers and organisations.

Phase 2 extended the Data Dictionary to include social determinants of health. We continued to co-design with the clinical and software industry to develop data sets and technical specifications to support auto-population and exchange of priority healthcare assessments, with a particular focus on the Aboriginal and Torres Strait Islander Health Check, commonly known as the MBS 715 Health Assessment. Using the FHIR Questionnaire and Structured Data Capture Specifications, health assessment forms more easily integrated within the primary care systems can be developed, reducing duplication of data entry and supporting data reuse.

This project has had impact beyond the specific programme deliverables. This has been the largest community-led, FHIR-based program in Australia. One of its key successes is the consideration of primary data use first, rather than the historical approach of defining the data standards by secondary use requirements, which often leads to difficulties with clinician buy-in and adoption. There has been strong recognition from both the profession and the clinical community on the benefit of common data standards and one clinical language, with industry already planning adoption of these standards. Other countries are now looking to our work and leveraging our outputs for their own common data models.

Active participation in the local and global standards community

Collaborators: SNOMED International and Australian Genomics Health Alliance

The FHIR community has continued to grow, as we partner with industry to host FHIR meetups across the country, in Brisbane, Melbourne and Sydney, with over 60 attendees at each event. Due to COVID-19, these events have now gone virtual. These meetups are helping raise awareness and drive adoption of not only the primary care outputs but the FHIR standard more generally, a key foundation for interoperability in Australia.

We actively participated in the HL7 International Working Group meeting in Sydney in February 2020. Ontoserver as a product was also a key enabler of the Connectathon. We also hosted an inaugural clinician event, with the aim of establishing a group of engaged clinicians to participate and provide clinical leadership into the development of the FHIR specifications. We continue to actively participate as members and co-chairs of HL7 Australia and HL7 International working groups.

We are committed to supporting SNOMED International through the Modelling and Terminology Advisory Groups and working groups, and contribute a number of papers and presentations to their Annual Expo, which demonstrates our globally leading expertise and product capabilities in this domain. The investment is key to ensuring a robust, fit-for-purpose clinical terminology standard to underpin our ongoing data interoperability and advanced analytics.

DevDays, hosted by Firely, is one of the highlights in the annual FHIR calendar. Held twice a year, in Amsterdam in November and in the US in June, this year DevDays transitioned to a virtual event. We were invited to provide the introduction to FHIR Terminology Services and Advanced Analytics using FHIR.

We led a FHIR Masterclass at the annual Health Informatics Conference in July 2019.

Team CSIRO and Healex Systems.

Ontoserver licensing in Germany

Collaborator: HiGHmed

HiGHmed is a consortium of eight university hospitals in Germany, working on novel, interoperable solutions in medical informatics. They aim to make medical patient data accessible for clinical research and education which will, in turn, improve patient care. Building safe data integration centres, the project aims to establish a technology platform enabling clinicians to make data-based and patient-centric decisions.

The HiGHmed consortium chose Ontoserver as the clinical terminology server to support their data management and interoperability requirements. The University Hospital of Cologne has established a central scaled Ontoserver implementation to support the members of the consortium, and four of the university hospitals established their own Ontoserver implementations which can syndicate from the central service. This project was kicked off with a three-day Connectathon in Berlin in October 2019.

We have partnered with Healex Systems, a Cologne-based company which specialises in the digitisation of knowledge, clinical research and information in the health sector, to deliver implementation and support services in Germany. Due to COVID-19, the scheduled onboarding workshops with over 40 participants of the consortium had to rapidly move from face-to-face workshops in Cologne in April 2020 to virtual sessions delivered over a series of web conferences.

Ontoserver proof of concept project: NHS Digital and NHS Wales Informatics Service

Collaborator: UK's National Health Service (NHS)

The proof of concept implementation of Ontoserver in the NHS Digital and NHS Wales Informatics Service continued with a key focus on building community momentum and a business case for NHS Digital to progress to procurement for a national terminology server. Wales actively progressed their proof of concept to deployment stage, developing a clinical information system for recording and sharing problem lists, allergies and alerts using SNOMED CT, with Ontoserver providing highly performant type-ahead search functionality to ensure ease of use for clinicians.

The largest FHIR Terminology Services Connectathon was held in Cardiff, Wales in October 2019. The two day event, hosted by Wales with our support, had over 140 participants representing NHS Digital, Wales, health care delivery organisations, software industry and partner organisations such as NICE, Genomics England and the Professional Records Standard Body.

Tracking, tracing and tackling antimicrobial resistance

Collaborators: University of Technology Sydney, OUTBREAK consortium partners

The Medical Research Future Fund's (MRFF) Frontier Program funded the OUTBREAK initiative to develop high-tech decision support systems using AI and huge amounts of data to track, trace and tackle drug-resistant infections. As part of this initiative, we have worked with Queensland partners including the Queensland Genomics Health Alliance and The Prince Charles Hospital, using our genomics, AI and machine learning expertise to support OUTBREAK's aims.

With The Prince Charles Hospital, we are developing a new tool to support monitoring to track, trace and tackle antimicrobial resistances in the emergency department.

The tool reconciles information from microbiology test results and patient discharge summaries to alert the emergency physician when a change of antibiotic treatment might be needed. From this, de-identified data can be used to create a dashboard of information about bacterial infections and their location, which can give early indications of hotspots of antimicrobial bacterial infection.

With the Queensland Genomics Health Alliance, we have been working on an infectious diseases project to provide seamless integration of information from microbiology laboratory test results for analysis, expediting the response to infectious disease outbreaks in hospitals and providing an early warning system for escalating pathogens and resistance threats.

Though the OUTBREAK initiative is a mammoth undertaking, it's hoped it will help protect Australians from antimicrobial resistant infections, reduce hospital admissions, and reduce related healthcare costs.

AMR dashboard showing aggregated information on bacterial infections and their location, which can give early indications of hotspots of antimicrobial bacterial infection.

CSIRO COVID-19 dashboard

We developed an interactive web-based dashboard to visualise and track reported cases of COVID-19 in Australia and the world. It was primarily developed to share real-time COVID-19 data with federal and state governments, government agencies, and health industry partners to support decisions around Australia's outbreak response.

The dashboard aggregates and analyses global data to identify and forecast trends in the global outbreak, and to identify COVID-19 case hotspots. Updated every 10 minutes, it shows:

- COVID-19 active cases, deaths, recoveries and total cases in Australia by state, including daily summaries
- information about testing and patients in hospitals, ICU and on ventilators
- visualisations of when control measures were introduced in Australia and how they have impacted infection rates
- graphs showing similar trends to Australia that could be used for forecasting cases and deaths
- daily growth factors which looks at new cases each day compared to new cases the previous day
- mobility trends in response to control measures
- a modelled effective disease reproduction number, developed in collaboration with CSIRO's Data61, showing the rate of transmission across each state of the country
- international data by country.

The dashboard's data is sourced from various international and national information sources including the downloadable database from the US Johns Hopkins University Center for Systems and Engineering, national and state government health department press releases, some tweets, and news media reports. Some of the Australian data is manually curated by us before being updated on the dashboard.

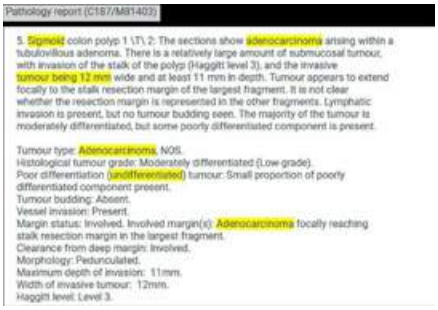
Automating cancer data registries

Collaborator: Cancer Alliance Queensland (CAQ), Queensland Health

Statistics about cancer incidence and mortality continue to remain several years out of date. The extent of manual processing of patient records by cancer registry coders and outdated information collection systems are delaying the delivery of more timely cancer information.

In partnership with Cancer Alliance Queensland (CAQ) within Queensland Health, we use AI technologies to extract information about cancers from a variety of different modalities, including pathology and radiology reports and death certificates, for a variety of reporting purposes such as cancer notifications, cancer staging and synoptic reporting. This is enabling CAQ to build a real-time, virtual cancer register that processes new histopathology reports from public and private pathology laboratories from across Queensland, as well as radiology reports and death certificates as they become available. This processed information supports the clinical coding of cancers to improve data collection capture, enhancing the quality of the data and providing capacity to support key activities, such as cancer monitoring and health service planning and research.

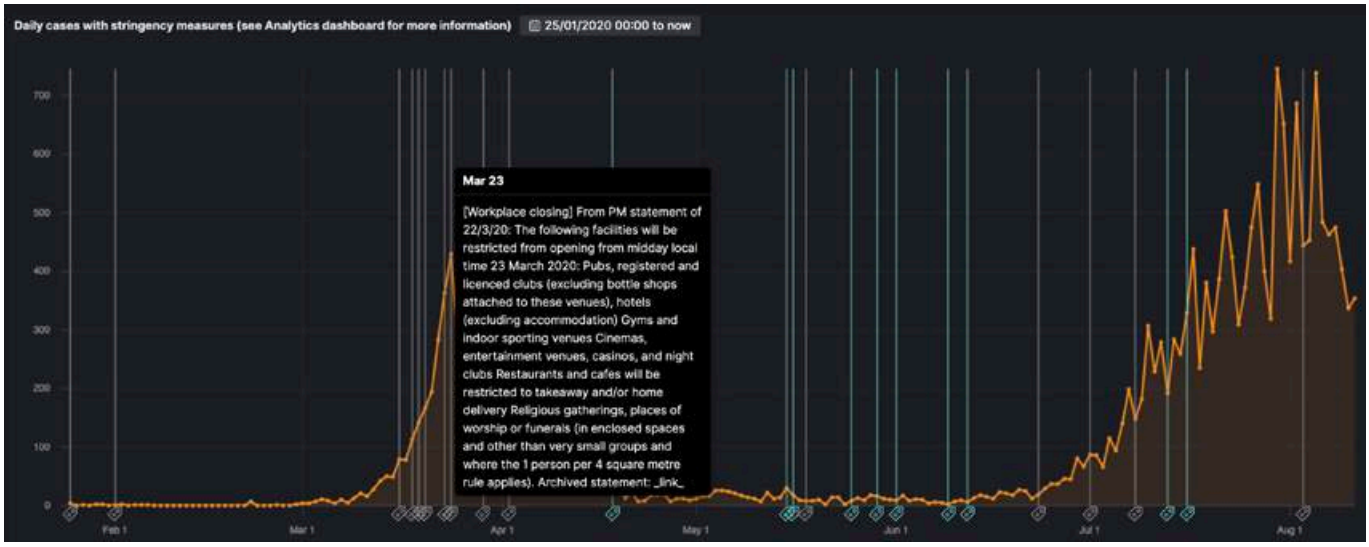
This medical text analytic service uses our Medtex platform to automatically read and analyse pathology and radiology reports and death certificates. Read more in Health Informatics: Platform Technologies.


Pathology report (C187/M81403)

5. Sigmoid colon polyp 1 \T\ 2: The sections show adenocarcinoma arising within a tubulovillous adenoma. There is a relatively large amount of submucosal tumour, with invasion of the stalk of the polyp (Haggitt level 3), and the invasive tumour being 12 mm wide and at least 11 mm in depth. Tumour appears to extend focally to the stalk resection margin of the largest fragment. It is not clear whether the resection margin is represented in the other fragments. Lymphatic invasion is present, but no tumour budding seen. The majority of the tumour is moderately differentiated, but some poorly differentiated component is present.

Tumour type: Adenocarcinoma, NOS.
Histological tumour grade: Moderately differentiated (Low grade).
Poor differentiation (undifferentiated) tumour: Small proportion of poorly differentiated component present.
Tumour budding: Absent.
Vessel invasion: Present.
Margin status: Involved. Involved margin(s): Adenocarcinoma focally reaching stalk resection margin in the largest fragment.
Clearance from deep margin: Involved.
Morphology: Pedunculated.
Maximum depth of invasion: 11mm.
Width of invasive tumour: 12mm.
Haggitt level: Level 3.

Medtex software processes narrative pathology reports and generates structured data with attentional mechanisms for explainability to aid clinical coders in cancer abstraction tasks. Image: CAQ.



An extract of our COVID-19 dashboard showing visualisations of when control measures were introduced in Australia and how they have impacted infection rates.

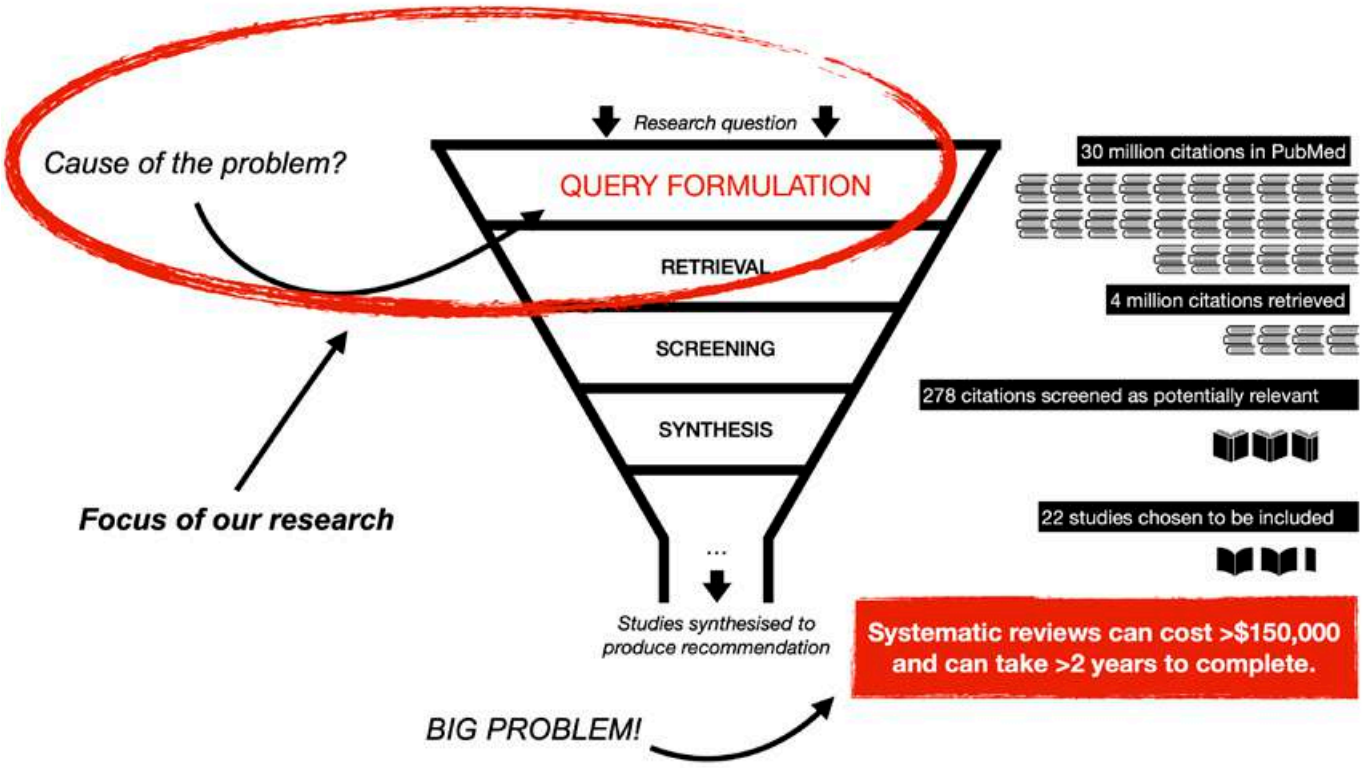
Search engines for compiling systematic reviews

Collaborators: Bond University, the Centre of Research Excellence in Digital Health

A systematic review is an extensive study compiling all evidence around a specific topic – think, "Do anti-malarial drugs help treat coronavirus?" Compiling a systematic review is a laborious and costly process that involves searching and manually reviewing potentially hundreds of thousands of research articles. It all begins, and all depends, on being able to formulate good search queries for your research question. Anyone who's used Google knows that how you formulate your query makes a big difference – and for systematic reviews people have to formulate complex, multi-statement queries (e.g., "covid OR coronavirus AND malaria or mosquito born diseases").

In this project, we have developed new search engine and machine learning technology to help people formulate better queries for systematic reviews. In the first instance, we take someone's initial query and, through a series of query transformations, generate a more effective query – this is done by learning from millions of queries what a good query looks like. In a further adaption, we forgo the need for people to manually write queries and instead generate them directly from the initial research question for the systematic review. Software tools have been built for users to use and visualise these methods.

The advantage of these methods is both fewer and better-quality search results for manual review. The outcome of this is higher quality and/or less costly systematic reviews, which are critical to both clinical practise and public policy. The tools that encompass these new methods are now being used by researchers at Bond University's Institute for Evidence-Based Healthcare as part of several important systematic reviews they are conducting.



The different phases of producing a systematic review. Query formulation is where it all begins and therefore impacts all the latter work.

Health Informatics: project updates

Automation of AMT Modelling

Collaborator: Australian Digital Health Agency

The Australian Medicines Terminology (AMT) is the national standard terminology for describing medicines and is a key enabler of medicines interoperability. AMT is authored manually by a team of pharmacists and released monthly by the Australian Digital Health Agency. The aim of this project was to develop algorithms to automatically produce AMT from drug registration information in the Australian Register of Therapeutic Goods (ARTG) to support the Australian Digital Health Agency in creating efficiencies in maintaining the AMT.

We have proposed algorithms to detect ingredients and their unit measures as well as strength values from the ARTG drug summary. The experimental evaluations showed that the accuracy performance was significantly improved from the baseline method to our proposed method. These results indicate the viability of developing a complete system to extract all necessary information to convert a drug summary into AMT data model with a high degree of accuracy.

SNOMED CT in QLD digital hospital projects

Collaborator: Office of the Clinical Information Officer (OCCIO), Queensland Health

We have continued close collaboration with Queensland Health's Office of the Clinical Information Officer (OCCIO) to support the use of SNOMED CT in the Cerner ieMR product deployed in Queensland hospitals. This involves providing education and support to the team around the use of SNOMED CT in surgery, emergency departments and trauma, particularly during terminology updates, as well as support and maintenance of SNOMAP-ED.

SNOMAP-ED is a tool which takes the original SNOMED CT-encoded patient data recorded by emergency department clinicians and transforms it to qualify for activity-based funding. This is being used in Queensland digital hospitals to allow the SNOMED CT-encoded data to maintain its true value for clinical care delivery and to ensure it complies with, and qualifies for, activity-based funding. SNOMAP-ED has both SNOMED concepts and ICD-10-AM codes which are updated twice per month and Queensland digital hospitals can submit data for activity-based funding in near real time.

Reporting for the Jamieson Trauma Institute

Collaborator: Jamieson Trauma Institute

The Jamieson Trauma Institute (JTI) is a collaboration of service partners aiming to improve services to people suffering traumatic injuries. Operating in a mixed data ecosystem, JTI receives and accesses data from various source systems, encoded in various vocabularies not necessarily equivalent in scope or specificity, and are therefore not directly comparable for population-wide statistical reporting, sophisticated analytics or research.

We worked with JTI to develop an overarching common layer of reporting categories informed by existing practice, SNOMED CT logic and JTI requirements and specifications. These categories can be used to aggregate both existing ICD-encoded data as well as SNOMED CT-encoded data.

A FHIR-based workflow for biomarker discovery and integrating AI into the clinic

Collaborator: Melbourne Genomics Health Alliance

The need for integrating data from multiple sources in the healthcare enterprise, and to integrate new technologies such as AI into the clinical workflow, requires a new approach. We propose a web-based, workflow platform called FORTE. FORTE maps standard operating procedures and clinical workflows into the FHIR framework and enables their execution. Each FORTE workflow comprises steps that can be automated or manually executed or performed. AI algorithms can then be executed as automated steps and their outputs made available further down the pipeline.

This project will help clinicians standardise the communication and description of data elements to better explain their processes and their provenance, to provide more transparency to their clinical workflow and facilitate reuse. FORTE also eases the integration of AI steps into the clinical workflow. Through a Digital + Domain grant, FORTE will be adapted to biomarker discovery and for integrating AI-based algorithms to the radiology clinic.

Health Informatics on FHIR with the University of Queensland

Collaborator: University of Queensland

We again partnered with the University of Queensland (UQ) to offer a Health Informatics on FHIR course to third- and fourth-year IT/Software Engineering students in the second semester of 2019. The course was led by CSIRO Distinguished Visitor Professor Mark Braunstein, from Georgia Tech in Atlanta USA, and Dr Chelsea Dobbins, lecturer at the UQ School of Information Technology and Electrical Engineering.

Ten students successfully undertook the course which involved Professor Braunstein's Health Informatics on FHIR online course, a series of guest lectures from local, interstate and international experts, and the development of SMART-on-FHIR apps (for interactive physical examinations, cancer staging, and for visualising family history) as part of a group project with clinical mentors. Guest lecturers from the AEHRC presented on FHIR, SMART apps, and clinical terminology. The health informatics course received strong evaluations from the students who undertook it, as well as from the medical school staff who participated as subject matter experts.

Queensland Genomics Health Alliance

Collaborator: Queensland Genomics Health Alliance

The Queensland Genomics Health Alliance is a $25M initiative to support the introduction of genomics into clinical care in Queensland. In 2017/18, the AEHRC partnered with the Queensland Institute of Medical Research Berghofer (QIMR-B), the Queensland Facility for Advanced Bioinformatics (QFAB), The University of Queensland and the Queensland University of Technology to lead the Genomics Information Management program in Phase 1. This project identified the key information management requirements for introducing genomics into the Queensland healthcare system.

In 2019/20, the AEHRC partnered with QIMR-B, to undertake a project to develop a Longitudinal Information Management Strategy (LIMS) and to identify opportunities for Advanced Decision Support (ADS) with genomics data. The project undertook a number of workshops with the Queensland Genomics clinical implementation projects, working with other Queensland Genomics stakeholders to identify the key requirements for a Longitudinal Information Management Strategy and to understand the requirements for clinical decision support. The Genomic Repository Strategy for Longitudinal Information Management has been further developed into a national approach to genomics information management in a project sponsored by the Australian Health Ministers Advisory Committee.

The workshops with the clinical projects identified a number of opportunities for machine learning and artificial intelligence to support the use of genomics data. This resulted in AEHRC developing the sVEP technology to support Annotation and Curation of genomics data - as reported by the Transformational Bioinformatics group. The AEHRC also supported the Queensland Infectious Diseases project with decision support through the processing of pathology data from bacteria.

Pathology and clinical data integration for infectious disease monitoring in a hospital setting

Collaborators: Queensland Genomics Health Alliance, Pathology Queensland, University of Queensland

Hospital-acquired infections (HAI) are a common and costly issue for modern health care globally, and can be a significant risk to hospital patients, particularly infections that are resistant to antibiotics. However, while laboratory reporting is an inherently manual process, prompt responses are often necessary, and automation and integration of HAI processes save time and improve data quality.

As part of our LIMS and ADS project with the Queensland Genomics Health Alliance, we collaborated with Pathology Queensland and the University of Queensland to implement a bioinformatics pipeline. This pipeline provides seamless integration of non-standardised data from the pathology laboratory to provide a standard API for accessing the data. This is enabling easier access to data for ward visualisation, dynamic analysis and reporting of outbreaks within a hospital setting. While this implementation has showcased the integration of pathology data for hospital-acquired infections, it can be extended to any laboratory information system.

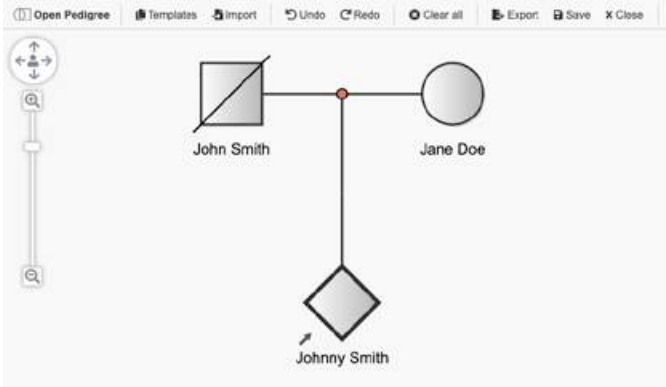
Australian Genomics Health Alliance

Collaborator: Australian Genomics Health Alliance

We lead the Phenotype Capture work stream within Project 2 of the NHMRC Australian Genomics Health Alliance. The objectives are to enable different sources of phenotype data to be used for research and clinical applications, and to represent different data in the same format, by transformation to computer-readable standards such as the Fast Healthcare Interoperability Resources (FHIR), and standardised terminologies such as SNOMED CT and the Human Phenotype Ontology (HPO).

During the past 12 months several important milestones were reached in project delivery and tool development. Highlights include: the release of a complete map between SNOMED CT and the Human Phenotype Ontology (HPO), a key component required to achieve interoperability between organisations using different terminologies to represent the same concepts; the release of a REDCap plugin that supports capturing pedigrees electronically; and significant improvements to the Redmatch platform, one of the key components that allows transforming REDCap data into standardised FHIR resources.

The tools have helped to dramatically improve the quality of the data being captured by many Australian Genomics Flagships and have also started to be used to implement additional functionality based on REDCap, such as electronic test ordering forms.



The REDCap plugin allows capturing family history information electronically.

A national approach to genomics information management

Collaborators: Queensland Health, Queensland Genomics Health Alliance

In 2017 the COAG Health Council released the first National Health Genomics Policy Framework. The framework identified five strategic priorities to support the integration of genomics into health care for Australians:

- Person-centred approach: Delivering high-quality care for people through a person-centred approach to genomics.
- Workforce: Building a skilled workforce that is literate in genomics.
- Financing: Ensuring sustainable and strategic investment in cost-effective genomics.
- Services: Maximising quality, safety and clinical utility of genomics in health care.
- Data: Responsible collection, storage, use and management of genomic data.

In 2019 Queensland Health was tasked with undertaking a study into Priority Area #5: Data. Acknowledging developments in genomics nationally and respective health jurisdictions the National Approach to Genomic Information Management (NAGIM) will propose approaches to harmonise investments in, and linkage between, clinical delivery systems and research infrastructure, establishing Australia as a world-leader in digital health and the rapid, safe adoption of medical genomics accounting for community and privacy concerns.

Through a series of workshops with Australia's state health jurisdictions, a framework for a national genomics information management approach has been developed and will be published shortly.

Melbourne Genomics Health Alliance

Collaborator: Melbourne Genomics Health Alliance

The AEHRC continues to lead CSIRO's involvement in the Melbourne Genomics Health Alliance. Over the past 12 months, Melbourne Genomics has delivered the GenoVic solution to a number of pathology labs across Melbourne. This is enabling whole genome and exam sequencing of patients along with the efficient analysis and curation of the sequence data and the return of clinical reports.

Two of our team members have been seconded into the GenoVic team to contribute to the development of the platform. The AEHRC has also supported Melbourne Genomics with expertise in the use of FHIR for interoperability and SNOEMD CT and Human Phenotype Ontology for clinical terminologies. The AEHRC has also undertaken bioinformatics projects with Melbourne Genomics and a chatbot project to facilitate informed decision-making by patients in the provision of additional findings analysis.

Edna: the chatbot to support communication about additional genomic findings

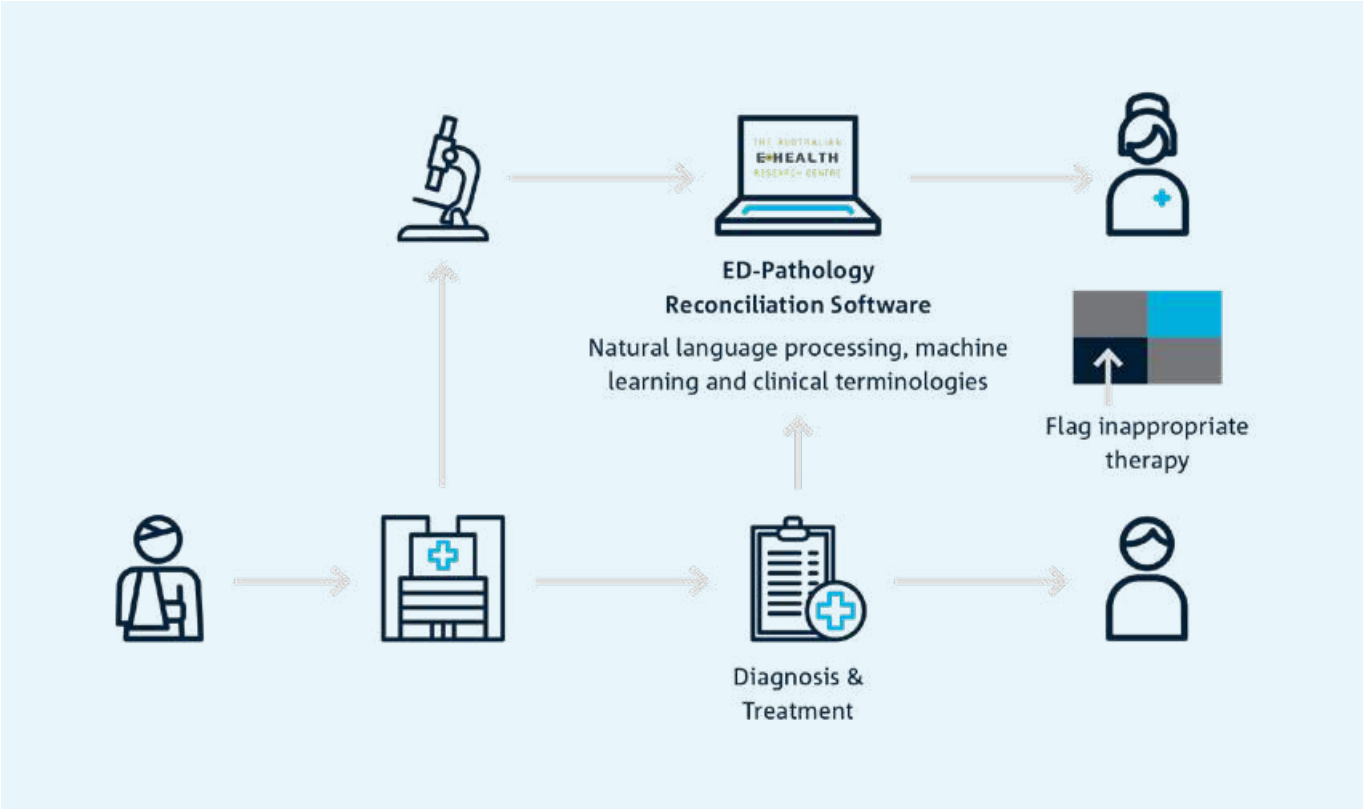
Collaborator: Melbourne Genomics Health Alliance

Genomic testing is primarily used to determine if there is a molecular diagnosis corresponding to a patient's medical condition. However, it also provides the potential to identify information about other health risks, or 'additional findings'. Chatbots are a rapidly emerging technology that have the potential to contribute to additional findings in healthcare delivery. They can be accessed at any time, collect and provide information, and recognise when to refer to a health professional.

Using transcripts from genetic counselling sessions, we developed a chatbot able to hold introductory conversations, explain terms, probe for information and summarise decision-making factors for the provision of additional findings analysis. Data was drawn from the Genetic Home Reference (NIH) and Human Phenotype Ontology to build the chatbot brain and algorithms were developed for the collection of family history. Information was included on implications for insurance and for other family members. As medical expertise and support group information are beyond the scope of current chatbot technology, Edna suggests contacting a genetic counsellor in response to these queries.

Edna was designed to complement genetic counselling by collecting and providing genomic information before or after pre-test consultations, and is currently undergoing feasibility testing with patients who have had genomic counselling.

Edna the trainee chatbot is able to both collect and provide information relevant to genomic healthcare.



The clinical decision support workflow for streamlining ED microbiology test result review.

Tackling antimicrobial resistance with test result reviews

Collaborator: Department of Emergency Medicine at The Prince Charles Hospital

Checking microbiology pathology laboratory reports to ensure positive results are not missed, and that patients receive appropriate antibiotic treatment after emergency department (ED) discharge, is an essential but laborious task. Due to a busy ED, resourcing issues and the turnaround time of microbiology reporting, it can often be up to a week after the patient's initial presentation to the ED that this checking process is performed. This process results in time inefficiencies with delays in reporting, delays in checking results, and delays in recalling patients. A timelier and efficient process is required to improve patient outcomes and staff resources.

In partnership with The Prince Charles Hospital ED, we have developed algorithms and models to reliably identify positive results from microbiology test results, and link these with patients' disposition as recorded in the ED information system to provide decision support to the currently manual checking process. This ensures bacterial infections are detected in a timely manner and acted on appropriately. The system supports clinicians with faster and more accurate test result reviews, improving patient outcomes and helping reduce the resourcing strain on hospital staffing. This also contributes to the hospital's Antimicrobial Stewardship program to ensure antimicrobials do not become ineffective and are available for future generations.

Beyond the health domain: a question answering system to help farmers in the field

Collaborators: University of Queensland, Grains Research Development Corporation

For several years we have been building search engine technology for the health domain, especially to support evidence-based medicine. But this work has many applications beyond health. In this project, we are applying our health research to the agricultural domain through a grant from the Grains Research Development Corporation. The project will help growers search grain-related resources to answer their growing-related question.

Like health, agriculture is increasingly data-driven, but people still struggle to find answers to their questions among the vast amount of information available online. We are building a conversational search system where growers can ask questions in natural language and get tailored responses, personalised to their location, crop, weather and expertise. We will develop a fully fledged system with new search methods, which will be fed back to our health work, showing the general applicability and impact of our search engine research.

Generating high-quality data abstractions from scanned clinical records

Collaborator: QIMR Berghofer Medical Research Institute

Medical research studies often rely on the manual collection of data from scanned typewritten clinical records, which can be laborious, time consuming and error prone because of the need to review individual clinical records. Extracting data from pathology reports is a critical aspect of cancer research studies. Such data provide confirmatory evidence that patients affected with a specific cancer type meet the diagnostic inclusion criteria for research and clinical studies.

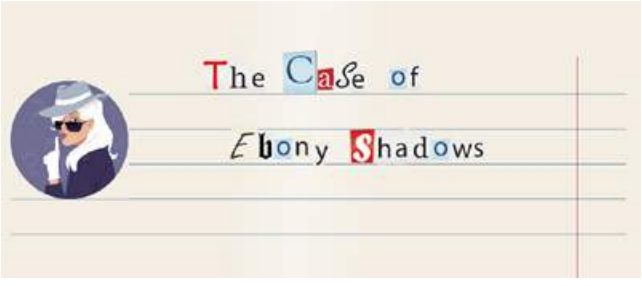
In partnership with the QIMR Berghofer Medical Research Institute, a rapid and convenient text-mining tool was developed. It automatically extracts pathology features from complex text-based scanned photocopies of typewritten clinical pathology reports drawn from multiple different sources, collected as part of the population-based Australian National Endometrial Cancer Study.

The method used search term trigger-based automation with OCR error correction and negation handling. It can adapt to address a wide range of textual nuances or artefacts resulting in 'noise' common to scanned PDF images. The tool was highly accurate in extracting information from scanned textual medical records and greatly enhanced the curation of a manually abstracted pathology research dataset.

Pain ROADMAP gamification for children with chronic pain

Collaborator: Metro North Hospital and Health Service

Continuing the success of the Pain ROADMAP platform for chronic pain intervention, we and collaborators from Metro North Hospital and Health Service obtained a $35,000 development grant to extend the platform to cater for children with chronic pain. We led the development of a gamification component in 2019, resulting in a game called 'The Case of Ebony Shadows' designed to increase the compliance of children users of the Pain ROADMAP mobile app.



The embedded game 'The Case of Ebony Shadows' was designed to encourage users to participate in the intervention by being entertaining and informative.

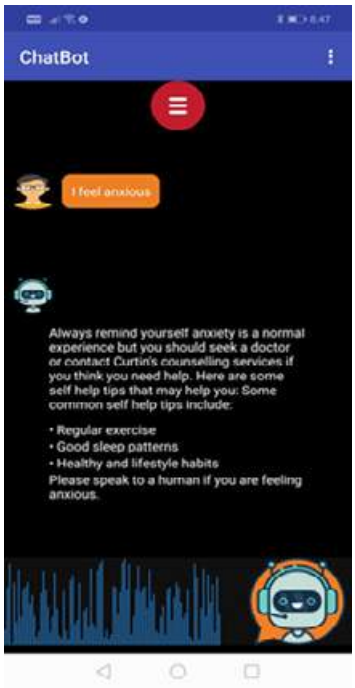
This is a text-based adventure game with close links to the chronic pain intervention being implemented in the platform. The platform was deployed in July 2020 at multiple pain clinic sites across Australia including the Royal Brisbane Hospital QLD, Melbourne Children's Hospital VIC, Support Kids in Pain QLD, The Therapy Space WA, Pain Specialists Australia VIC and St Vincent's Hospital QLD. As of August 2020, recruitment is at 25% and on-schedule to be completed by the end of the year.

'Hear' to Help, facilitating participation in tertiary education for people with autism

Collaborators: Autism CRC, Curtin University, ASPECT Australian, Autism Hub

There are an increasing number of university students who identify as being on the autism spectrum or having a related condition. This increase reflects aspirations often expressed by adolescents on the spectrum to continue their education post-secondary school, and there is evidence to suggest that those who do have better life outcomes. While students on the spectrum who used support systems had a better overall university experience, these systems tend to be underutilised. One way of making the support systems more accessible to students is to provide the available resources through a chatbot.

Using a strong co-development model, particularly with the Curtin Specialist Mentoring Program, we developed a chatbot that allows users to navigate social, physical and environmental cues associated with higher education, as well as providing information on anxiety and depression, and university counselling services. The chatbot is available for smartphone or web use and provides relevant resources sourced from student support services and health services. Additionally, the chatbot can provide communication strategies for various scenarios, such as asking for an extension or understanding legal rights.



As approximately 40% of people with autism experience anxiety, it was important that the Hear to Help chatbot was designed to provide information on mental wellbeing.

Health Informatics: postdoc and student highlights

Postdoctoral fellow

Thanh Vu

CSIRO Research+ Postdoctoral Fellowship

Automating clinical data registries for personalised health using deep learning and electronic health records (EHR)

Improving the delivery of health outcomes is dependent on an up-to-date clinical data registry. This research will develop and trial an automated clinical data registry built upon revolutionary "deep learning" algorithms. The overall aim of the research is to develop a chest pain clinical data registry built from automatically extracted clinical information from both unstructured and structured data sources of patients presenting to the emergency department with possible cardiac chest pain. Chest pain is a disease entity requiring a process of investigations and appropriate interventions and has never been fully incorporated in a clinical registry setting in Australia despite consistently being in the top ten presenting complaints to emergency departments and costing the Australian economy $6.8 billion in loss of income and health expenditures in the 2017-2018 financial year alone.

The information extracted into the clinical registry is envisioned to translate into actionable knowledge for clinicians, researchers and administrators for investigating and managing patients who present with possible cardiac chest pain. In particular, the chest pain clinical registry would be used to identify variations in practice occurring outside recommendations for risk stratification and the occurrence of major adverse cardiac events after risk stratification. This will provide real-time information to personalise care pathways, improve health outcomes and reduce unnecessary costs.

PhD students

Anton van der Vegt

AEHRC PhD Top-Up, Scholarship University of Queensland

Bridging the human-task cognitive gap. A theoretical framework applied to medical search

The healthcare problem associated with clinicians not answering, or incorrectly answering, clinical questions is both serious and sizeable. Unanswered or incorrectly answered clinical questions can result in poor clinical decisions, reduced levels of patient care and ultimately inferior or adverse clinical outcomes. Two important reasons why clinical questions are not pursued are because clinicians are time poor and don't believe the information resource can help them to answer their question. Our research is focused on the effectiveness of electronic information retrieval solutions, that provide direct access to scientific medical literature, for clinicians to use to find answers to their clinical questions.

Liebo Liu

UNSW – CSIRO Industry PhD

Extracting value from unstructured health data

Many sources of health data, such as hospital and primary care electronic medical records, contain data that are unstructured, such as free-text clinical notes and reports. These data are increasingly becoming available in an aggregated form for research and analysis ("secondary use"), for example, the hospital discharge summaries, referral letters and reports of pathology and imaging that are included in Australia's My Health Record. However, we need robust new methods and tools to extract value from these unstructured data, for example, to obtain diagnoses and medication information from hospital discharge summaries.

This research will apply natural language processing (NLP) technologies, including machine learning methods for named entity recognition (NER), to extract structured clinical information from narrative text. The emphasis will be on developing tools to maximise the utility of the My Health Record for secondary uses that will reduce waste and duplication in health care, and drive high-value care.

Jinghui Liu

CSIRO R+ Postgraduate Scholarship,
Scholarship University of Melbourne

Unlocking electronic health records (EHR) to provide practice-based evidence

The research involves the automatic extraction of key information from clinical free text to provide decision support based on evidence-based care. Natural language processing (NLP) and machine learning models will be used to identify concepts from clinical text for the purposes of phenotyping and identifying patient cohorts. The overall goal of the project is to build systems that are able to process large corpora of biomedical and clinical text so as to help clinicians to make use of existing knowledge and aggregated patient data to develop personalised treatment and prevention plans.

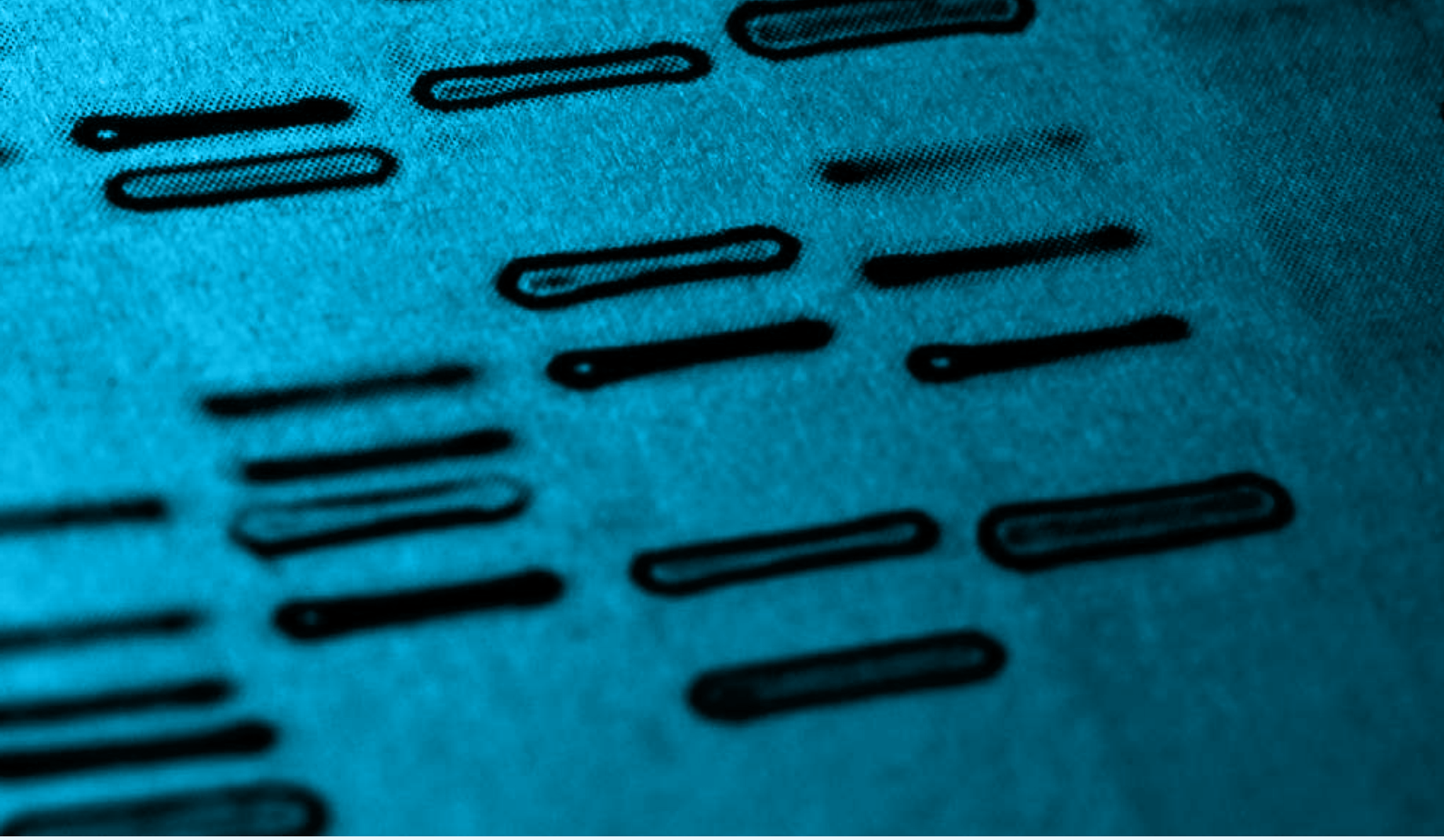
The Transformational Bioinformatics group

Group Leader: Dr Denis Bauer

The Transformational Bioinformatics group is world-leading in cloud-native genomics research, developing novel machine learning and advanced cloud architectures to drive innovation in the use of genomics in the health system. The group delivers impact in two main genomics disciplines: genome sequence analysis and digital genome engineering.

Transformational Bioinformatics' science and impact highlights for 2019/20

- The group worked with CSIRO's Australian Centre for Disease Preparedness to analyse the SARS-COV-2 virus genome, informing their decision on which strain of the virus to use for vaccine trials. This resulted in CSIRO's first paper related to the coronavirus vaccine and was highlighted in The Weekend Australian and The Sydney Morning Herald.
- Working with the Motor Neurone Disease Unit from Macquarie University, we identified new molecular disease origins for Amyotrophic Lateral Sclerosis, leading to Nature and Cell journal publications and presenting at one of the largest molecular biology conferences (ISMB 2019).
- We worked with the Australian SME Drop Bio to provide analytical and software development capability for their blood-based direct-to-consumer product on inflammation.
- For our own R&D, we released an Analytics-as-a-Service solution on the AWS Marketplace, becoming the first public sector organisation to have developed this new commercialisation channel. This work was highlighted in the Australian Financial Review as well as the international AWS podcast.
- Overall, the group has published nine journal papers (five first/senior author) and more than 17 conference presentations, including seven keynotes at major conferences with up to 500 attendees such as the International Bioinformatics Conference, International Genomics Working group and Serverless Days.
- The group has secured $300,000 in competitive funding and has engaged 10 companies in customer discovery conversations (e.g., Agilent, Sherlock Bioscience, NSW Health Pathology, Queensland Pathology).



Genome Insights team

Team Leader: Dr Natalie Twine

The Genome Insights team generates insights into genome-trait relations by analysing population-scale 'omics (genomics, transcriptomics, methylomics) and integrating with observational data. This will help find the genetic origins of disease and ultimately lead to better diagnostics and new treatments. The developed software solutions also support bringing genomic information into clinical practice by enabling genetic risk score predictions or data-driven ancestry analysis.

Digital Genome Engineering

Team Leader: Dr Laurence Wilson

The Digital Genome Engineering team develops analytics and web-services to improve genome engineering applications in the health and biosecurity spaces. Computationally guiding editing machineries, such as CRISPR-Cas9, will improve accuracy and efficiency and enable their applications in human health, for example in genetic surgery and gene therapy or lab-free at-home diagnostics for genetic or infectious diseases.

Transformational Bioinformatics: platform technologies

VariantSpark

Collaborators: Motor Neurone Disease Centre, Macquarie University; Project MinE ALS genomics consortium

Our genomes hold information that can substantially improve clinical care. However, reading this information and linking it to function is challenging. While Genome Wide Association studies have identified strong individual contributors for monogenic disease and polygenic risk scores extend this towards calculating the overall disease risk for complex diseases, there is no methodology able to incorporate both polygenic and individual genetic effects. VariantSpark is designed to specifically address this challenge.

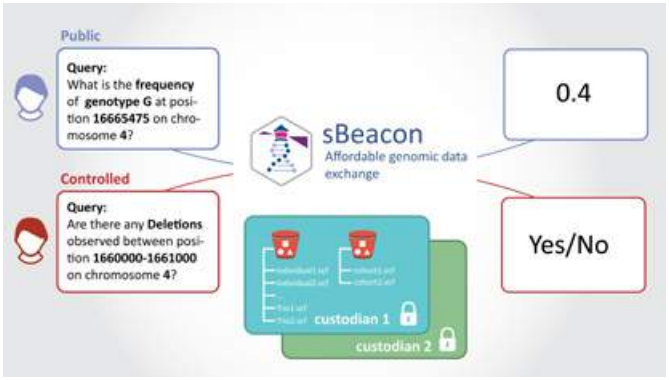
VariantSpark is implemented using distributed computing with the Apache Spark platform. This allows VariantSpark to process large-scale genomic datasets of tens of terabytes.

Over the last 12 months we extended VariantSpark to multi-omics health-data analysis and therefore serve other industries. An active community of developers and researchers is now involved in the VariantSpark project to improve the code-base and explain its application in the scope of health.

Compared to alternatives, VariantSpark is the fastest and the only software that scales linearly with data size and CPU. VariantSpark is currently used to analyse UK-biobank and Welcome-Trust datasets and consortium datasets like Amyotrophic Lateral Sclerosis (ALS, Project MinE) and the Alzheimer's Disease Neuroimaging Initiative. An eco-system of open source software has been built around VariantSpark to create realistic synthetic datasets (PEPS) and visualise interacting genes from VariantSpark output (BitEpi). Recognition from the Australian Bioinformatics and Computational Biology Society will help VariantSpark grow an Australian community that can facilitate the cloud-based sharing of bioinformatics software.

VariantSpark outcomes include an article published in the Australian Financial Review and a feature episode on the international AWS podcast. We recently published VariantSpark in Oxford journal GigaScience, a champion for reproducible large data research. We also have an impactful case study on ALS, where we discovered novel disease genes in Australian ALS patients with VariantSpark. Read more in Transformational Bioinformatics: Project Reports.

VariantSpark can process both big and 'wide' genomic data to drive biological insights.



Serverless Beacon: helping take genomic analysis from the cloud to the clinic.

Serverless Beacon

Reading the genome to search for the cause of a disease has improved the lives of many children enrolled in clinical trials. However, converting research into clinical practice requires the ability to query large volumes of data and find the needle in the haystack efficiently. This is hampered by traditional server and database-based approaches being too expensive and unable to scale with accumulating medical information.

We partnered with the Melbourne Genomics Health Alliance (MGHA) to develop a serverless approach to exchange human genomic information between organisations.

We developed the Serverless Beacon, which reduces the running cost to as little as $4.18/month and keeps runtime constant at about one second. It enables distributed data resources to be contributed to an sBeacon, allowing data owners to maintain full control over sharing conditions and enabling them to revoke access themselves without affecting the operation of the sBeacon at large. This serverless implementation enables rapid querying of large datasets and reduces the time to progress from research to clinic.

We delivered the solution to MGHA and drew interest from the Australian Genomics Health Alliance and Genomics England. Read more in Transformational Bioinformatics: Project Reports.

GT-Scan Suite

Collaborators: JCSMR, ANU, Gene Therapy Unit, CMRI, Westmead; Translational Vectorology Group, CMRI, Westmead

This project develops computational solutions that improve the accuracy of genome engineering applications (on-target scoring, SNP-aware off-target search) to enable novel application areas in high-precision applications such as human health. The task of finding a suitable genome editing spot is comparable to finding the right grain of sand on the beach; it needs to have the right shape and colour (properties for CRISPR to bind) and also be unique compared to all other grains on the beach (for CRISPR not to accidentally bind to another gene).

This is a very expensive task computationally. We reduced the overall runtime for this task from weeks to seconds by massively parallelising the individual search tasks using a revolutionary new compute approach called Functions-as-a-Service or serverless. We also improved accuracy by 30% by tapping into CSIRO's 25-year experience in the science of how the genome's 3D organisation affects the accessibility of the genomic address. Finally, the machine learning models were built to more precisely fit experimental use cases (e.g. SNP-aware prediction for wild populations) thereby giving the ability to personalise results to individual patients.

Over the year we established a cloud-based computational framework for designing a wide range of CRISPR-based experiments (available at gt-scan.csiro.au). This platform is comprised of several published tools including TUSCAN (published in The CRISPR Journal), CUNE (published in Nature Scientific Reports) and VARSCOT (published in BMC Biotechnology). Our work led to a review on CRISPR-Cas9 predictive tools and has been presented at many international conferences, including the main international CRISPR conference CRISPR2019 in Quebec City, Canada. Read more in Transformational Bioinformatics: Project Updates.

Transformational Bioinformatics: project reports

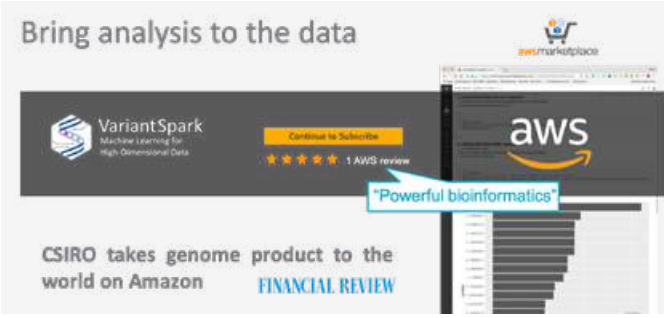
VariantSpark on AWS, publication and podcast

Collaborator: Amazon Web Services (AWS)

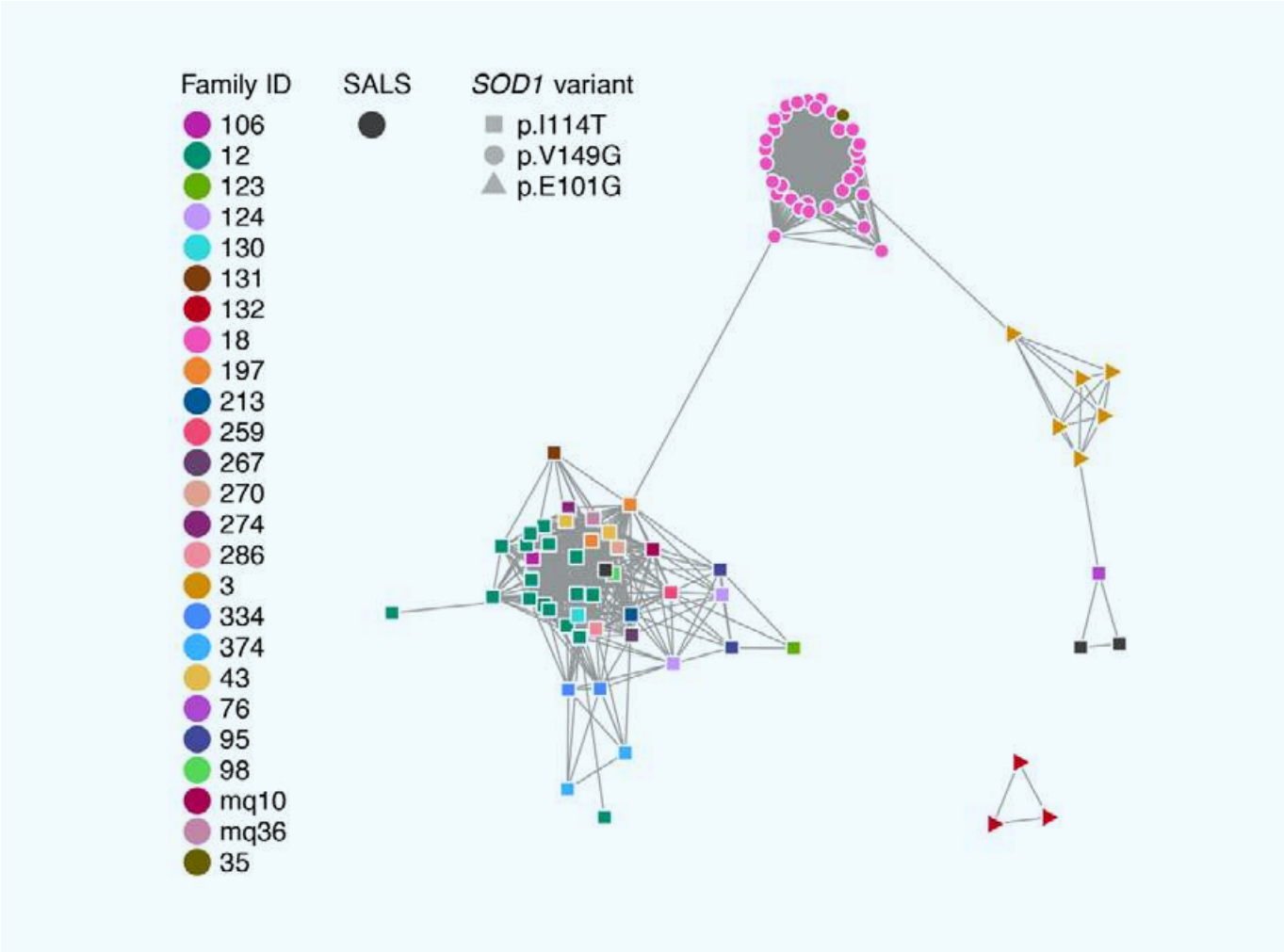
VariantSpark is a powerful machine learning platform built for the high-impact domain of human genomics. It deploys as a self-serve privacy and data-ownership preserving cloud platform, which enables academic consortia, big pharma and hospitals to analyse large-cohort genomic data to identify disease genes and develop new diagnostics or treatment avenues. Read more on VariantSpark in Transformational Bioinformatics: Platform Technologies.

Reducing the barrier to entry, we automated computer cluster configuration by packaging the VariantSpark install as infrastructure-as-code self-deploy package on Amazon Web Services (AWS), as well as as other platforms such as DataBricks (Azure) and Terra (GCP). This year we went one step further by making VariantSpark available as a digital-product on the AWS Marketplace, which adds version-controlled updates and additional service-level support to the already existing automated deploy for VariantSpark on AWS.

With this, CSIRO became the first public sector organisation worldwide to publish a health product on the AWS Marketplace. We have provided video tutorials to assist researchers to deploy these computational environments, and compiled notebooks with example workflows for different use cases. We actively maintain online discussion channels like Gitter and GitHub issues to foster input from the bioinformatics and IT community.



VariantSpark is the first public-sector platform released as a digital product on AWS Marketplace.



TRIBES connects 19 distinct ALS families over the SOD1 gene locus.

NHMRC Dementia Team Grant: motor neuron disease and dementia

Collaborators: Macquarie University, International Project MinE

We are a partner in the NHMRC Dementia Team Grant led by Macquarie University, which focuses on genetic causes of motor neuron disease or Amyotrophic Lateral Sclerosis (ALS), a devastating neurodegenerative disease that leads to death within two years of diagnosis. In this five-year project, we are responsible for the genomic data analysis of 800 Australian ALS genomes. These samples form the Australian contribution to the international Project MinE consortium and CSIRO is engaged with this consortium by analysing the 22,000 case-control cohort.

We have applied our VariantSpark technology to the 800 Australian ALS genomes. VariantSpark can identify variants that are interacting with each other as well as those independently driving disease, a critical feature essential for analysing complex disorders such as ALS.

Using VariantSpark we have identified a potential novel disease gene for ALS active in the Australian population. Collaborative work with Macquarie University has been published in Scientific Reports. We are now engaging with Project MinE, an international research project on ALS with information on 22,000 individuals. Through this collaboration we have published work in high impact journal Cell Neuron.

We have also applied our in-house relatedness tool, TRIBES, to the ALS cohort. TRIBES identifies the shared genomic region between relatives, substantially narrowing the search space for the genomic origin of disease. Using TRIBES on the 800 ALS patient genomes, we uncovered 54 novel relationship pairs and disease-critical including candidate ALS genes DYNC1H1, FIG4 and APOE. We also able to link 19 distinct ALS families over known ALS gene SOD1. This work has recently been published as a CSIRO lead authorship in Nature's Genomic Medicine.

We presented research outcomes from this project as a keynote at the International Conference on Frontotemporal Dementias in Sydney and at International Intelligent Systems in Molecular Biology in Switzerland.

sVEP: serverless variant effect predictor

Collaborators: Queensland Genomics Health Alliance, QIMR Berghofer

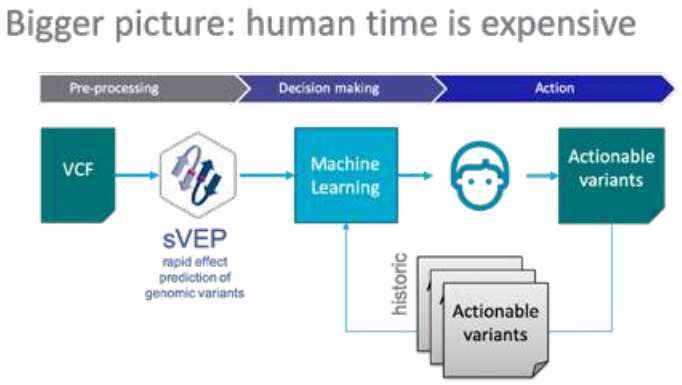
We partnered with QIMR Berghofer as part of the Queensland Genomics Health Alliance to improve the annotation of genetic variants and enable clinical decisions to be delivered faster.

When a patient's genome has been sequenced, a genetic pathologist must review any changes in the sequence (called variants or mutations) to identify any variants that are the likely cause of a disease or could help inform treatment decisions. As part of this clinical reporting, the pathologist categorises variants in the sequence as either 'pathogenic', 'non-pathogenic' or levels of uncertainty in between. An automated pre-annotation stage reduces the huge number of variants in each sequence to a set of potential variants for the pathologist to review. This pre-annotation stage is slow and does not take into account a range of information, such as previous decisions made by the pathologist, data in local or international knowledge bases, or data only reported in academic publications.

We have developed a new version of the variant effect predictor (VEP), a software tool originally developed by the European Bioinformatics Institute and in widespread use. Addressing both the flexibility and time constraints of VEP, our version uses cloud-native architectures to provide a highly modular and resource-efficient implementation of the variant annotation pipeline, serverless VEP (sVEP). This includes using machine learning (ML) methods to incorporate previous decisions from the curator.

With an estimated 99% speedup over the traditional implementation, sVEP will increase the turnaround time for pathology labs considerably and indirectly improve the diagnostic process.

We will partner with pathology labs to develop an ML-based methodology that fits into their workflow by using their historic annotation data to train a variant prioritisation tool that mimics the decision-making process of a human.



Workflow diagram outlining the process of sVEP, a cloud-based variant annotation platform.

Serverless Beacon

Collaborators: MaxKelson, AWS and Intel, CSIR-IGIB (India), NSW Health Pathology

We led a project team from MaxKelson, AWS and Intel to improve how genomic data can be shared in a privacy-preserving manner enabling fast global knowledge exchange to accelerate knowledge gain and disease diagnostics.

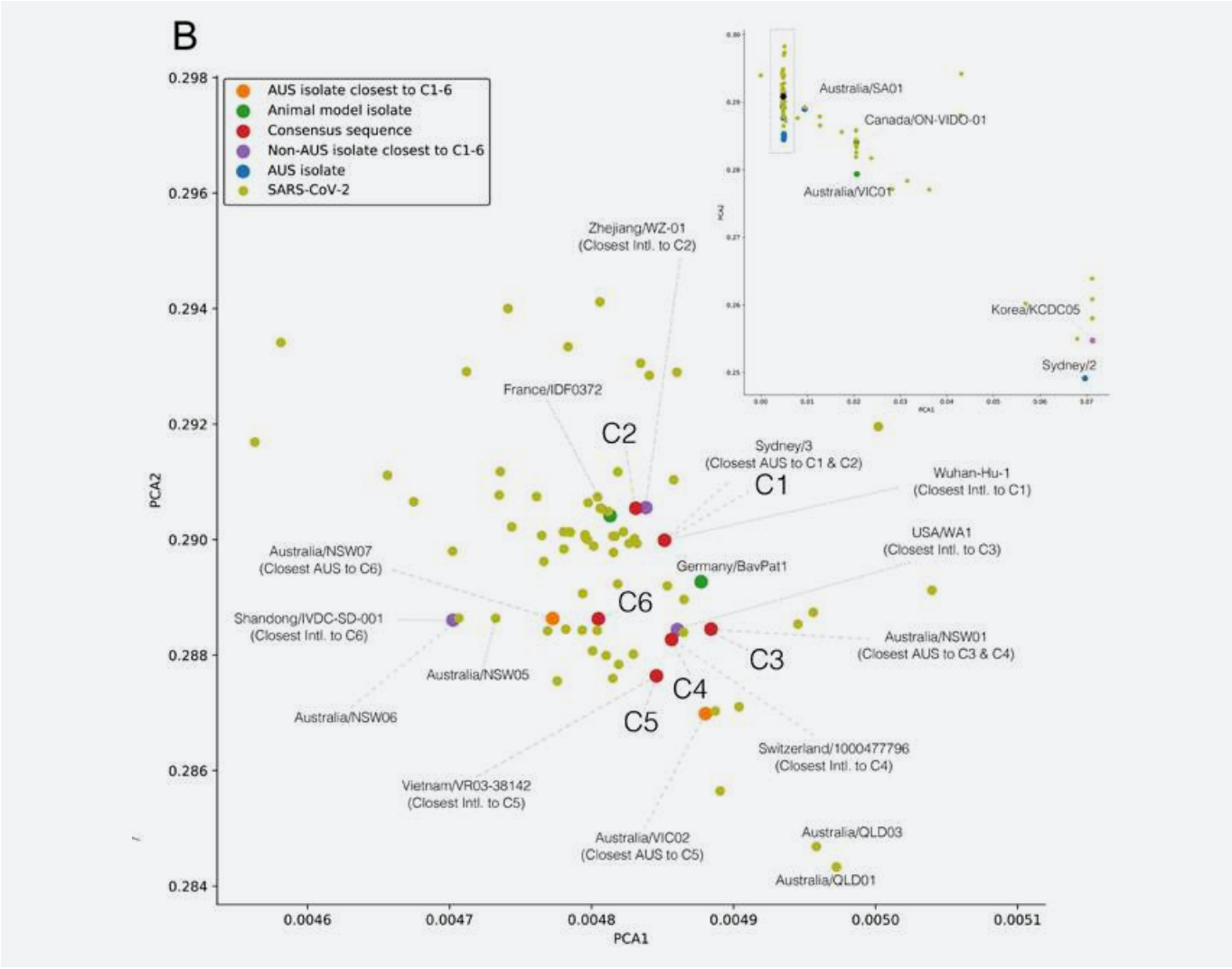
With the importance of genetic information in the clinic, as well as the increasing size and quantity of data available, new processing methods are required. We developed the Serverless Beacon, a genomic exchange approach that makes use of the latest in cloud technology. Our serverless implementation allows for the rapid querying of large datasets, streamlining the approach and reducing the time to progress from research to clinic.

The framework was architected to provide instantaneous analysis of non-local data on demand, with zero downtime and minimal running costs. We used Terraform to write the infrastructure, enabling rapid iteration and version control at the architecture level. In order to maintain governance over our infrastructure created in this way, we developed a custom Continuous Deployment service that built and securely maintained each project, providing visibility and security over the entire organisation's cloud infrastructure.

Our implementation has led to an increased query speed of up to 2000% over conventional methods; querying 100,000 genomes with 85 million variants in one second, compared to the current average of 40 seconds. At a query rate of 100/hr, this implementation costs only 0.2% as much as the conventional method. To handle our cohort it costs $4.18 per month, compared to $4000 per month if using traditional methods.

We have also adapted the Beacon protocol to serve out information about the genomic mutation of the COVID-19 virus. We partnered with NSW Health Pathology and India's CSIR-IGIB to stand up a web service able to track the mutational frequency of the virus in Indian and Australian data (read more on this work in this report's COVID-19 section).

Read more on Serverless Beacon in Transformational Bioinformatics: Platform Technologies.



Identification of potential candidates for COVID-19 vaccine development.

Informing public health responses for infectious disease outbreaks such as COVID-19

Collaborator: CSIRO's Australian Centre for Disease Preparedness

Due to the ever-increasing mobility of the world's population, localised infections can rapidly escalate into global threats. While COVID-19 has been the most severe threat, the World Health Organization has declared six other infectious diseases a 'Public Health Emergency of International Concern' since 2009. To inform public health measures more efficiently, novel analysis technologies are required to rapidly gain insights into large volumes of information.

Understanding how a pathogen evolves during an outbreak is crucial for the development of diagnostics, treatments and vaccines. In collaboration with CSIRO's Australian Centre for Disease Preparedness, formerly known as the Australian Animal Health Laboratory (AAHL), we developed an approach to monitor the evolutionary drift of SARS-CoV-2 during the COVID-19 pandemic. Our approach involved analysing the frequency of oligonucleotides for every SARS-CoV-2 genome sequenced around the world. These oligonucleotides serve as a genomic fingerprint unique to each SARS-CoV-2 isolate. By using this approach, we identified potential candidates to inform the choice of the animal model used in vaccine development.

This work led to CSIRO's first published COVID-19 peer-reviewed paper in Transboundary and Emerging Diseases, which uses bioinformatics to inform strain selection for critical vaccine research.

Transformational Bioinformatics: project updates

Using proteins as proxy for health

Collaborator: Drop Bio

Partnering with Drop Bio, we have performed a longitudinal analysis of protein biomarkers in the blood. In this clinical trial project, participants sent blood samples at regular time points, which were analysed to determine the concentration of specific markers indicative of the individual's health. We built infrastructure and machine learning-based solutions to analyse and interpret the blood biomarker data.

Drop can now use the framework and analysis approaches to process future clinical trial data and provide information to customers on their health, disease predisposition and advice on how to regain "healthy" levels of blood markers. Specific outcomes for this project include: securing a Kickstarter grant ($200,000) to support Australian SMEs, building essential infrastructure for processing and management of customer's biomarker data, and using custom built solutions we have analysed the first set of customer data to establish best practice methods.

Detecting foreign DNA using genomic signatures

Collaborator: OUTBREAK consortium

This project focuses on developing methods for detecting the presence of dangerous DNA within a genome, such as gene-drives within a wild population, antimicrobial resistance genes among bacteria, or viral integration sites in a patient. Detection of these events is critical for both biosecurity and within the clinic. To address this, we developed an approach to determine whether foreign DNA has been inserted into a genome. Our approach involves analysing the frequency of oligonucleotides in a genome. These oligonucleotides represent words within a genome, and every species can have its own genomic vocabulary (i.e, genomic signature).

By identifying regions of a genome that "sound" different to their surroundings, we can pinpoint bits of DNA that do not belong. By using this approach, we can separate inserted genes (e.g. gene-drives and bacterial plasmids) from a host genome, identify specific species among a large population, or monitor the spread of genetic traits. The technology can also be leveraged to create next-generation diagnostics, allowing users to accurately detect pathogens and distinguish between highly related strains.

We have developed a scalable method for calculating the genomic signatures of DNA/RNA sequences. These signatures can then be analysed to detect the presence of gene-drives within a host chromosome. This work is being lead by our postdoc Aidan Tay. Our work in this field has been published on multiple blogs and contributed to CSIRO's first SARS-CoV-2 publication. We are also part of the OUTBREAK consortium, which successfully applied for MRFF funding ($1M) to tackle antimicrobial resistance.

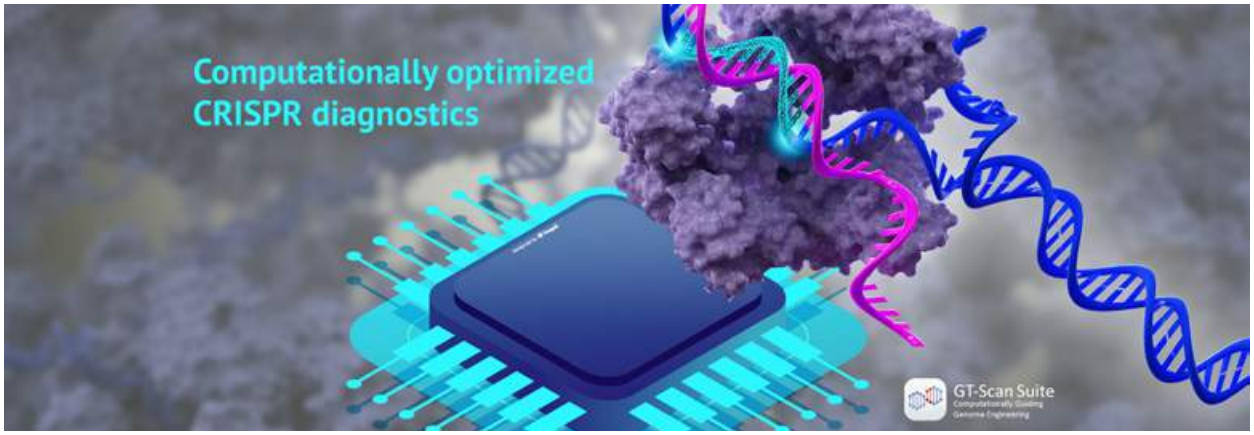
MRFF c-FIND and SAUTE

Collaborator: Walter and Eliza Hall Institute of Medical Research (WEHI)

CRISPR-based diagnostics can detect the presence of pathogens through recognition of associated DNA at incredibly low concentrations. The power of these new tools is limited only by the ability to design strategies that can accurately distinguish between the pathogenic DNA and all other related sequences. To assist in this process, we have developed SAUTE: a web-based tool for designing CRISPR strategies to differentiate between highly related sequences.

The platform works by analysing all suggested genomes to identify unique sequences. Different combinations of target genomes can be queried and compared to any number of other genomes to identify unique strategies for identifying a group of pathogens amongst a larger related family.

Development is being led by Brendan Hosking and Daniel Reti. We have also collaborated with researchers from WEHI, Victoria who are part of the Medical Research Future Fund c-FIND, which aims to develop next generation diagnostics. We are also in discussions with SHERLOCK Biosciences around potentially using SAUTE to fine-tune CRISPR-diagnostics for their platform.



CRISPR chip to revolutionise diagnostics.

Identifying viral integrations in a host genome.

Identifying viral integration sites

Collaborator: Children's Medical Research Institute, Westmead

Viral infections can play a causative role in cancer development, with 10-15% of total human cancer cases linked to a handful of cancer-associated viruses. One well-characterised example is the association between human papillomavirus (HPV) and cervical cancer. With the ever-increasing amount of genomic data available from biobanks and consortia such as the Cancer Genome Atlas and the International Cancer Genome Consortium, this project aims to explore the role of potential novel cancer-associated viruses.

In collaboration with the Gene Therapy Unit from the Children's Medical Research Institute (CMRI) at Westmead, we first developed a pipeline to identify viral integration sites in sequence data. In this approach, we identify direct evidence for integration by comparing alignments of sequence data to human and viral genomes. This pipeline can be used to investigate the interactions between the human genome and naturally occurring viruses, as well as vectors used in treatments such as gene therapies. Work to analyse sequence data from cancer and matched healthy control tissue in a variety of cancer types is ongoing.

The collaboration with CMRI is led by our postdoc Suzanne Scott, who has been working to build collaborations within the Westmead campus.

Modelling viral evolution

Collaborator: CSIRO's Australian Centre for Disease Preparedness

The ability for viruses to rapidly evolve makes it difficult to predict the next pandemic, meaning responses tend to be reactive rather than proactive. Significant work has gone into sequencing and cataloguing past strains, so there is a large historical dataset. This means we can analyse how these viruses have previously evolved. We have begun a project to study and model how different viruses have evolved in the past, with the hopes of being able to predict future evolution events, allowing us to proactively identify potential pandemic strains.

The project is being led by our postdoc Cameron Hosking, who is working to develop new methods for analysing viral evolution including identifying recombination and reassortment events. Specifically, he has explored the most cited and promising published reassortment detection algorithms and their suitability to datasets with tens of thousands of available sequences. We have also developed our own method for detecting viral reassortment events amongst highly similar strains, critical for predicting future evolution events.

Digitally guided genome editing for gene therapy

Collaborator: Children's Medical Research Institute, Westmead

Genome engineering offers a new treatment avenue for particular genetic diseases. However, delivering this precision in practice is difficult due to a wide range of influencing factors ranging from differences in genomic makeup to environmental influences. It is critical to precisely understand governing factors to ensure gene editing results in the desired change to the gene.

We are improving gene editing precision and efficiency with our GT-Scan suite of software tools, which aim to find the right editing spot for specific genes for specific applications (read more in Transformational Bioinformatics: Platform Technologies). For example, our CUNE software can help researchers design and optimise their approaches for inserting new sequences into DNA. Alternatively, VARSCOT can be used to identify the best gene editing approach for a specific individual, taking into account their natural genetic variation.

Our models will also contribute to gene therapy applications with our collaborators at the Children's Medical Research Institute. This treatment aims to correct causative mutations within a patient's DNA, reducing the need for invasive surgery. Our software helps by identifying the best gene-editing approach to take, as well as using a patient's genomic profile to personalise the treatment. Our outcomes include several publications and news articles.

Transformational Bioinformatics: postdoc and student highlights

Postdoctoral highlight

Arash Bayat, Postdoctoral Researcher

Arash has pioneered the nexus of machine learning based genomics and advanced cloud architectures specifically adapted for research into complex genetic traits. He has followed through for VariantSpark to have demonstrated impact (publications, use-cases, partnerships), as well as designed and implemented auxiliary software to make the VariantSpark suite a full end-to-end offering for the bioinformatics community (PEPs, BitEpi). Read more on this suite in Transformational Bioinformatics: Platform Technologies.

PhD student highlight

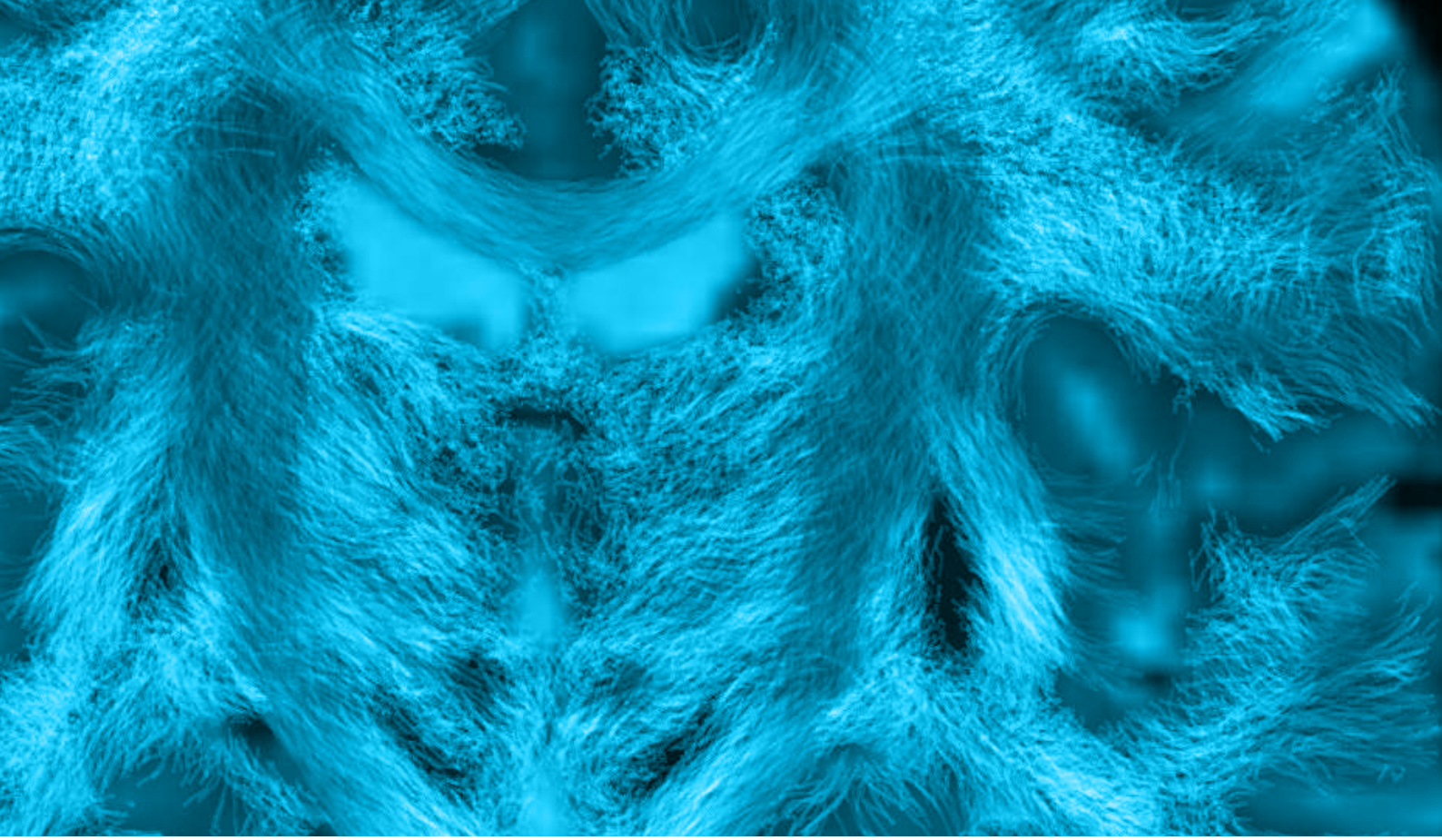
Aidan O'Brien, PhD student co-supervised with ANU

Genome editing includes inserting synthetic DNA into the genome at precise locations through CRISPR-Cas9 and homology-directed-repair. Being able to do this precisely and efficiently requires extensive computational optimisation. This project builds sophisticated machine learning models for researchers to identify optimal genomic locations for intervention (read more about GT Scan Suite in Transformational Bioinformatics: Platform Technologies). Together with the Australian National University's CRISPR facility, the computational tools will be validated on novel datasets to enable new application areas.

The Biomedical Informatics group

Group Leader: Jurgen Fripp

The Biomedical Informatics group develops and validates novel and advanced computational and statistical methods for use in medical research and clinical translation.
Our particular focus is on using medical imaging biomarkers, machine learning and statistical techniques that enable precision health (prediction, staging, prevention and treatment) when used in combination with various 'omics, neuropsychology, smart sensing and clinical phenotypes.
The developed techniques are deployed in hospitals and on our cloud informatics platform to be used in a wide range of large observational and randomised controlled trials across the human lifespan (from pregnancy to ageing) and across the disease spectrum (including osteoarthritis, cerebral palsy, cancer and dementia).



Biomedical Informatics' science and impact highlights for 2019/20

- Over 100 men at two hospitals have received radiation therapy for localised prostate cancer based on our MRI conversion software. MRI allows better identification of soft tissue organs and is more accurate than traditional CT scanning. Results showing the successful clinical use of this technology in a prospective multi-centre clinical study were published.
- Each year in Australia, approximately 600 infants are diagnosed with cerebral palsy, usually at around 19 months. Early detection of at risk infants would allow for improved diagnosis and prognosis. In collaboration with the University of Queensland, we have now recruited more than 500 infants for brain MRI in the neonatal period and more than 100 children aged over 6 years. This research will enable timely, effective interventions.
- Our patented cloud based Computational Analysis of PET (CapAIBL) was extended to include the centiloid quantification approach. This was validated on post-mortem data and published in Alzheimer's Research and Therapy.
- Our group delivered on an increasing number of projects from across an extensive network of collaborations, including several large NHMRC clinical studies and trials. The recognition of our capabilities in clinical study data management is increasing with multiple studies requesting and relying on our support and expertise.
- We performed validation on the world-best blood based biomarker for Alzheimer's disease pathology across two cohorts. We performed analyses on both cross sectional and longitudinal analyses validating ~90% accuracy for the blood based biomarker to predict Alzheimer's disease pathology.
- More than 40 journal publications.

Biostatistics team

Team Leader: James Doecke

The Biostatistics team works within a plethora of different projects across a wide array of medical data. We have specialists in bioinformatics that trawl gigabytes of genomics data, imaging specialists who process and analyse medical imaging data, and biostatistical experts who investigate novel statistical methodologies then apply these to medical data to identify disease-specific relationships. Our collaborators rely on our specialist analytical collaborations to move their research from the bench to the bedside, from collecting data through publishing results in high impact journals.

Intelligent Imaging team

Team Leader: Jason Dowling

The Intelligent Imaging team works with clinicians, industry, and patients to develop, validate and translate: imaging based AI and machine learning tools for improved disease diagnosis; treatment planning and treatment delivery; blood-based diagnostics; and innovative new therapies. In collaboration with clinical partners, our team produces high-impact scientific research in a range of medical disciplines, including oncology, cardiology, radiology, sports medicine, respiratory physiology and orthopaedic surgery.

Neurodevelopment and Plasticity team

Team Leader: Dana Bradford

Our focus is on developing imaging techniques that provide enhanced information about neuropathology for improved detection and diagnosis leading to a better understanding of prognosis for neurodevelopmental disorders and brain trauma. We aim to use advances in neuroimaging to measure localisation and extent of neuroplasticity in response to evidence-based interventions.

Neuroimaging team

Team Leader: Vincent Doré

The Neuroimaging team members use their deep knowledge of medical instrumentation, image processing and machine learning algorithms to automatically extract and present pertinent information from medical image data, both at the scale of populations and individuals. The team contributes to image-based biomarker analysis for a number of large studies and supports a range of large Alzheimer's disease trials around Australia, including in the Alzheimer Dementia Network (ADNeT). ADNeT is part of Australia's quest to find cures and prevent and better manage dementia, involving a registry of clinical trial volunteers to fast-track research and translation. We are also partnering with Maxwell Plus in a CRC-P project to translate CSIRO's CapAIBL software in a new platform and to use machine learning methods to increase the throughput of reporting. This will involve EC approval of the software tool so it will be available for clinical use in nuclear medicine and radiology.

Biomedical Informatics: platform technologies

Medical image processing platform

We have developed software to handle a range of clinical use cases and different medical imaging modalities. This platform supports a range of supervised and unsupervised artificial intelligence and machine learning techniques to extract clinically relevant information or knowledge from medical images. This may involve tasks such as image enhancement, feature detection, tissue segmentation, registration and normalisation, shape appearance and relationship modelling, classification and clustering, comparisons of groups, and investigation of longitudinal changes. These tasks are generally fully automatic and involve a combination of statistical, machine and deep learning methods.

The platform leverages open source image analysis libraries such as ITK and VTK, and consists of both C++ and Python libraries. Software using this platform has been deployed and used for clinical diagnosis and treatment in trial settings. This platform has been used in various projects including musculoskeletal image analysis and MR-alone radiation therapy; read more in Biomedical Informatics: Project Reports and Project Updates.

AWS data collection platform

Collection of data (personal and medical) is the most important step in any study or clinical trial concerning human health. Effective data collection requires an electronic platform that allows for ease of use but is also secure and adheres to legal and ethical rules and regulations. With many studies and trials that we work on being multi-centre, there is a need for a highly available, web-based platform that can be customised and optimised for each study.

We built this data collection platform using a collection of open source and in-house software systems. Electronic data capture is handled using RedCAP. An in-house system has been built for storing personal information and linking these to project identifiers. Along with other project specific modules (e.g a volunteer portal), the platform is implemented on the Amazon Web Services (AWS) cloud platform.

Our implementation will allow us and our collaborators to more effectively perform data collection in the numerous studies we are involved in. Moreover, being a bespoke collection of tools, we can easily expand and customise any new implementation, thus providing us with a truly flexible system. This platform is undergoing user evaluation and feedback for ADNET and PISA. It is principally being used for the AIBL/ADNET and PISA projects; read more in Biomedical Informatics: Project Reports and Project Updates.

MilxCloud: cloud image analytics

Recent developments in medical imaging have allowed the in-vivo examination of brain pathology associated with Alzheimer's disease, such as Aβ plaques, glucose metabolism, cortical atrophy and more recently, tau tangles. PET imaging allows the detection of the pathology of Alzheimer's disease decades before the onset of clinical symptoms and provides invaluable insight into the development of the disease, while MRI provides useful information of the neurodegeneration. In-vivo brain imaging has then an increasingly important role in therapeutic trials.

This method has been implemented as a workflow in the Galaxy framework (galaxyproject.org) to move the milxview computation to a cloud environment. PET or MRI images are uploaded to a cloud-based platform where they are analysed. A PDF report containing quantifications, along with surface projection of the biomarker is automatically generated and emailed to the user. An evaluation version of the tool is available at milxcloud.csiro.au.

The web-based implementation of our tools allows result scanning and analysing to be performed in two different sites. The Z-score display of our report allows a universal visualisation and comparison of tau and Aβ imaging PET scans. It allows the report to be sent and reviewed by a specialist not specifically trained for the tracer used for scanning. It will allow reducing the cost of analysing PET scans and will provide wider access to tau and Aβ imaging scan, including to Australia's remote areas.

Registered users can use quantification for all amyloid PET, atrophy quantification and hyper intensity segmentation. We have been working on the new harmonisation of PET quantification, which will be implemented in the next version. It is principally being used for the AIBL/ADNET and PISA projects; read more in Biomedical Informatics: Project Reports and Project Updates.

AssessCP

We have developed software to extract quantitative information from MRIs of children with brain injury, such as those with cerebral palsy, acquired brain injury and Autism Spectrum Disorder. Using a range of artificial intelligence and machine learning techniques that include image alignment to a standard space, brain tissue segmentation, shape modelling and clustering, we can extract measures of anatomical volume, cortical shape, and lesion burden. These quantitative measures are then provided in an automatically generated PDF report to clinicians, to illustrate where the patient sits relative to an age-matched typically developing cohort.

The software methods leverage open source Python libraries, as well as C++ image analysis libraries such as ITK and VTK. The overall pipeline is implemented as a part of the MilxCloud environment, removing the need to install any third-party software. Once complete, the resulting PDF report is emailed to the user. An evaluation version of the tool is available at milxcloud.csiro.au.

This software has been deployed and used to quantify differences in brain structure pre- and post-motor rehabilitation intervention, and to elucidate subtle differences in brain structure associated with genetic markers associated with cerebral palsy. It has been used in cross-sectional and longitudinal (i.e. intervention) studies of paediatric cohorts in collaboration with the Queensland Cerebral Palsy and Rehabilitation Research Centre, including Mitii, Mitii-ABI and HABIT-ILE.

Biostatistics and bioinformatics with ML and AI

Our team works on multiple reports with collaborators using large data sets. Collaborators and team members design statistical analyses plans (SAPs) to investigate the data as per collaborator research priorities. Once the SAPs have been agreed upon, team members design, produce and deliver reproducible reports using machine learning and artificial intelligence (ML and AI) methods to trawl through the data and investigate the collaborator research questions.

Team members use programming platforms such as R-Studio (with the R statistical environment) and Python (iPython) to design the statistical/bioinformatics workflow. When the data becomes too large for standard processing, certain packets of analyses are passed to the HPC, with results sent back to either Python or R. Typical ML/AI technologies used include Bayesian or Frequentist methods such as Bayesian Graphical Network (BGN), the Least Absolute Shrinkage and Selection Operator (LASSO), Random Forests, Mixture modelling, Generalised Boosted Trees etc.

Derivation of sets of biomarkers identified through the ML/AI technologies are consistently being used in journal publications and IP disclosures. An example is a provisional patent with the University of Melbourne where the ML/AI technologies identified a set of biomarkers to separate participants with Parkinson's disease from healthy controls with >85% accuracy.

Biomedical Informatics: project reports

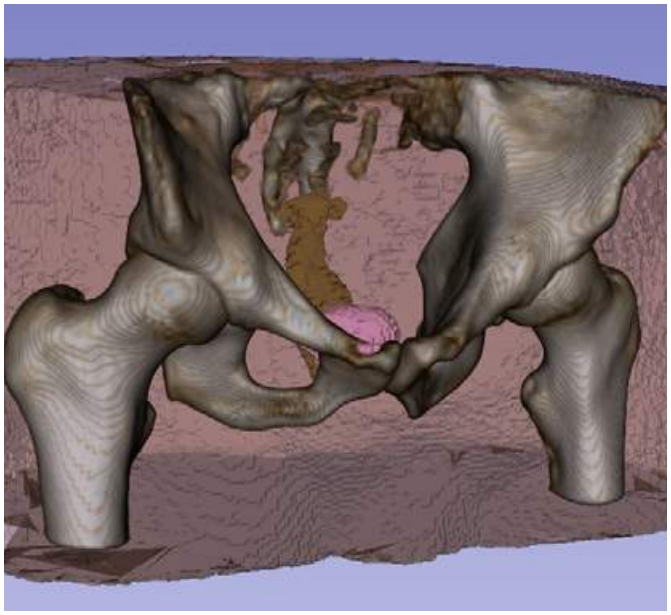
Australian Dementia Network (ADNeT)

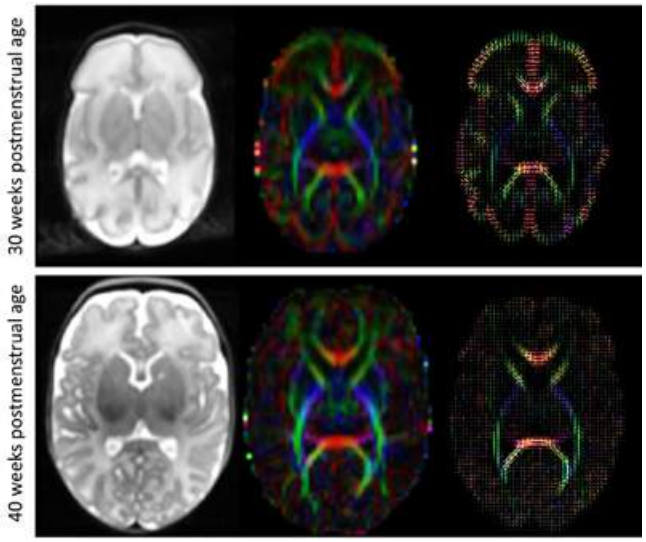
Collaborators: University of Melbourne, University of New South Wales, Monash University, Edith Cowan University, Flinders University, SAHMRI, University of Sydney, NeuRA, Macquarie University, QIMR Berghofer, University of Tasmania

The Australian Dementia Network (ADNeT: australiandementianetwork.org.au, PI Prof Rowe, University of Melbourne) is a large collaboration with 14 partners. It aims to improve quality of care and quality of diagnosis, and accelerate development of new therapies. One major outcome will be to establish an integrated network of dementia researchers, clinicians and health service providers to enable ongoing, high-quality translation of research into clinical care for Australians living with cognitive impairment and dementia. In addition, ADNeT will enable fast recruitment of trial-ready research participants, and will support participants through their involvement in clinical trials. This will be achieved through three main initiatives: an ADNeT registry, memory clinics, and screening and trials.

Technology support: We are providing the core data collection, storage and harmonisation for the whole ADNeT ecosystem as well as providing the image quantification and clinical translation for the thousands of medical images associated with this novel and far-reaching project.

Statistical analysis: Our Biostatistics team combines data from multiple modalities to answer clinical research questions. This involves using statistical methods to combine data from imaging, genetics, genomics, proteomics, neuropsychology and clinical biomarkers. The team works with national and international collaborators to investigate destructive pathological process in Alzheimer's disease.





Rapid development in the preterm brain is apparent comparing postnatal structural (left) and diffusion (middle/right) imaging taken between 29-35 weeks (top) and at 40 weeks (bottom).

MRI-alone radiation therapy planning for prostate cancer

Collaborators: Calvary Mater Newcastle Hospital, Liverpool Hospital

Modern image-guided external beam radiation therapy relies on computed tomography (CT) scans to predict radiation absorption and scattering during treatment delivery. However, MRI is considerably better than CT at identifying soft tissue boundaries, reducing side effects including damage to normal tissues such as the bladder and rectum, which can lead to rectal bleeding, incontinence, and erectile problems.

Collaborating with the Calvary Mater Newcastle Hospital and Liverpool Hospital, we developed software that integrates with existing radiation oncology workflows and automatically generates CT information and organ boundaries from standard MRI scans. This removes the need for both CT and MRI scans, and reduces the potential errors from combining the two scans. This will reduce side effects and increase the efficiency of prostate radiotherapy. The software uses a suite of artificial intelligence techniques to solve different tasks at each step through the process. Over two years we undertook a Phase II multi-centre prospective trial for 25 patients who received MRI-alone localised prostate cancer external beam radiation therapy. This trial was successfully completed and results have been published.

Predicting outcomes for infants born preterm

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre, University of Queensland

Very preterm infants are at high risk of adverse neurodevelopmental outcome, including motor and cognitive disabilities. In collaboration with the Queensland Cerebral Palsy and Rehabilitation Research Centre and the Perinatal Research Centre, we aimed to predict later neurodevelopmental outcomes of infants born <32 weeks gestational age from MRI scans acquired at 29-35 weeks post menstrual age (PMA) and approximately 40 weeks PMA (term equivalent age) and concurrent motor, neurological and neurobehavioural assessments.

This dataset was used for a number of analyses. Our team was the first to apply a relatively new analysis framework for advanced diffusion weighted brain MRI to a neonatal cohort. Using this framework, we demonstrated that brain microstructure and morphology of preterm infants without apparent brain injury was altered compared to that of term born infants. We also identified that several brain regions were associated with later motor and cognitive outcomes at one and two years corrected age. These findings indicate that infants with higher information transfer capacity at term equivalent age have better neurodevelopmental outcomes, and may also have a higher capacity for retaining or improving their performance on developmental assessments.

Using a convolutional neural network approach, we predicted the “brain age” of preterm infants and proposed the deviation between “brain age” and “actual age” as a potential indicator for later adverse outcomes. Using the same approach, we demonstrated that adverse motor outcome at two years corrected age can be predicted directly from brain MRI acquired at 29-35 weeks PMA. Taken together, our work provides novel insights into early brain development and presents an important step toward early prediction of adverse outcomes, enabling earlier intervention for at-risk infants.

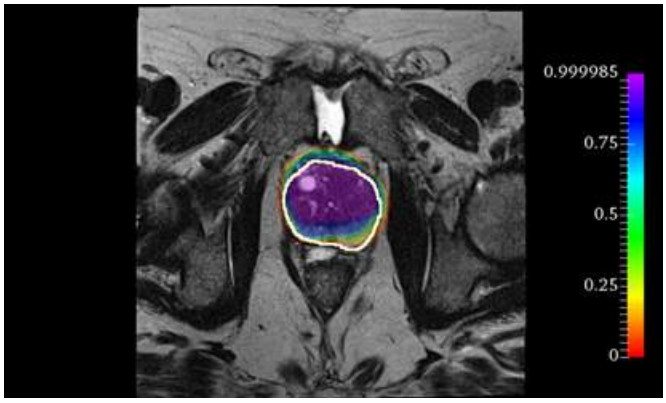
Biomedical Informatics: project updates

Improving radiotherapy treatment clinical trial quality assurance

Collaborators: Ingham Institute, Liverpool Hospital

This project is a collaboration with the Ingham Institute and the Liverpool Hospital, NSW, and is supported by a three-year CSIRO R+ postdoctoral fellow position. This project involves developing new artificial intelligence methods, for both real-time quality assurance for clinicians, and for mining large clinical oncology datasets to discover new relationships between patient characteristics, treatment delivery and treatment outcomes. The use of automated software to validate the quality of data against clinical protocols has the exciting potential to improve recommendations from clinical trials, identify contouring inconsistencies in real time, and to normalise retrospective trial results.

One of the main challenges in radiation therapy trials is the very limited number of "gold truth" expert contours, particularly for deep learning models. To date, the project has focused on transfer learning from models trained from larger datasets and modifying these with a smaller set of augmented expert contours.



Probabilistic estimate of MRI manual prostate contouring accuracy from the PROMETHEUS trial.

Musculoskeletal image analysis: ChondralHealth

Collaborators: University of Queensland, Siemens Healthineers

The ChondralHealth project aims to develop image processing techniques for MRI of human joints (knee, hip and shoulder) for non-invasive assessment of common chronic conditions including osteoarthritis. We have developed algorithms for automated segmentation of joint cartilages from MRI scans and used these to identify morphological and biochemical quantitative descriptors of cartilage health. We are running a clinical trial with the Steadman Philippon Research Institute, USA, to validate these measures in a pre-clinical setting.

Our methods for bone and cartilage segmentation are utilised in the "MR Hip Intervention and Planning System" (mrHIPS) project which enables bone lesion and soft tissue visualisation and quantification, and a framework for modelling of hip joint kinematics. These models have been enhanced through image acquisition using the 7T MRI scanner at the University of Queensland. Both projects have been supported by Siemens Healthineers, Germany, who assist with translation of the technology to clinical environments.

MRI-based paediatric lung structure and function assessment

Collaborators: University of Queensland, Queensland Children's Hospital, Siemens Healthineers, Herston Imaging Research Facility

This project aims to improve health outcomes for children with cystic fibrosis (CF) and ataxia-telangiectasia (A-T) by using MRI to provide information on lung status.

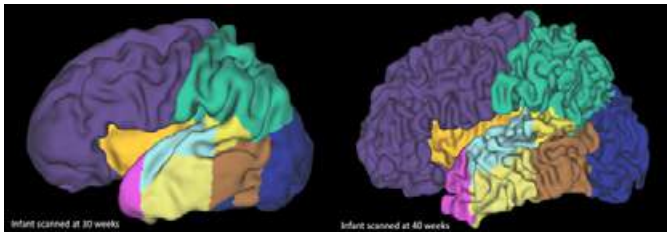
Currently the most informative method for lung imaging in children with CF is computed tomography (CT) scanning. CT scans combine a large number of X-ray images, and repeated CT scanning increases a child's cancer risk due to the radiation dose delivered. For this reason children currently only have CT scans every two years, during which time untreated, asymptomatic infections can permanently damage their airways. Clinicians are also unable to quickly and accurately evaluate response to treatment. Meanwhile, children with A-T are extremely radio-sensitive and cannot have CT scans. Non-invasive monitoring of disease progression and treatment response is vitally important in managing disease onset and extending life for these patients.

To address this clinical need we are developing image acquisition methods and software to extract quantitative disease status metrics from MRI. This work has been supported by a three-year CSIRO postdoc grant and external funding from the AT Children's Project, the US CF Foundation, and a recent 2020 NHMRC MRFF grant.

Advanced neuroimaging to enable earlier detection of adverse neurological outcomes in high-risk infants

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre (University of Queensland), Monash University, Herston Imaging Research Facility

With collaborators from Queensland Cerebral Palsy and Rehabilitation Centre and Monash University, with whom we previously acquired one of the largest cohorts of infants born preterm, we are working towards developing a set of advanced MRI analyses to predict two-year-old infants' developmental "fingerprint" from images acquired close to birth. The technical development of this project is still in progress, however recent advancements



Cortical surface segmentation using a modified version of the developing Human Connectome Pipeline, illustrating the rapid cortical development of an infant between 30 and 40 weeks gestation age.

have been establishing a pipeline for performing super-resolution of the clinical sequences, and performing segmentation of the cortical and subcortical brain regions. In addition, we have submitted an Ideas grant application based on this project to the NHMRC.

The eventual aim of the toolbox is a cloud-based "Developing Brains toolbox" to provide clinicians with a standardised clinical report that will would allow for earlier diagnosis of developmental disorders, facilitating earlier interventions when the brain can better recover from injury.

Innovative web-based clinical decision support tool for paediatric brain injury

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre (University of Queensland), IRCCS Stella Maris Foundation

Working with research and clinical collaborators from Queensland Cerebral Palsy and Rehabilitation Research Centre and IRCCS Stella Maris Foundation, this project aimed to develop a suite of new image processing methods for analysing brain MRIs of children with severe brain injury, such as those with cerebral palsy and acquired brain injury, and provide a standardised clinical report on the quantitative findings. These methods have been developed, with publications on the methodologies published in NeuroImage and Human Brain Mapping in the past 12 months and are currently being validated on a cohort with Autism Spectrum Disorder.

This project has resulted in the development of the AssessCP cloud-based tool, available on AEHRC's MILXcloud framework for use by our collaborators, and is currently being used in several research studies including HABIT-ILE, PREDICT and PREBO-6. Read more on AssessCP in Biomedical Informatics: Platform Technologies.

Be Clear Online: speech treatment for adults with non-progressive dysarthria

Collaborator: University of Queensland

Dysarthria is a motor speech disorder characterised by slow and uncoordinated movements of the speech musculature, resulting in decreased speech intelligibility that may impact on social participation. Be Clear is an intensive clear speech treatment program developed by the University of Queensland, based on principles of neuroplasticity and motor learning. It involves intensive practice on salient communication topics, a randomised practice schedule, and an external focus of attention on clarity. An online version of the program has been developed by the RECOVER Injury Research Centre.

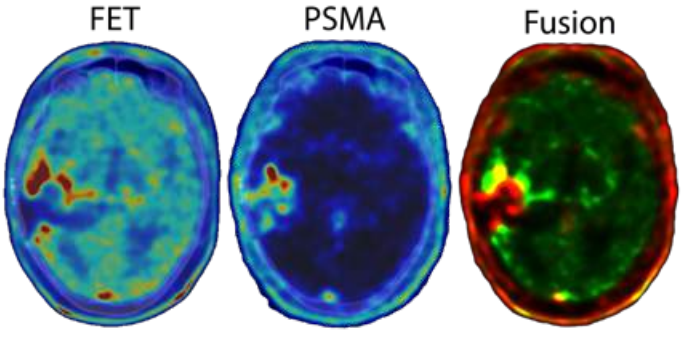
To investigate the impact of this online program on neuroplasticity in the speech production pathways, we are conducting tractography analysis of the bilateral ventral and dorsal cortico-bulbar tracts and bilateral hand related cortico-spinal tracts to determine any microstructural changes. It is envisaged this work will contribute to a body of knowledge of neuroplasticity underpinning speech recovery.

Developing theranostics for difficult-to-treat cancers

Collaborators: GenesisCare, CSIRO Manufacturing, Royal Brisbane Hospital Department of Nuclear Medicine

A $5.1M partnership between CSIRO's Probing Biosystems Future Science Platform and cancer care provider GenesisCare aims to develop new cyclic peptide theranostics for difficult to treat cancers, and to access GenesisCare's national clinical network for rapid translation of new theranostics into first-in-human trials. This project involves discovery of new theranostic targets through bioinformatics analysis of more than 11,000 patient samples covering 32 different cancers. In collaboration with CSIRO Manufacturing, we are isolating high affinity binders to new targets through panning of cyclic peptide phage display libraries containing more than five billion binders.

The project is further supported by a collaboration with the Royal Brisbane Hospital Department of Nuclear Medicine to develop radiochemical methods for labelling new cyclic peptides with positron emitting isotopes for PET imaging and alpha- and beta-emitting isotopes for therapeutic applications.



Co-registered 18F-FET and 68Ga-PSMA images acquired in a patient with high grade glioma.

Anatomically-Guided Nuclear Medical Imaging Reconstruction

Collaborators: University College London, Herston Imaging Research Facility

In epilepsy, accurate localisation of seizure foci allows superior surgical planning. PET is an available tool to locate the seizure focus, however can be limited by resolution. Combining with high resolution MR allows the synergistic advantages of MR resolution and PET functional imaging to be combined.

In collaboration with University College London, this project will consist of three overarching research objectives:

- Technical developments required to overcome existing challenges in PET/MR analysis
- Validation, optimisation and integration of this workflow for several clinical use cases and seamless integration to the PET/MR scanner at the Herston Imaging Research Facility
- Prospectively evaluate the clinical utility of the workflow in interictal epilepsy FDG-PET, by comparing with standard clinical care.

Healthy ageing and Alzheimer's disease research

Collaborators: Austin Health, Florey Institute of Neuroscience, McCusker Alzheimer's Research Foundation, Edith Cowan University, Macquarie University

Neurodegenerative diseases are a group of age-related brain illnesses that result in progressive loss of brain tissue and cognitive function. Early detection is a critical component to developing effective treatment for various forms of these diseases, including Alzheimer's disease, as it allows interventions before widespread and irreversible tissue loss. The primary pathway for early detection is through identification of neuropathology biomarkers derived from neuroimaging.

Our Neuroimaging team combines knowledge from collaborating physicians with deep knowledge of medical instrumentation, image processing and machine learning algorithms to automatically extract and present pertinent information from medical image data both at the scale of populations and individuals. We provide automated quantification of such biomarkers to collaborators at Austin Health, the Florey Institute of Neuroscience, McCusker Alzheimer's Research Foundation, Edith Cowan University, and Macquarie University as part of the Australian Imaging and Biomarker and Lifestyle (AIBL) study, KARVIAH, 3D and ToTAL studies. Within these collaborations we have provided strong evidence that Aβ-amyloid plaque accumulation commences 10-20 years before clinical symptoms, highlighting a significant window for pre-clinical treatment.

Prospective Imaging Study of Ageing (PISA): genes, brain and behaviour

Collaborators: QIMR Berghofer, University of Queensland

PISA studies the interplay between genetic, epigenetic and environmental factors for dementia, and also aims to identify risk factors that could be modified through intervention, such as lifestyle choices. The study, performed in collaboration with QIMR Berghofer, is a unique international research resource providing new links to studies into the causes of dementia, assisting clinical trials in dementia prevention and bringing about new possibilities for translational research into this important public health issue.

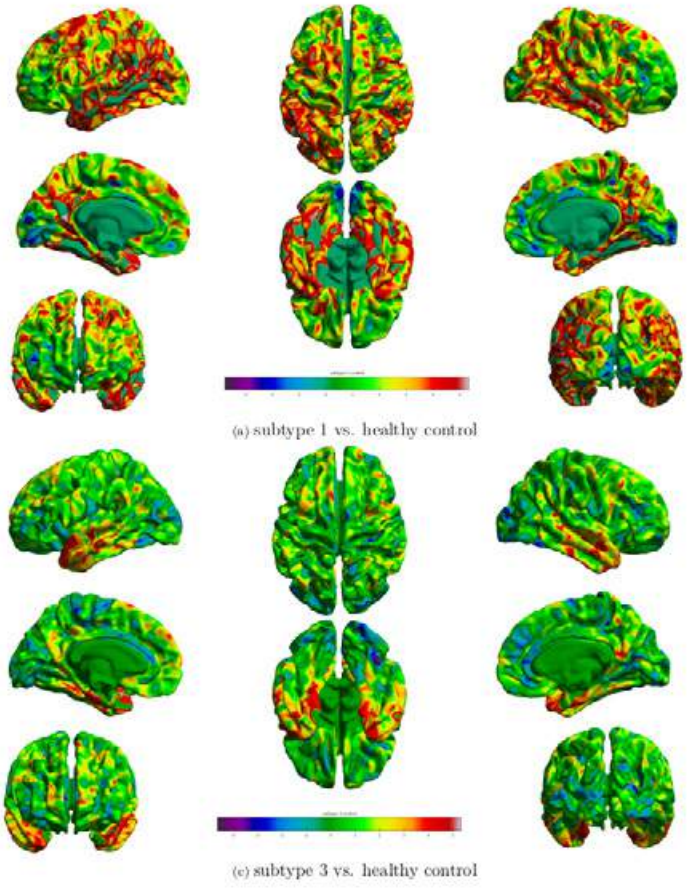
We are applying cutting edge imaging technologies to examine the neurobiological features associated with high risk for dementia, and identify the changes that lead to a patient's transition from high risk to cognitive impairment. The combined use of genetic risk scores and neurobiological markers creates a potential prognostic marker for dementia development. Outcomes of the study will inform and establish a platform for future intervention programs that target preventing and treating dementia. Currently the baseline cohort of 293 subjects has been recruited for the PISA imaging study.

Sterling's Dream: cholinergic degeneration

Collaborators: The Prince Charles Hospital, Queensland Brain Institute (University of Queensland)

Cholinesterase inhibitors (ChEI) are a major class of cognitive enhancing drugs designed to target the symptomatic treatment of Alzheimer's disease. This is based on the knowledge that cholinergic degeneration of the basal forebrain is a hallmark pathological feature of Alzheimer's with specific vulnerability to amyloid-beta (Aβ). Despite widespread use in clinical practice, in reality only 30-35% of patients respond to treatment. The ability to identify patients who will respond to ChEI using biomarkers would significantly impact treatment and policy guidelines for the use of these cognitive enhancing drugs.

In collaboration with Queensland Brain Institute and The Prince Charles Hospital, we are investigating novel PET tracers to gain a better understanding of the differences in the characteristics of healthy brains compared with those with early stages of Alzheimer's disease. The current cohort of 17 participants underwent the baseline PET imaging using florbetaben (FBB; for amyloid) and FEOBV radiotracers (90 and 180 minutes post bolus injection). High resolution 3D structural MRI scans were acquired for analysis. Follow-up cognitive assessment will be performed including post-cholinesterase inhibitor therapy. Aβ depositions were automatically quantified in FBB PET data using CapAIBL. Future work will derive a novel biomarker based on FEOBV images and investigate its association with cognitive performance and imaging biomarkers of Alzheimer's disease.



Identified Alzheimer's subtypes compared with healthy control. Shown are statistical p-maps corrected for multiple comparisons (FWE p<0.05).

Identifying Alzheimer's disease brain atrophy subtypes by deep learning

Collaborators: AIBL, CSIRO's Precision Health Future Science Platform

Alzheimer's disease (AD) is a heterogeneous disease with multiple different clinical and pathological characteristics. Characterising the heterogeneous nature of AD could allow clinicians to provide more precise diagnosis and tailored treatments.

Existing approaches fall into two categories. One class relies on the prior diagnosis of disease subtypes, where accurate and reliable clinical labels are difficult to acquire. Another class puts emphasis on the voxel-based similarity between subjects, which suffers from low statistical power. In order to tackle the aforementioned limitations, it is necessary to develop a data-driven approach that can automatically identify distinct pathological patterns and separate the samples into different groups.

Therefore, we propose a data driven deep neural network clustering approach used to identify AD subtypes based on cortical thickness. The proposed method successfully identifies clinically distinct anatomical subtypes. It remains to be determined in future studies whether this subtyping approach can be applied at earlier stages.

Alzheimer's Dementia Onset and Progression in International Cohorts (ADOPIC)

Collaborators: ADOPIC/NIH grant with Melbourne University, Washington University, ADNI, AIBL, ADNeT

ADOPIC is a NIH-funded project that involves harmonising retrospective data from three large international longitudinal cohorts, including AIBL. After harmonisation, statistical approaches will be used to investigate onset and progression of various biomarkers. Data including medical imaging, CSF biomarkers, whole genome sequencing and neuropsychological data are being merged from AIBL, the ACS and ADNI. The aim of this project is to combine data from all three cohorts for those participants who have had three or more data collections. Once these data are collected, cleaned and harmonised, analytical assessment of disease related changes in biomarkers over time will be assessed.

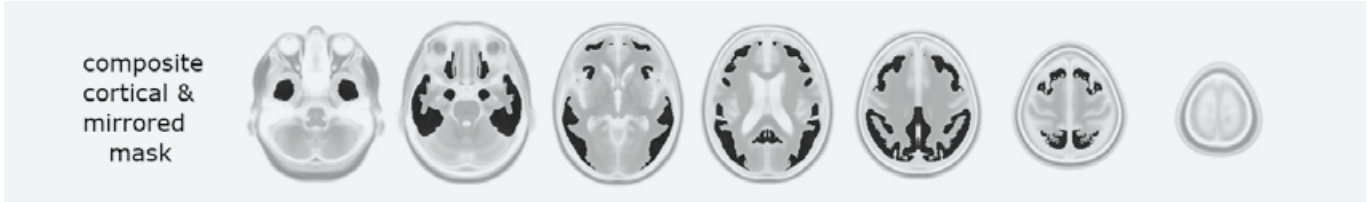
As expectations increase for data-driven knowledge and understanding, it is necessary to consider data streams in combination with each other, not as silos, to provide improved classification, categorisation of comorbidity burden, diagnosis and prognosis at the individual level. This requires increased sample sizes as the complexity increases which in turn requires harmonisation of data across studies and markers.

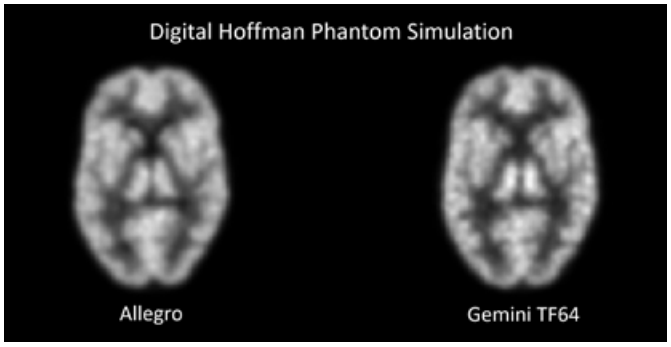
Universal tau sampling mask

Collaborator: Austin Hospital

The introduction of the Amyloid/Tau/Neurodegeneration (A/T/N) framework raised several issues in regard to the definition of T+. Where should tau scans be sampled? Based on which tracer?

We constructed a "universal" tau mask for the Alzheimer's disease continuum based on three commonly used tau tracers aiming at standardising tau sampling (and quantification) across tracers and across centres. The "universal" tau mask can also be sub-segmented into smaller regions to focus on specific areas or to construct a subset of composite masks that might better capture early tau deposition and spreading. Further refinement of the tau mask will require the addition of more tau tracers (RO948, GTP1, PBB3, etc.)





Preliminary results showing the output of the simulation of the digital Hoffman phantom on two different cameras (Allegra and Gemini TF64).

PET camera harmonisation

Collaborators: ADOPIC/NIH grant with Melbourne University, Washington University, ADNI, AIBL and ADNet

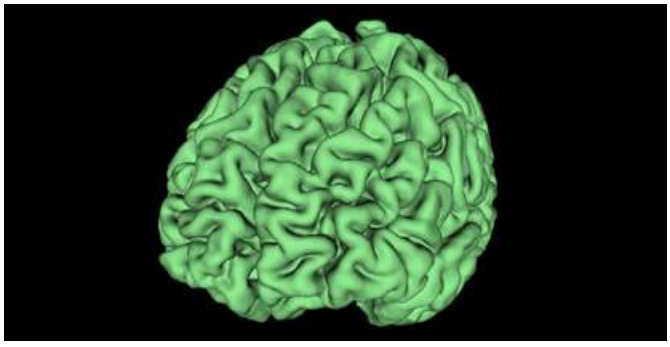
Positron emission tomography (PET) neuroimaging allows the in vivo assessment of brain function and pathology changes. It has been increasingly used in dementia to assess the presence of Aβ and tau pathologies. However, there is a known effect of the scanner and of the reconstruction algorithm on these biomarkers' quantification. This project aims to correct PET biomarker quantification for the scanner and reconstruction variability to provide fully standardised and accurate quantifications.

We are developing a new platform to simulate the characteristics of different PET scanners. This will allow us to measure and minimise inter-scanner variability. The proposed platform consists of three modules: phantom generation, PET physics simulation, and reconstruction modules.

UK Biobank: functional connectivity patterns and depressive symptoms

Collaborator: QIMR Berghofer

Biomarkers for depression are not well understood as there is no baseline measure of what is normal or abnormal. The large heterogeneity observed in depressive symptoms is indicative that diverse circuit level abnormalities could contribute to similar symptoms of depression. We have used our deep learning approaches to evaluate the spatio-temporal information from a large number of functional MR images in the UK Biobank study. We used this technique to accurately subgroup individuals with differing functional connectivity patterns into three different subtypes of depressive symptoms.



Example of a reconstructed surface from an MR image.

Cortical surface reconstruction from brain MR images

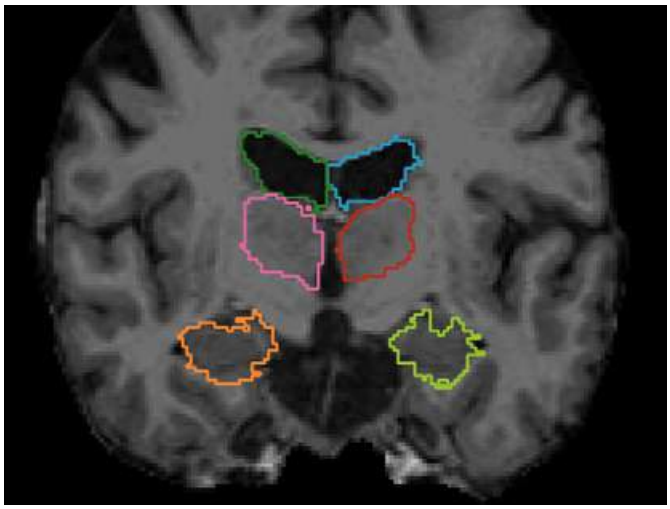
Collaborators: Queensland University of Technology, Maxwell Plus

An important step in the quantitative analysis of the human brain structure, like studies in sulcal morphometry and cortical thickness, is the reconstruction of the cerebral cortex from magnetic resonance (MR) images. However, the existing cortical reconstruction approaches have their applicability limited by the large processing time needed and resolution obtained. Aided by recent advances in deep learning, we aim to develop fast and accurate techniques for cortical surface reconstruction from MR images with applications in cortical thickness estimation and parcellation.

Cubic B-spline based interpolation for medical imaging

Collaborators: Queensland University of Technology, Maxwell Plus

An omnipresent step in medical image processing is the transformation of anatomical images during, for instance, registration, zooming, and resizing. While elaborated interpolation methods have been developed with



Example MR coronal slices with six parcellations ventricles (blue/dark green), thalami (red/pink), and hippocampi (lime/orange). The image shows the prediction with VoxelMorph with cubic B-spline.

CPU implementation, the latest high-end deep-learned powered medical image computer systems are built upon rudimentary interpolation methods (i.e. nearest neighbours, linear interpolations). To alleviate these limitations, we developed a backpropagable and numerically affordable GPU version of cubic B-spline interpolation. In order to validate the enhancements brought by this change of interpolation technique, we benchmark two models for patient-to-patient MR image registration using a self-supervised registration method VoxelMorph.

Neuropsychology and its disorders

Collaborator: Biogen Inc.

Investigation of the rates of cognitive decline in an ever-ageing Australian population is a difficult task. In collaboration with the AIBL neuropsychology team, we recently published work on a cognitively normal population showing that visuospatial measures of cognitive function were able to separate older Australians who were cognitively normal but had Alzheimer's disease pathology. The results showed progressive decline in visuospatial function was an early identifier of coming changes in cognition, a validation of what has been seen internationally.

Further to this, many projects within AIBL look at blood, CSF and medical imaging biomarkers as tools to predict those that decline quickly over time. Working with the pharmaceutical company Biogen, we showed that early decreases in hippocampal volume was a predictor of those participants with fast changes (over 18 months) in both MMSE and the clinical dementia rating sub of boxes score.

Biomarkers for Parkinson's disease

Collaborator: University of Melbourne

Working with collaborators at the University of Melbourne, our research identified a key combination of blood-based biomarkers to predict Parkinson's disease with 86% accuracy, a large change from individual biomarkers which provided a maximum accuracy of 70%. The biomarkers were key metabolites of the Kynurenine pathway which has been shown to be disrupted in many other conditions. Interestingly many of these biomarkers were specific to Parkinson's disease and were not altered in Alzheimer's disease.

Instrumental relationships with pharmaceutical companies

Collaborators: Roche, Eisai, Biogen, Abbvie

We have projects with large international pharmaceutical companies Roche, Biogen, Eisai and Abbvie to assess both the early detection of biomarkers predictive of Alzheimer's disease (AD) pathology, and the cognitive trajectory of the disease from its very early stages (prodromal and pre-clinical) through to late stage clinical AD. Research is focused around changes in cognition, blood and CSF-based biomarkers and pathological proteins via PET imaging. Along with collaborators from world-leading laboratories, our team members are instrumental in round table discussions to discuss the best way forward in conducting research across multiple countries. Our work with Biogen was used as background for their FDA application for the first treatment for AD.

Saliva and plasma biomarkers separate healthy individuals from those with AD

Collaborator: CSIRO Nutrition and Health

Using a small cohort of healthy volunteers alongside a small cohort of people diagnosed with Alzheimer's disease (AD), collaborators Wayne Leifert and Maxime Francois in CSIRO Nutrition and Health designed biomarkers to target metabolites and proteins that may be altered in AD. Statistical analyses led by our Biostatistics team identified 100% separation accuracy in certain biomarkers from saliva and plasma, and results are being validated in a separate population.

CSIRO-designed vitamin formulations reduce DNA damage biomarkers

Collaborators: Pfizer, CSIRO Nutrition and Health

Working with Dr Michael Fenech (Pfizer) and Dr Caroline Bull (CSIRO Nutrition and Health), our Biostatistics team showed that a novel vitamin formulation reduced DNA damage biomarkers in cells deficient of homeostatic vitamins. The study showed DNA damage levels that were increased in vitamin deficient cells were reduced to that from normal cells, a world-first for a vitamin formulation.

Biomedical Informatics: postdoc and student highlights

Postdoctoral fellows

Lee Reid

CONSULT - guiding neurosurgery

Collaborators: Royal Brisbane and Women's Hospital, University of Valencia, and Hospital Clinic, Barcelona. Funders: Advance Queensland (Research Fellowship), the Royal Australian and New Zealand College of Radiologists, and RBWH Foundation (Diamond Care Grant).

CONSULT aims to reduce adverse events in neurosurgery by using cutting-edge brain mapping techniques, including advanced imaging. The software produces a 3D model of a patient's brain and wiring patterns so neurosurgeons can plan the safest angle and depth to perform brain surgery without inducing critical injuries. CONSULT has been evaluated in over 20 participants that have undergone neurosurgery and has been tested for safety using over 500 normative datasets from public repositories.

Timothy Cox

Constructing multivariate disease curves

Using as a base the four-step method for construct single variable trajectory disease curves, previously proposed by our group, Tim developed a five-step method for constructing multivariable curves from multivariate longitudinal data. The method allows the staging of different disease variables and estimation of individuals' progression along the disease trajectory. Tim has applied the five-step methods to construct the disease trajectory curves for the results of a set of cognitive tests from the ABIL dataset. Testing found that the CVLT test results declines first followed by LMII and then BNT, the results of the MMSE and CDR-SOB then decline and increase respectively together later.

Rosita Shishegar

Harmonising longitudinal measures of cognition across two large cohorts of Alzheimer's disease: AIBL and ADNI

As part of an international NIH-funded project, Rosita Shishegar has proposed a method for constructing databases that allow integration of cognitive data from the different cohorts wherein the original or initial data remain unchanged. The developed data harmonisation method (i.e. non-parametric multivariate imputation using random forests (missForest)) was employed to impute missing data on the basis of an underlying latent structure of cognition reflected in performance on the cognitive tests in the different neuropsychological test batteries used in the AIBL and ADNI cohort studies.

Scores for tests administered in one cohort but not the other were imputed in the cohort for which they were missing. For example, the Rey Auditory Verbal Learning Test (RAVLT), not administered in AIBL, was imputed for AIBL and the California Verbal Learning Test (CVLT-II) not administered in ADNI, was imputed for ADNI. This resulted in similarly high levels of significant discrimination ($p<0.001$) between clinical classifications for both the actual and the imputed scores of the CVLT-II and RAVLT.

PhD student profiles

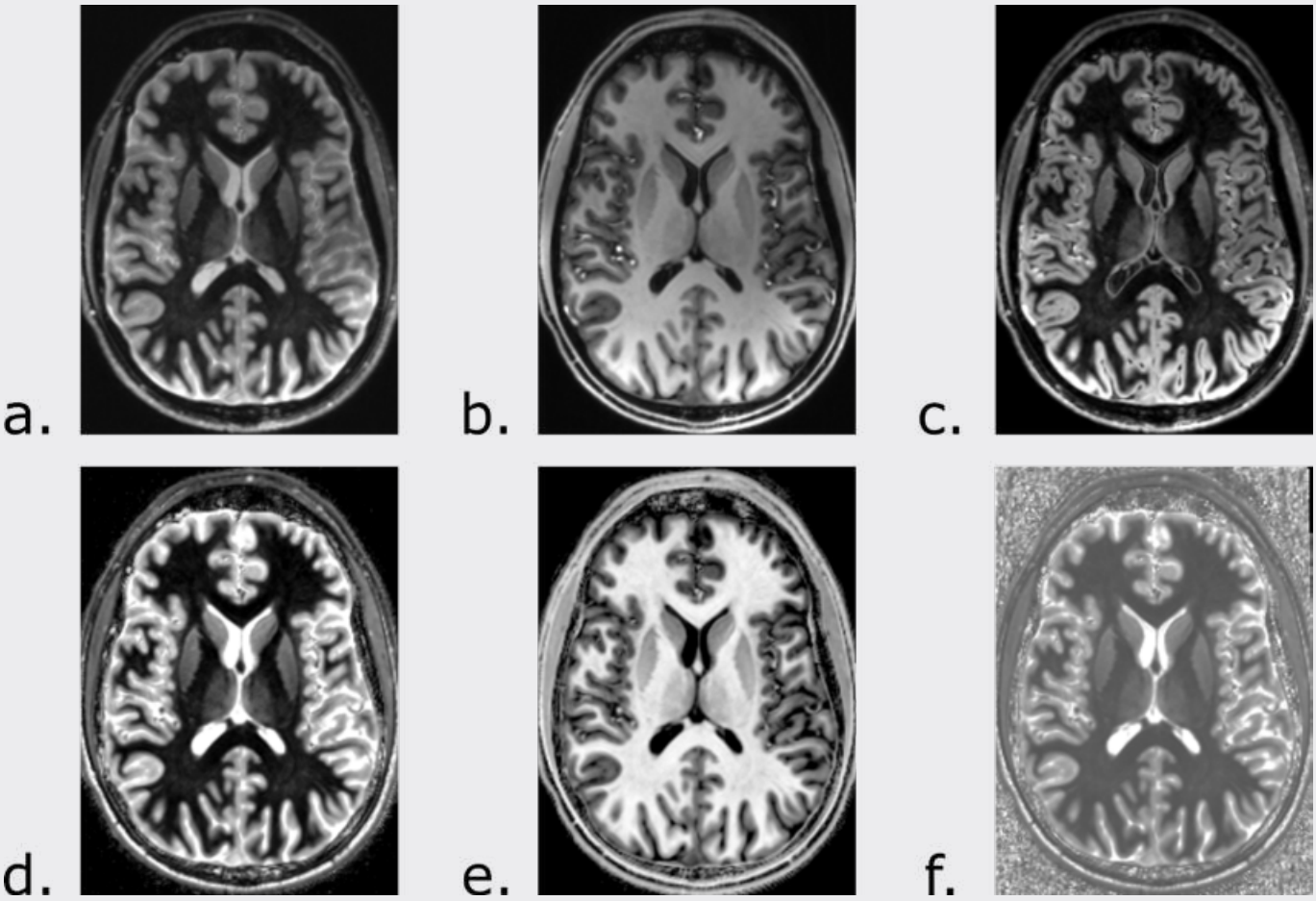
Jeremy Beaumont

Towards new means of performing multi-T1w contrast imaging and T1 mapping of the brain with the Fluid And White matter Suppression (FLAWS) magnetic resonance sequence

The acquisition of magnetic resonance (MR) images with different contrasts (T1, T2, diffusion, ...) is today a standard procedure in both research and clinical practice. Typically, images are acquired in separate measurements, then pre-processing steps are needed to spatially normalise the data before analysis. In this context, magnetic resonance imaging (MRI) sequences that provide, in a single acquisition, co-registered datasets with different contrasts are of interest to reduce the amount of data processing and to minimise loss of information due to interpolation and other possible confounding effects. This PhD project focuses on the Fluid And White matter Suppression (FLAWS) sequence to provide multiple co-registered T1w contrasts and T1 maps of the brain in a single MR acquisition.

A method was developed to optimise the FLAWS sequence with a physical model based on the use of the Bloch equations. This optimisation method allowed to provide parameters to acquire FLAWS images at the magnetic field strength of 1.5T and 7T, where no optimisation of the sequence was proposed. This optimisation method is currently being investigated to provide fast FLAWS acquisitions (6 mins instead of 10 mins) using new image reconstructions techniques such as compressed sensing.

A new FLAWS image reconstruction was proposed to provide multiple T1w contrast with a reduced sensitivity to the bias induced by the MRI coils. We demonstrated that the new images obtained from that new reconstruction method allowed to measure the T1 relaxation time of tissues for quantitative imaging.



Example of FLAWS images acquired at 7T.

The Health Services group

Group Leader: Mohan Karunanithi

The rapid uptake of mobile, sensor and Internet technologies is changing the way services are provided and accessed in all walks of life – including health services.

Our Health Services researchers work closely with clinicians and consumers to develop innovative care delivery models to address the burden that chronic diseases/conditions and aged care are placing on the health system. To achieve this, our teams test and validate technology-based care delivery models of mobile- and tele-health to manage conditions such as eye-diseases, cardiovascular diseases, diabetes, ageing and hip replacements.

Our scientists and engineers use our expertise in mobile technology, home monitoring, telemedicine, wellbeing and behavioural change to improve health services to urban, rural and remote Australians.

Health Services' science and impact highlights for 2019/20

- An implementation trial of the M♡THer platform commenced in the Brisbane Metro South region for up to 2000 pregnant women with gestational diabetes, to improve communication with their clinicians, enable self-management and timely intervention.
- A Smarter Safer Homes (SSH) platform randomised control trial among 200 older people, to improve quality of life and care through self-management and support from aged care providers, completed its recruitment and six-month assessment. A follow up study using SSH to better assess the needs of government-funded aged care home service packages also commenced among 30 older people. Both aged care trials implemented revised procedures to continue during the COVID-19 lockdown.
- The BabyCam trial to enable parents to monitor their pre-term infants was recognised for outstanding achievement at the Queensland Health Excellence Awards.
- A retinal imaging study investigating novel markers of hypertension (n=300) was completed. Preliminary analysis of correlation between fine vessel loss and hypertension mediated damage on kidney and large blood vessel, providing a capacity of non-invasive retinal imaging for cardiovascular risk.
- The Health Services group had 36 publications, including in Nature Scientific Reports on the automated detection of age-related macular degeneration, and a journal paper on the outcomes of an innovative telemonitoring enhanced care program trial for chronic heart failure.

Artificial Intelligence in Tele-Health team

Team Leader: Shaun Frost

The Artificial Intelligence in Tele-Health team develops diagnostic and decision support systems for remote delivery of health services. The multi-disciplinary team brings together expertise in clinical research, telemedicine systems and artificial intelligence for medical image and data analysis. The team works with key stakeholders and collaborators to develop and trial these solutions to demonstrate improved health outcomes and health service delivery.

Health Internet of Things team

Team Leader: Qing Zhang

With wireless sensors, mobile technologies and health technologies pervasive in everyday use, new and rich sources of data are now accessible to determine people's lifestyles and how those lifestyles influence their health and wellbeing. The Health Internet of Things team has developed an innovative home-care platform that can access and aggregate data wirelessly from the environment and/or wearable devices, and mobile or internet devices. Using machine learning and artificial intelligence, we have been developing and exploring smart data analytics on aggregated data sets to better support the older community and people with disabilities to live longer in their homes, and also to support their carers and service providers.

Mobile Health Systems team

Team Leader: Marlien Varnfield

With the wide uptake of smartphone, internet and health monitoring technologies in people's everyday lifestyles, the Mobile Health Systems team is translating the delivery of healthcare from acute care settings into the community to relieve the undue pressures hospitals face in managing chronic diseases and illnesses. Our team has demonstrated capabilities as a world leader in providing scientific evidence supporting mobile health. The team's objective is to make prevention and management of chronic disease services accessible to all people from their homes or communities. To enable this, the team works closely with clinical partners already providing such services to develop new innovative care models using technology-based systems, and test them through clinical trials to develop an evidence base.

Tele-Health Solutions team

Team Leader: Janardhan Vignarajan

The Tele-Health Solutions team develops and trials solutions that enable delivery of healthcare remotely and support research involving tele-health. Enabling tele-health research in hospitals and remote healthcare requires in-depth knowledge and a constantly updated technology skill set. Our in-house software engineering team works with clinicians to deliver cutting-edge software outcomes usable in the health service industry. The team specialises in technology deployment in desktop, web and mobile environments using cloud and traditional infrastructure.

Health Services: platform technologies

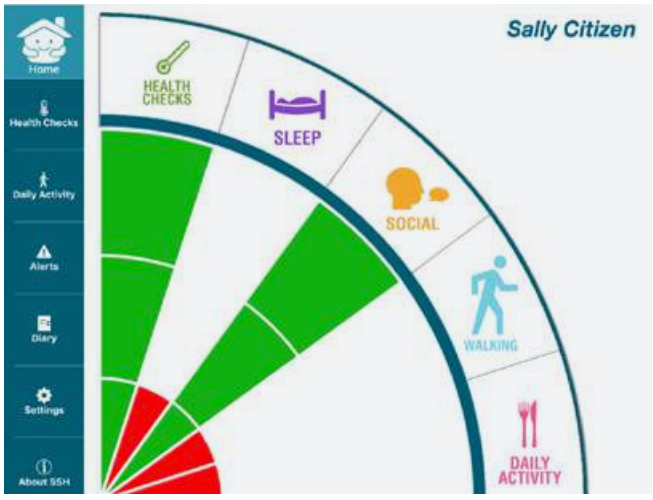
Smarter Safer Homes platform

Our Smarter Safer Homes (SSH) platform was developed to support older people to be functionally independent and live longer in their own homes as they age. The platform uses cutting edge pervasive communication and wireless sensor and monitoring technology, and features a novel metric that determines personalised functional independence, indexed through the "Objective Activity of Daily Living".

The SSH platform includes a sensor-based in-home monitoring system (data collection), a cloud computing server (data analyses), and a client module (data presentation) with a tablet app, a family portal and a care provider portal. It was designed with consumers to establish features that would enable them to self-manage, and engage support from formal and informal care providers.

The SSH platform technology readiness is at TRL 7 being demonstrated in the aged care domain. The platform has been through several pilot studies since 2013, and is now undergoing a randomised control trial among 200 older people receiving support from aged providers we are collaborating with. Once validated, this technology could have the capacity to enable care providers and families to provide timely and on-demand intervention, and substantially reduce costs and improve quality of life to the older community.

Read more about our latest SSH work in the Health Services: Project Reports and Project Updates sections, and the AEHRC and Indigenous Health section.



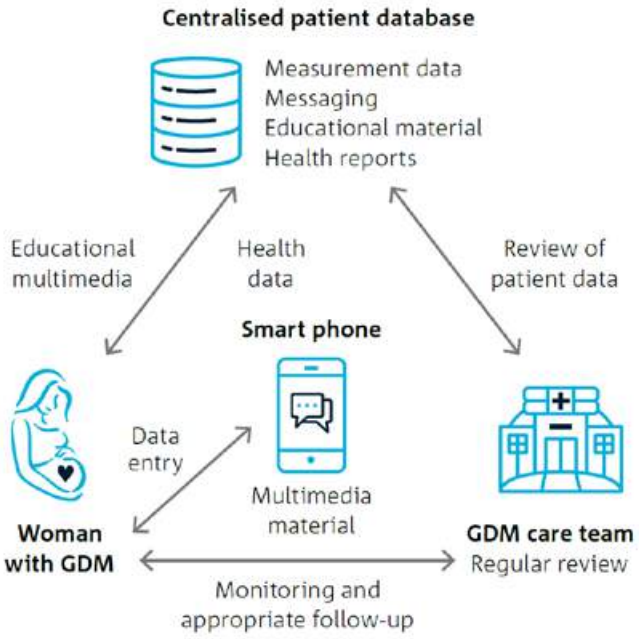
The SSH mobile application enables residents to view data derived from the sensors and medical devices.

Mobile Health platform

Our mHealth platform comprises of smartphone, internet and wearable technologies to support self-management for a range of chronic conditions. A smartphone app is used for data capture through Bluetooth-connected devices or self-reporting. These data include clinical measures (weight, blood pressure, blood glucose, exercise, stress, symptoms, medications, etc.). Motivational notifications and educational multimedia content (such as links to educational materials) are provided through the app.

Consumers are able to view their own data as visual (graphical) and textual reports on entered data. Entries to the app are automatically updated to a password-protected clinician web portal which enables healthcare practitioners from different specialised disciplines to access and assess patients' progress, and provide timely intervention accordingly. Data can also be reviewed by healthcare practitioners during medical appointments to assist in discussions with patients. The patient profile is compiled through the clinician portal to ensure that each patient's app is tailored and individualised according to their specific needs.

Applications of the mHealth platform for various medical conditions are being evaluated in collaboration with our health service and industry partners. Current projects include the M♡THer solution for women being managed for gestational diabetes mellitus (read more in the Health Services: Project Reports section), and a number of studies to test mHealth solutions for the management of chronic lung conditions, heart disease, concussion in children and early diagnoses of cerebral palsy.



Components of the M♡THer platform and data communication.

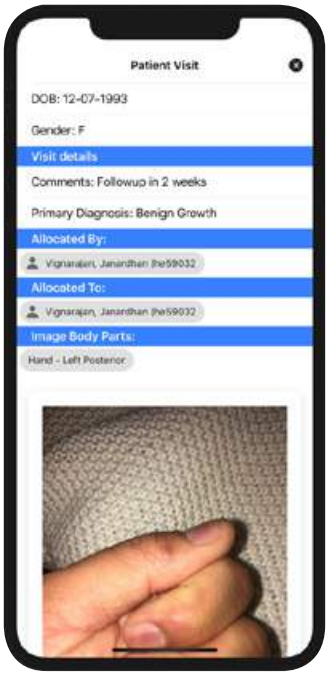
Medical Image Communication & Exchange (MICE) platform

Maintaining well-managed medical image communication and storage systems is a major problem hospitals face. In collaboration with South Metropolitan Health Service (WA), we developed MICE, a secure and safe mobile health platform which assists clinicians to send patient-related images securely to others.

The MICE platform does not store any information on the clinician's smartphone, and automatically sends records to the hospital's electronic medical record system, helping protect patient confidentiality and privacy through a controlled process. The platform consists of a centralised server which handles the communication, along with two mobile applications (MICE and eCo). The platform also has web access, providing various features including integration with hospital infrastructure.

We are working with partners to deploy the technology in different clinical settings, such as burns ward rounds, plastics, emergency cases and home-based patient visits by nurses. Read more in the Health Services: Project Reports section.

The MICE app.



The MICE app image review.

Remote-I: store and forward telehealth platform

Our Remote-I platform is a cloud-based information management system comprised of clinical data management, web access from mobile and web browsers, and a store-and-forward document handling system. The platform's flexibility has enabled us to test it across multiple scenarios. It has been customised for rural settings for the Remote Eye Care Delivery in Northern Australia (CRCNA) project; read more in the Health Services: Project Updates section.

The technology has been deployed into CSIRO-managed cloud infrastructure with implemented cybersecurity best practices such as two-factor authentication, encrypted end-to-end communication and well-monitored cloud infrastructure. It is designed to be highly scalable and can be translated into different clinical settings. Medical device integrations were also achieved through a client-side application (the Remote-I Sync app) which reduces the clinical double entry of data. The technology handles various file formats including JPEG, PNG and DICOM.

M♡THer implementation trial, Aboriginal and Torres Strait Islander feasibility study

Collaborators: Metro South Hospital and Health Service (MSHHS), Mater Mothers' Hospital, Queensland Aboriginal and Islander Health Council (QAIHC), Western Queensland Hospital and Health Service, Gidgee Healing

Gestational diabetes occurs in one in 10 pregnancies and requires careful monitoring by the patient and a team of healthcare professionals. To support patients and clinicians, we initially designed and developed a mobile platform, M♡THer, with Metro South Hospital and Health Service (MSHHS) to support pregnant women with gestational diabetes and reduce their need to visit hospital. It was based on our mHealth platform; read more in the Health Services: Platform Technologies section.

The platform was designed to replace manual paper-based record keeping, expected to reach the patient's clinical team every week or two by a combination of email, phone and fax. A smartphone app helps patients better manage and track their condition at home, and a web-based clinical portal helps their clinical team monitor key health indicators remotely. M♡THer was successfully trialled in a feasibility study with 40 women at Redland Hospital in 2017-18.

In 2020, we began an implementation trial of the M♡THer platform, aiming to recruit up to 2000 women at Mater Mothers' Hospital and several MSHHS hospitals in Queensland. This study aims to demonstrate evidence of the platform's effectiveness to help make it more widely available in the future. Recruitment has commenced at Mater Mothers' and Redland Hospitals, and will soon be expanded to Logan and Beaudesert Hospitals.

We are also collaborating with the Queensland Aboriginal and Islander Health Council (QAIHC) to explore the needs and preferences of how Aboriginal and Torres Strait Islander patients and the Aboriginal and Torres Strait Islander Community Controlled Health Organisation workforce engage with e-health, and specifically with the M♡THer platform. We will soon begin a feasibility study to investigate how the solution can add value to wellbeing outcomes of Aboriginal and Torres Strait Islander peoples in Mount Isa, with Western Queensland Hospital and Health Service and Gidgee Healing.

Patients can record blood glucose levels and other key readings in the M♡THer app.

Universal smart toy sensor system for monitoring child development

Collaborator: Royal Far West

Children with atypical or delayed development often have a challenging time regulating their emotions, partly caused by subtle physiological drivers which can be challenging to manage and interpret outside of a trained clinical setting. Age-appropriate ability to self-regulate is essential for social success and progression, so support strategies and networks are essential. Technology can be used to support successful management by providing insight into the physiological underpinning of emotions and behaviour, including physiological signals such as heart rate, heart rate variability and electrodermal activity. These signals can be measured continuously and safely using wearable sensors, such as the Empatica E4 smartwatch.

With Royal Far West, we developed a study methodology to evaluate whether physiological signal monitoring could be used to predict behavioural dysregulation (meltdowns). Advanced notice from physiological cues may assist parents and carers in co-management, and help track developmental progress. After gaining ethics approval, we performed a preliminary study recruiting five students to participate for up to one week. In that week, they wore an E4 smartwatch and their parent, teacher, or carer rated their behavioural state according to a preset metric.

The E4 smartwatch used for physiological signal monitoring in school-aged children.

We used a supervised learning approach using physiological data and behavioural observations to develop a support vector machine global and subject dependent prediction model, with accuracy of ~85% in predicting child behavioural state. The outcomes of this study were communicated to participants and their parents, and published as a refereed short paper in the proceedings of the 42nd Annual International Conference of the Engineering in Medicine and Biology Society. Participating families expressed enthusiasm and were happy to be included. Children and parent feedback is being incorporated into a next-generation system for accurate and safe ubiquitous developmental monitoring.

We are continuing to build on these preliminary outcomes and our collaboration with the Royal Far West to develop new methods to evaluate and help management of challenging behavioural problems.

A roadmap to inform a digital robotics strategy for Queensland Health

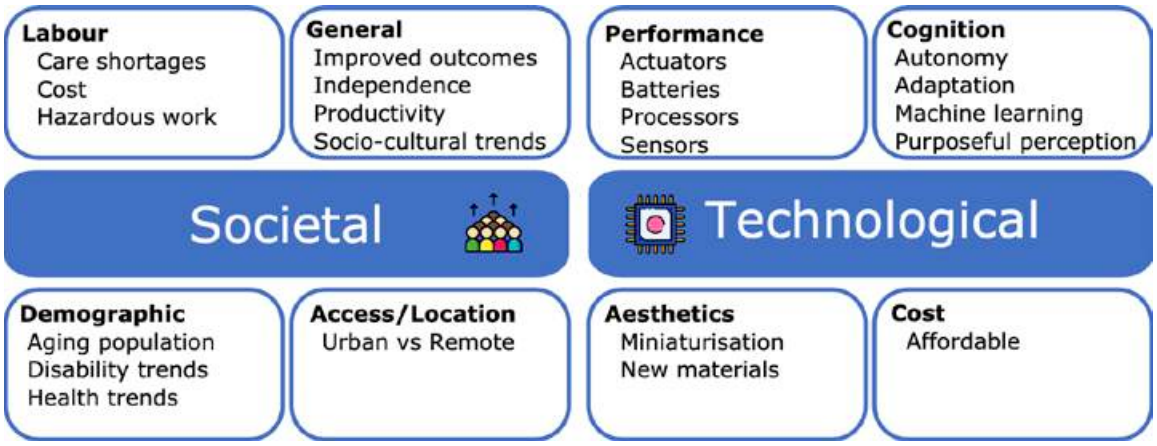
Collaborator: eHealth Queensland (Queensland Health)

The application of robotics in healthcare is a relatively new and exciting area, driven by the expectation that robots will be able to help societies solve challenges and trends over the next decades. The spectrum of robotics in healthcare spans a wide range of environments, user populations, and applications, from simple machines to support the laundry delivery in a hospital, to highly complex robots that can aid a human surgeon.

This project's main objective was to chart key opportunities and considerations for implementing robots in healthcare, to inform the development of a new digital robotics strategy for Queensland Health. We identified the main stakeholders, settings and activities of robotics in healthcare, and aimed to raise awareness about the main drivers, challenges and opportunities of robots in healthcare among a wider audience.

In this report, applications of robotics in healthcare were divided into five main areas: service, assistive, socially assistive, teleoperated and interventional robots. There was particular interest in systems that support clinicians rather than exclude or replace them, and those that could provide quick and tangible benefits. The identification of the main drivers, challenges and opportunities for robotics in healthcare can be used to inform the strategic direction to maximise quality, acceptability, safety and availability of the technology. Over the next decade, it is expected that a range of new technologies will improve robots' interactive abilities, allowing them to be more self-sufficient and work more closely with humans. Robots will also take on many different forms, suiting them for new and unexplored functions.

The final report should be used as a stepping stone to stimulate wider discussions surrounding robotics in healthcare, to guide eHealth Queensland with the next steps on the development of the a new robotics strategy to inform decisions associated with purchasing, developing, and implementing robotic applications.



Main drivers for the deployment of robots in healthcare.

Smarter Safer Homes: evaluation of Objective ADL and user experience

Collaborator: integratedliving Australia

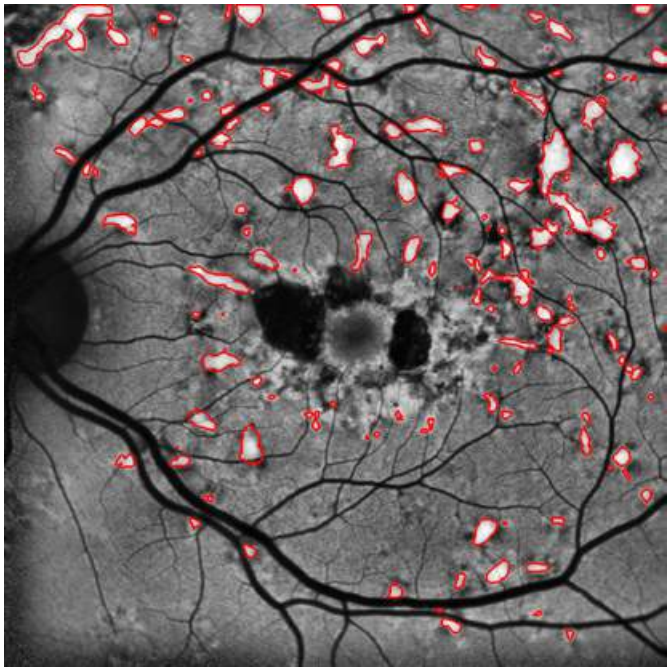
We evaluated the impact of implementing the Smarter Smarter Safer Homes (SSH) platform as an innovative home care service delivery model. Read more about SSH in the Health Services: Platform Technologies section.

Specifically, this study evaluated the accuracy and effectiveness of the Objective Activity of Daily Living (OADL) scale (CSIRO patent pending) by comparing algorithm output against participants' self-reported daily health and wellbeing status.

We recruited 12 individuals aged 65 years and older in the Brisbane metropolitan area through integratedliving Australia, an aged care service provider which receives funding from the Australian and state governments to provide care services and in-home support services to older people in regional, rural and remote Australia. All participants received the SSH kit and were able to access the SSH platform for up to 12 months. Individualised functional independence (OADL) was measured by SSH using the same framework of Activities of Daily Living measure (ADL), practiced clinically.

During the 12-month study, participants input their daily health and wellbeing status, represented as emojis, through the diary module of the SSH app. Preliminary data analysis shows OADL is 78% accurate in predicting the daily health and wellbeing status of senior home residents. The validated OADL algorithm enables care and support from aged care service providers in a preventive and timely manner, and in accordance with individual needs.

The SSH app, showing an individual's Objective Activity of Daily Living.



Deep learning (red outlines) segmentation of hyperautofluorescent flecks.

Progression monitoring in juvenile macular disease

Collaborator: Lions Eye Institute

Stargardt disease is the most common form of inherited retinal disease, leading to macular degeneration and permanent vision loss. A diagnostic feature of the disease is flecks, which appear as bright fluorescent spots in fundus autofluorescence (FAF) imaging. The size and number of flecks increase with disease progression. Manual segmentation of flecks allows disease monitoring but is time-consuming.

Using U-Net convolutional neural network architecture constructed with a residual neural network (ResNet) encoder, we developed and validated a deep learning approach for segmenting Stargardt flecks and tracking disease progress through longitudinal images. The number and total area of flecks are calculated and compared longitudinally, with outputs compared to expert clinician manual grading.

Testing from 10 separate Stargardt FAF images demonstrated a good overall agreement between manual counting and deep learning in both fleck count and fleck area. Longitudinal data were available in both eyes from six patients, with both manual and deep learning segmentation performed on all (n = 82) images. Both methods detected a similar upward trend in fleck number and area over time.

We demonstrated the feasibility of utilising deep learning to segment and quantify FAF lesions, laying the foundation for future studies using fleck parameters as a trial outcome measure in Stargardt disease. More importantly, we trained and put forward a deep learning-based fleck segmentation method less time-consuming than manual marking.

Medical image and data exchange using smartphones (MICE)

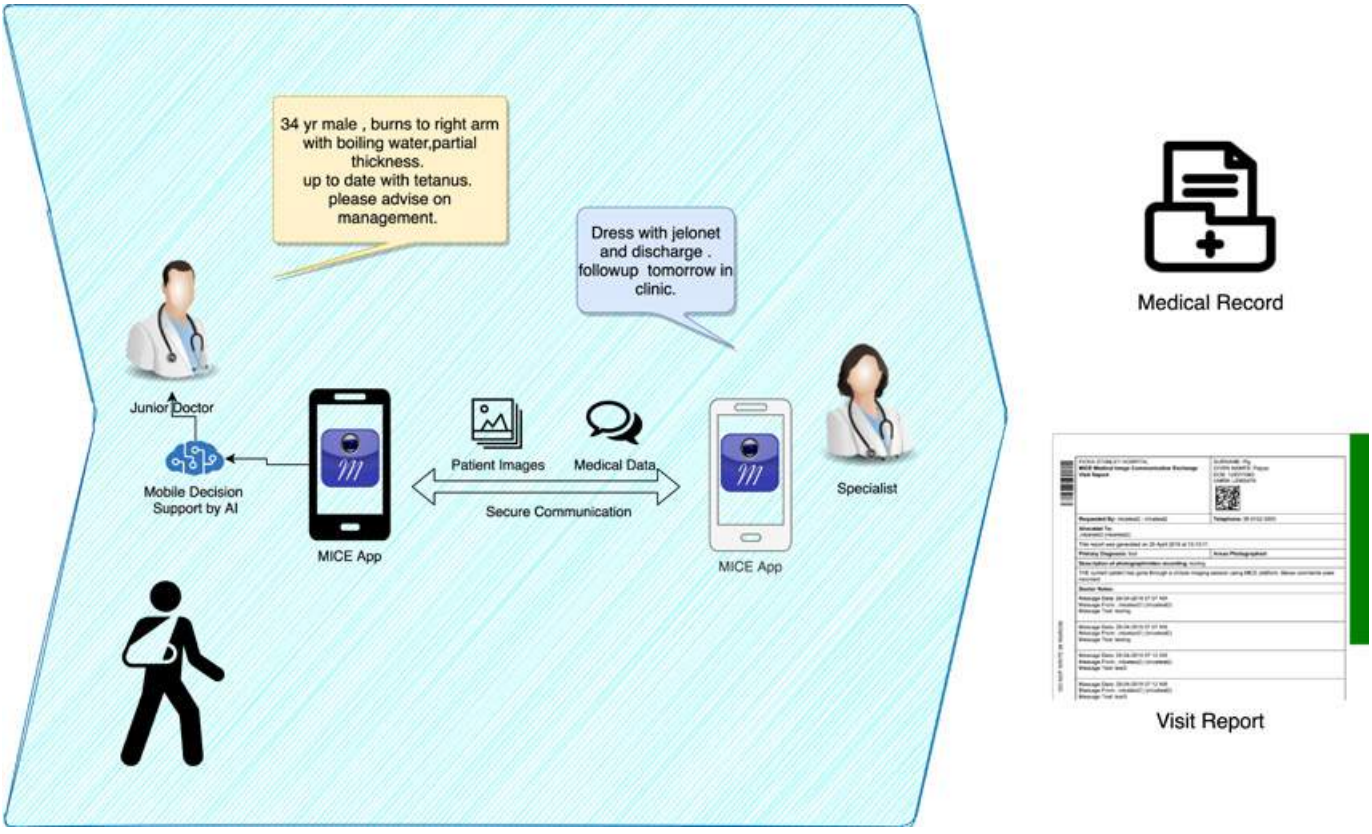
Collaborators: South Metropolitan Health Service (SMHS Western Australia), Western Australia Department of Health (WA Health)

In collaboration with SMHS, we developed the MICE (Medical Image Communication & Exchange) mobile health platform to transmit medical images, patient consent and clinical data in a secure and organised manner that keeps data and images in approved health care systems. Read more about MICE in the Health Services: Platform Technologies section.

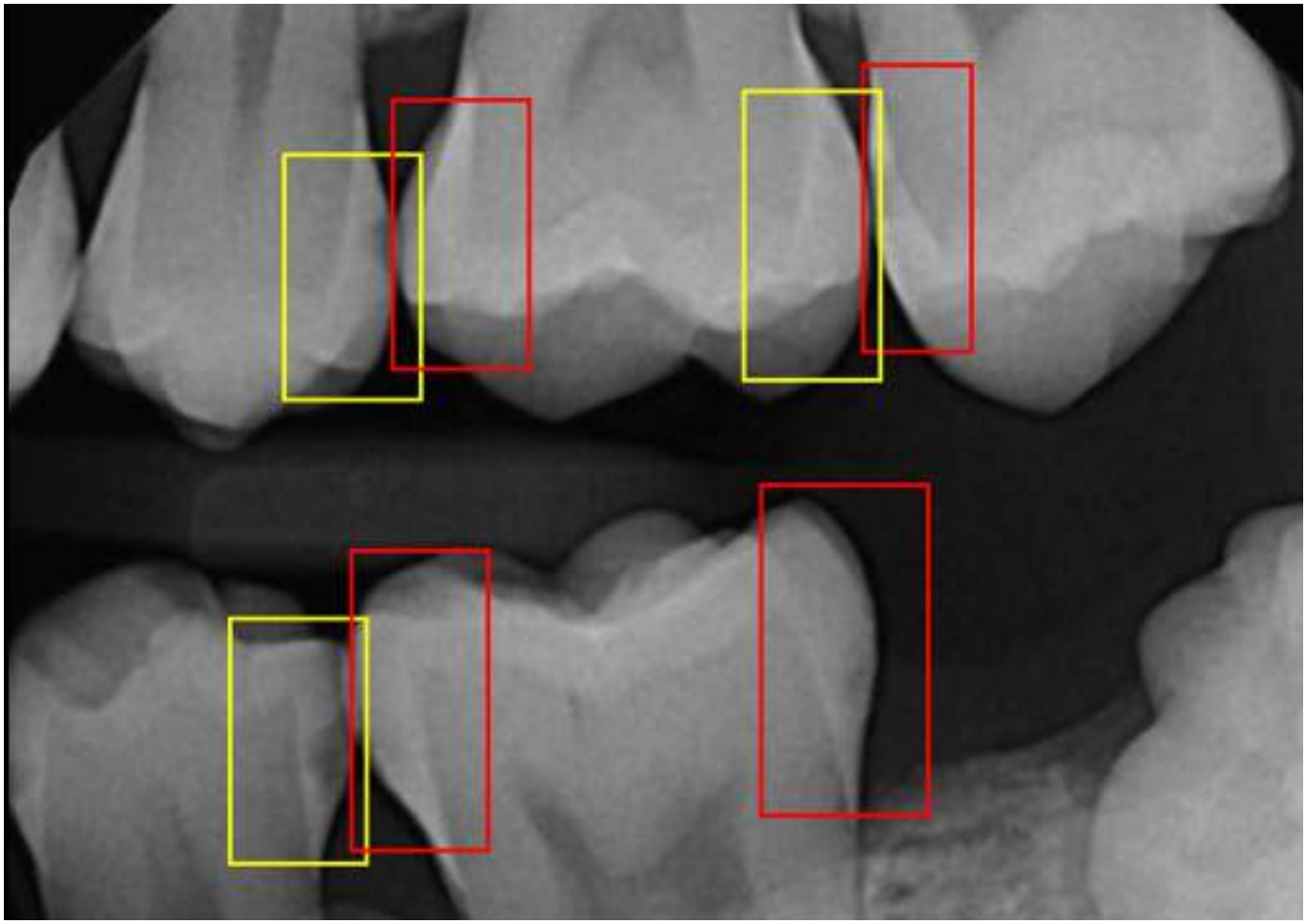
The platform is being used in burns, plastics, rural and emergency clinical settings. Its seamless record-keeping process and medical data integrations provide great value to specialists and the hospital by retaining patient records in an orderly manner.

We have successfully published two mobile apps (MICE and eCo) in the Google Play Store and Apple App Store. A custom distribution method to organisations was also implemented with SMHS Apple Business Manager (ABM). The technology is also distributed via WA Health's Microsoft Office 365 subscription service, allowing any WA Health doctors the ability to self-signup to access the system.

The platform has captured more than 1500 patient records with over 50 users, and user adoption is growing, reducing paper-based reporting. Its use has been extended to remote home care settings where nurses upload patient images during patient home visits, improving communication with clinicians.



An example of the MICE platform workflow in a burns clinic.



An example of a dental radiographic image (bitewing radiograph) with annotations/bounding boxes around detected carious lesions.

Development and validation of artificial intelligence to detect dental caries in oral radiographs

Collaborators: The University of Western Australia, Western Australia Department of Health (WA Health)

Early detection and accurate diagnosis of dental caries (tooth decay) are important for timely treatment decisions and improved oral health outcomes. Detection of dental caries in the early stages is challenging, as it may not be readily visible during a dental examination and can be difficult to detect by trained human eyes in radiographs.

Radiography is a vital adjunct for diagnosis of dental caries, but digital radiography is no more accurate than traditional radiographic methods. This is in addition to substantial time needed by dental practitioners for tooth numbering and filling out dental charts. Hence, there is a need for a more accurate tools for detection of carious lesions to enable appropriate and timely treatment.

In recent years, artificial intelligence methods such as deep learning techniques have demonstrated great promise for disease detection and classification from medical images. We are collaborating with clinicians to develop a system for tooth numbering/classifications and caries detection from dental X-ray images, to assess the validity and reliability of the deep learning models in comparison to human (dentist) reviews.

This project will deliver a library of oral radiographic images with a ground truth database created. The deep learning-based machine learning model will be validated and tested against human grading. We have also created an image annotation tool which simplifies the image grading and tooth numbering process that comparatively increases the efficiency of the data preparation. We will also focus on measuring the acceptability and performance of the AI-based detection and clinical translation of such technology in the dental industry.

Health Services: project updates

Smarter Safer Homes: supporting older people living in their own homes through enhanced care models

Collaborators: integratedliving Australia, Anglicare Southern Queensland, All About Living Australia, Griffith University

This project aims to use the Smarter Safer Homes (SSH) platform to revolutionise aged care services delivered to people in their homes, through:

- developing innovative service models appropriate across a range of service and geographical settings which are effective, client-driven and focused.
- enabling a platform that not only tailors to individuals' basic functional and health needs, but also supports formal and informal carers' needs.

To achieve this, we are evaluating the improvement in the quality of life and care provided to older people at home using the SSH platform through a randomised controlled trial. In addition, we are also evaluating the cost-benefit analysis of the care provision using the SSH platform. In the past year, 195 participants have been recruited in collaboration with service providers. The project has completed a mid-trial assessment for all participants and the trial is due to complete by the end of 2020, with outcomes published in 2021.

Smarter Safer Homes: consumer-centric and on-demand aged care service delivery

Collaborator: Anglicare Southern Queensland, integratedliving Australia, Griffith University

This project aims to develop a novel consumer-centred and on-demand aged care service delivery model of the Commonwealth Home Support Programme (CHSP) to support older persons who choose to receive care in their own homes. This project will use the SSH platform to gain an understanding of whether the home care service package accessed for the individual aged person through CHSP funding was appropriate. This will inform the consumer and the care provider on the most appropriate level of home care service package, or determine if the service package an individual is accessing should be revised.

This is an observational cohort study, with a novel CHSP model being piloted and evaluated among older-aged participants. Over the past year, the CHSP project received ethics approval and has already recruited 13 participants aged 65 years and older across metropolitan areas in Queensland, from aged care service providers.

Climate Safe Rooms

Collaborator: Geelong Sustainability Group

This pilot program aims to improve comfort levels within a home by creating a Climate Safe Room, which is a room within the home that is upgraded to maintain comfort during both summer and winter temperature extremes. The program will also measure the health and wellbeing outcomes and energy bill savings that result from making the home more comfortable to live in, all year round.

The pilot will deliver Climate Safe Rooms to approximately 20 residents in the City of Greater Geelong region. Desired objectives are to trial a variety of delivery methods and capture key learnings, prove the Climate Safe Room concept effectiveness and scope pathways for future project delivery at scale.

Over the past year, we have recruited 16 participants: 13 participants have the Smarter Safer Home platform installed, eight participants have received one-to-one energy efficiency behaviour change sessions, and one participant has the solar installation as part of the in-home retrofit option.

Socially assistive robots to enhance resilience from bullying in students with autism and intellectual disability

Collaborator: Murray Bridge High School

Bullying in schools is a widespread problem among young people. Autistic adolescents are at higher risk for victimisation, with as many as 70% being victims of bullying, with verbal and social forms of bullying being the most common. Students who report greater resilience experience less distress regarding bullying.

This project developed a new robot-assisted intervention program to support the development of resilience in high school students on the autism spectrum. The program was incorporated into an android-based app to be used by teachers to control the humanoid robot NAO (Softbank Robotics) during the delivery and evaluation of the program. In the coming year, we will be conducting a study to evaluate the impact of the program in a group of high school students with autism and intellectual disability.

EMFIT Quantified Sleep (QS) sensor.

Behaviour and lifestyle quantification by smart sensing - Prospective Imaging Study of Ageing (PISA)

Collaborators: QIMR Berghofer Medical Research Institute, University of Queensland, University of Western Australia

This project aims to elucidate neurobiological, psychological and physiological changes at a very early stage of dementia. The lifestyle stream aims to collect longitudinal sleep sensor data from healthy older adults and participants who are living with dementia, monitor changes in their sleep patterns, and investigate the features extracted from sleep that can act as an indicator of cognitive decline. In 2019, 124 participants were recruited to monitor their sleep patterns using EMFIT QS for around 2-5 months.

A pilot study has also been conducted at the Prince Charles Hospital (TPCH) Sleep Sciences Lab to validate the EMFIT sleep measurements. In 2020-21, we aim to complete the participant recruitment for the PISA lifestyle stream and undertake PISA data analysis using data from other streams, i.e. neuroimaging, neuropsychology, and genetics.

User perceptions of digital technologies to monitor health and wellbeing during pregnancy

Collaborator: Gold Coast University Hospital

This project sits in CSIRO's Precision Health Future Science Platform and aims to develop an integrated platform collecting precision health data to facilitate active assessment of multiple pregnancy-related conditions, at home, and from a combination of medical and lifestyle data. In the last year, we have completed a user needs study with pregnant/postpartum women and clinicians working in different disciplines of perinatal care.

The study has developed in-depth understandings on the potential benefits and challenges of using the new platform for risk assessment and monitoring during pregnancy, the preferences of using wearable and health monitoring among pregnant women, and clinicians' perceptions on parameters for mHealth monitoring and suitability for different medical conditions. Our future work will include investigations of clinical, technical and practical factors associated with the precision health platform before the final technology design is undertaken.

Technology assessment framework for Precision Health innovations

Existing and emerging technologies — such as wearable sensors, smartphones, mobile applications and artificial intelligence — are making way to improve healthcare models and patient outcomes. These technologies have the potential to become precision health (PH) innovations. However, not all innovations have the required scientific evidence to support their claims.

In response, an assessment framework was developed to facilitate and standardise the assessment of PH innovations. The proposed framework identifies four main categories for assessment: technical, clinical, human factors and implementation. Guiding statements, metrics and recommendations are used against each category. The new framework supports innovators and researchers in leveraging current and emerging technologies for PH solutions.

Wearable sensors for early detection of cerebral palsy

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre

Cerebral Palsy is the most common physical disability in children, with an incidence of one in 700 in Australia and even higher in developing countries. Cerebral Palsy is usually caused by an injury to the brain at or around birth, but is frequently diagnosed at between 18 and 24 months of age. Earlier diagnosis provides opportunities for targeted intervention at a time of maximum neuroplasticity, thereby increasing lifetime health outcomes.

We have developed a suite of small wearable sensors to measure infant movements and track their longitudinal progression. Infant movement development may provide an early insight into infants at high risk of Cerebral Palsy and inform follow-up investigations. In the past year, we completed an initial study with infants recruited from the Queensland Children's Hospital, Royal Brisbane and Women's Hospital, and the Mater Mothers Hospital to track movement development from 12-18 weeks corrected age.

We are currently recruiting additional infants at high-risk of Cerebral Palsy from sites across Southeast Queensland to investigate the feasibility of in-home wearable sensor assessments performed by the parent or caregiver.

Prediction of stress-induced episodes in children

Collaborator: Royal Far West

Children, particularly those with abnormal or delayed development, have a reduced ability to self-regulate their emotions and behaviour. Emotion dysregulation can be recognised and acted on by clinicians or parents, but external indications of dysregulation are also accompanied by internal physiological changes, such as an increase in heart rate.

We conducted a preliminary study to assess the feasibility and acceptability of the Empatica E4 wearable band to monitor physiological signals throughout normal daily activities. Prediction of emotion dysregulation will assist parents and clinicians to the incidence of aggressive behaviours that could endanger the children and others in the environment, in turn improving social and emotional outcomes. Our initial (person dependent) models are able to correctly classify the behavioural state of children with up to 85% accuracy. In the coming years, we aim to collect additional data to improve and generalise our models.

Evaluating the effects of robots on the story retelling skills of children on the autism spectrum

Collaborators: Queensland University of Technology, Autism Hub

The aim of this project is to evaluate the effects of humanoid robot-assisted interventions on the story retelling skills of school-age children on the autism spectrum. This project is funded by the Autism CRC. The expected outcomes include a guide for teachers and schools planning to implement robot-assisted interventions for supporting story retelling learning activities with children on the autism spectrum. This project is being conducted through a mixed-method design, using two different robots (NAO and Pepper) in three different schools. Over the past 12 months, we completed recruitment and data collection from one school and expect to finalise the full study in the coming year.

SoftBank Robotics' humanoid robot NAO.

Activate TKR: Mobile support for orthopaedic rehab

Over the past few years, we have been working on behalf of Johnson & Johnson Medical Devices Australia to design, develop and trial Activate TKR, an orthopaedic support technology platform to support patients in managing their total knee replacement (TKR) surgery. This platform comprises a mobile app, a wearable activity tracker and a clinical web portal.

The randomised controlled trial of Activate TKR had several significant milestones this year. We completed recruitment of 133 patients across four trial sites in New South Wales and Queensland, and had each participant complete their participation in the intervention phase of the project. One hundred and twenty patients have completed their trial participation and the remaining patients will provide information at their 52-week review by November 2020. Qualitative analysis with patients and clinicians has been completed with positive outcomes and several papers are under review.

Health-e Minds

Collaborator: Sunshine Coast Hospital and Health Service

We studied a digital technology platform designed to support patients with serious mental illness (SMI). Our aim was to support the management of persons with SMI and to enhance multidisciplinary care provided by their treating clinicians. Recruitment of patients aged 18 years and older, with confirmed SMI, commenced in October 2019. The primary outcome was user adoption (patient and clinician usage and user satisfaction) and secondary outcomes included patient quality of life and depression measures.

Recruitment at the end of November 2019 was 17 patients. Feedback on the Health-e Minds platform was mixed, which is not unexpected for this population cohort. Novel to the platform is a farm game component that rewards patients, using their measured activities (as measured by the app) against goals set in consultation with their clinician through the clinical portal. Final analysis of the data is currently underway.

Health-e Minds' farm game component.

m-Health program for chronic obstructive pulmonary disease

Collaborator: Prince Charles Hospital

Chronic obstructive pulmonary disease (COPD) affects one in seven Australians over the age of 40 years. Self-management of COPD through clinical and social support is recommended to prevent progression of the disease. However, evidence has shown patient adherence to self-management has been sub-optimal.

We developed MH-COPD, a mHealth-enhanced program to support disease management, with the Prince Charles Hospital. The MH-COPD is undergoing a randomised controlled trial to test its effectiveness in improving the patient and clinical adherence to self-management through recommended guidelines for COPD. In the MH-COPD program, patients use a smartphone app at home to review educational videos, monitor COPD symptoms and risk factors, follow their action plan, and learn to use inhalers effectively. The trial is expected to be complete in 2021.

Rehabilitation for pulmonary disease (m-PR)

Collaborators: Northern Sydney Local Health District, University of Sydney, Better Breathing Foundation

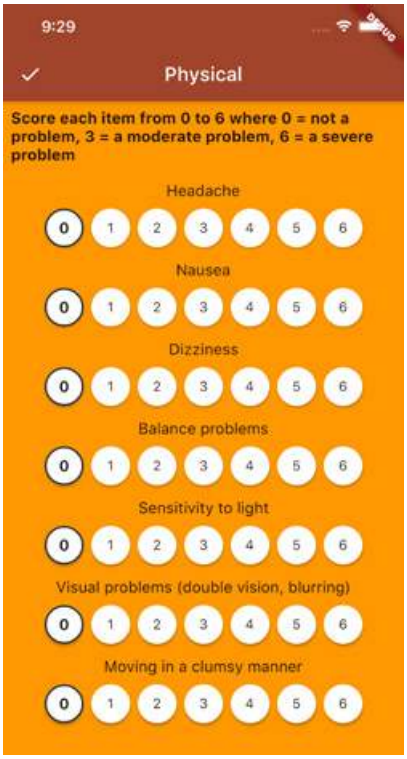
We developed and evaluated a Mobile Pulmonary Rehabilitation App (m-PR), based on the MH-COPD program. The aim is to undertake a pilot study in Northern Sydney Local Health District, NSW. Our primary objective is to determine, in people with COPD, if a mobile pulmonary rehabilitation (m-PR) program is equivalent to face-to-face pulmonary rehabilitation in terms of improvements in exercise capacity and health status.

The secondary objective of this study is to determine, in people with COPD, if the m-PR program results in equivalent outcomes as face-to-face pulmonary rehabilitation in terms of improvements in quality of life, symptoms, psychological status, daily physical activity levels, uptake and completion of a pulmonary rehabilitation program. The study aims to commence in September 2020, and participants will be randomly allocated into an m-PR group (intervention, n=67) or face-to-face pulmonary rehabilitation group (control, n=34) in a 2:1 ratio favouring the m-PR group.

Child health: post-concussion management

Collaborator: University of Queensland

Research has shown that 36-63% of patients and families with paediatric concussion do not receive either verbal or written information upon discharge from emergency departments. Further, the discharge information pamphlets themselves are variable and may omit key facts, be out-of-date, or have scant information about post-concussive symptoms (PCS). This represents a significant exclusion of patients without adequate knowledge of PCS given that up to 25% of paediatric cases have PCS for more than a month following injury. Therefore, it is vital that families are guided safely through the sub-acute and recovery stages following a concussion injury.



The app was designed for children with post-concussive symptoms.

In partnership with the University of Queensland Acquired Brain Injury in Children (AbiC) program, we have developed a technology-assisted clinical care program for PCS which includes an app to deliver validated questionnaires (the PSCI and PedsQL) and a Satisfaction with Care survey to research participants to track recovery and record outcomes following a concussion injury. This study will commence once all ethics approvals have been obtained and COVID-19 restrictions are eased.

Remote eye care delivery in northern Australia

Collaborator: Department of Health (QLD) Telehealth Support Unit

The project is funded by CSIRO and the Cooperative Research Centre for Developing Northern Australia. The main project objective is to establish an innovative model of service delivery for diabetic retinopathy management in remote communities. The research aspects of the proposed work primarily relate to qualitative and quantitative analysis to evaluate the service. Data will be gathered throughout the project to evaluate the project against two specific objectives: improved efficiencies for northern Australia, as well as improved capabilities and wellbeing of the northern Australian community. We successfully developed and deployed the screening technology in the cloud and enrolled five community sites. The telemedicine platform was successfully deployed and has gone through rigorous security hardening processes to mitigate security and privacy risks. The platform provides seamless integration of retinal cameras into the clinical workflow.

Retinal imaging in resistant hypertension

Collaborator: Royal Perth Hospital Hypertension Clinic

This project aims to identify novel retinal imaging markers that may closely correlate with best practice blood pressure measurements and other signs of hypertensive organ damage in high-risk patients.

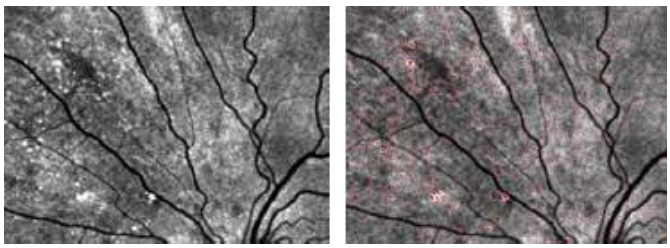
Data collection has been completed for 300 participants. Preliminary analysis has found associations between loss of fine vessels in the retina and hypertension mediated damage to the kidney and large blood vessels of the body. Non-invasive retinal imaging may provide a measure of the integrated blood pressure burden a patient has been exposed to at any given time and provide a simple, inexpensive test for accurate prediction of cardiovascular risk. Longitudinal assessment and the corresponding changes in retinal markers may also serve as an indicator of adequate or inadequate anti-hypertensive treatment.

Another trial on the effects of tropicamide pupil dilating eye drops on the retinal vasculature has been completed (N=42) and results were published in 2019.

Ocular biomarkers for Alzheimer's disease

Collaborator: Neurovision Imaging Inc

We have been developing ocular biomarkers for early detection of Alzheimer's disease. We use curcumin fluorescence via volunteers reported intake of a curcumin supplement to light up the amyloid-beta plaques in people's retinas. If what we see in the eye tests correlates with what is occurring in their brains, we will have the makings of a screening tool for Alzheimer's, which will enable us to identify early development and hence, early intervention to stop or delay Alzheimer's progression.



A post-curcumin retinal fluorescence image from a patient positive to brain signs of Alzheimer's disease (PET SUVR = 2.13), and the same image with detected fluorescent spots highlighted in red.

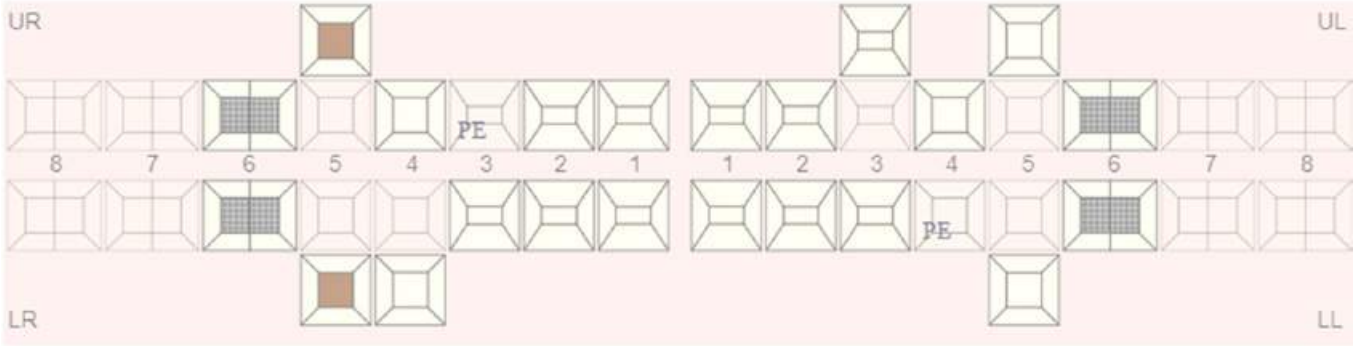
From preliminary analysis conducted on clinical data collected over three studies, we have published papers in the Journal of Ophthalmology and Current Alzheimer Research reporting on changes in the way the pupil responds to light and the optical properties of retinal vessels in Alzheimer's disease. These ocular changes are also evident in pre-clinical Alzheimer's participants, suggesting that eye testing could be useful for detecting Alzheimer's many years prior to symptoms, allowing earlier testing of interventions.

Teledental pathway of dental care to improve oral health in school children

Collaborator: University of Western Australia

This project was funded by the Foundation For Children and CSIRO to develop a telemedicine solution in dental imaging using smartphones. We proposed a paradigm shift in providing dental care for school children through the introduction of user-friendly technology to provide a foundation for a sustainable "School Dental Service". We developed a mobile app and a web-based dental assessment system to acquire dental images from a child's mouth at their school.

The system has captured over 150 children's records with over 750 images. The records were independently reviewed by three dental assistants. Initial research results show that the photographic approach to dental screening, used within the framework of its limitations, could still offer an economic and reliable means of remote dental screening in large numbers of people in need.



Our web-based dental assessment system.

Health Services: postdoc and student highlights

Postdoctoral fellows

Dr Mohamed Estai, AEHRC

Evaluation of artificial intelligence for the detection of diabetic retinopathy (DR) in patients with diabetes attending RPH

We will evaluate the integration of an artificial intelligence-based deep learning system for DR into an existing eye screening program at the Royal Perth Hospital's Ophthalmology Department to provide a foundation for automated eye screening to enhance the prevention program for DR-related vision loss. This smart system will enable accurate and timely detection of DR, and facilitate referrals of patients with severe DR while optimising screening frequency with low-risk patients screened less frequently.

Read more in Health Services: Project Reports.

Dr Mahnoosh Kholghi

Prospective Imaging Study of Ageing (PISA): behaviour and lifestyle quantification by smart sensing

In collaboration with QIMR Berghofer Medical Research Institute, the University of Queensland and the University of Western Australia, this project aims to elucidate neurobiological, psychological and physiological changes at a very early stage of dementia. The lifestyle stream of the project aims to collect longitudinal sleep sensor data from healthy older adults and participants who are living with dementia, monitor changes in their sleep patterns, and investigate the features extracted from sleep that can act as an indicator of cognitive decline.

Read more in Health Services: Project Updates.

PhD students

Vera Buss, University of New South Wales

Development of risk profiling matrix for chronic diseases and preventive smartphone application

Cardiovascular disease and type 2 diabetes mellitus are two of the most prevalent chronic diseases. A smartphone application is intended to help laypersons without cardiovascular disease or type 2 diabetes mellitus understand their current risk of these two conditions and motivate them to take action towards reducing their current risk or to remain on a healthy track.

Yashodhya Vachila Vijesinghe, Queensland University of Technology

Automatic prediction of fall and frailty of seniors using clinical data

This study aims to predict falls among the elderly patients using past medical data by applying data mining techniques. A feature selection model is proposed to select a set of discriminative features to represent falls and no falls from clinical notes. From this a question and answer based on automated frailty index calculation will be proposed. The research also focuses on determining the relationship between frailty and falls by applying deep learning techniques.

The AEHRC and Indigenous health

Ray Mahoney, Senior Research Scientist, Indigenous Health at the AEHRC.

The Australian e-Health Research Centre is committed to increasing its contribution to addressing the health disparities between Indigenous and non-Indigenous people in Australia. We are partnering with Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHO) to co-design and co-develop potential e-Health solutions to complement existing successful models of care for some of the most significant health issues in their communities.

We are seeking to leverage our platforms, technologies and projects to identify opportunities to work with the Indigenous community to improve health outcomes.

For example, we are exploring our mobile health technologies to address issues in cardiovascular health or gestational diabetes management, two health issues with a significant gap between Indigenous and non-Indigenous health outcomes; our Smarter Safer Homes platform to support older Indigenous communities; and our data standards work to improve measuring of Indigenous health outcomes.

The AEHRC and QAIHC staff at the AEHRC Colloquium in March 2020.

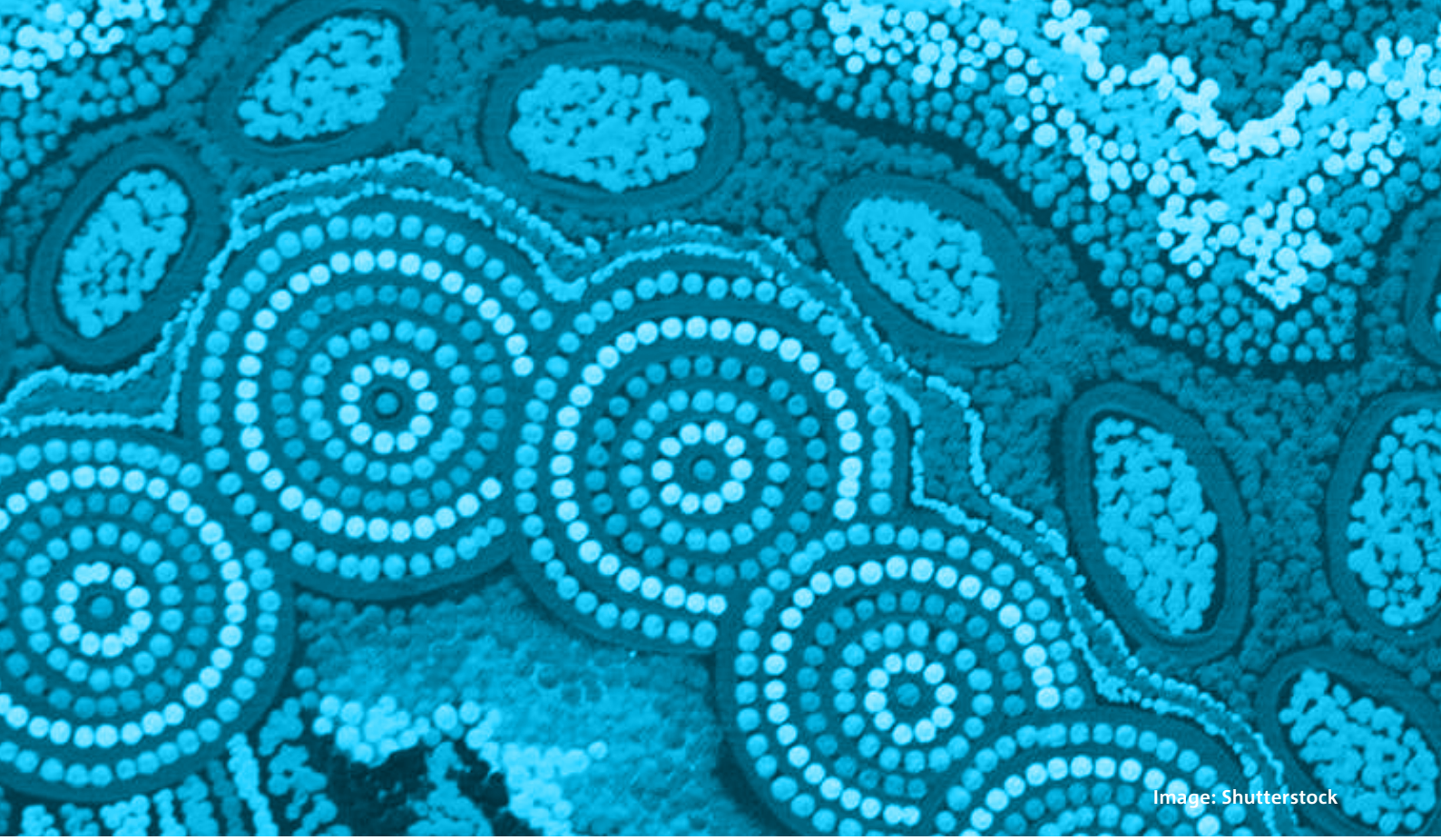


Image: Shutterstock

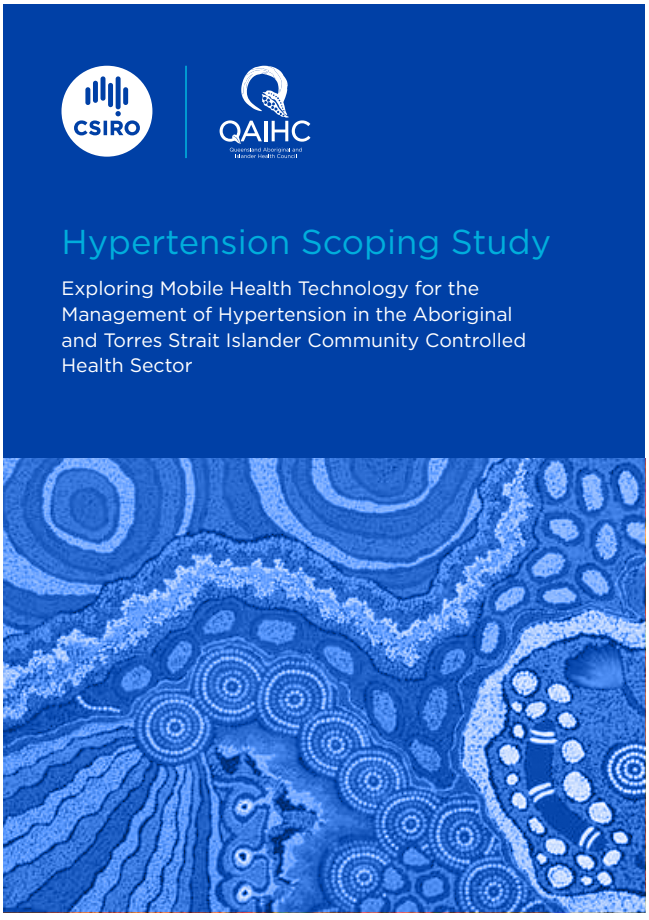
The AEHRC and Indigenous Health: project updates

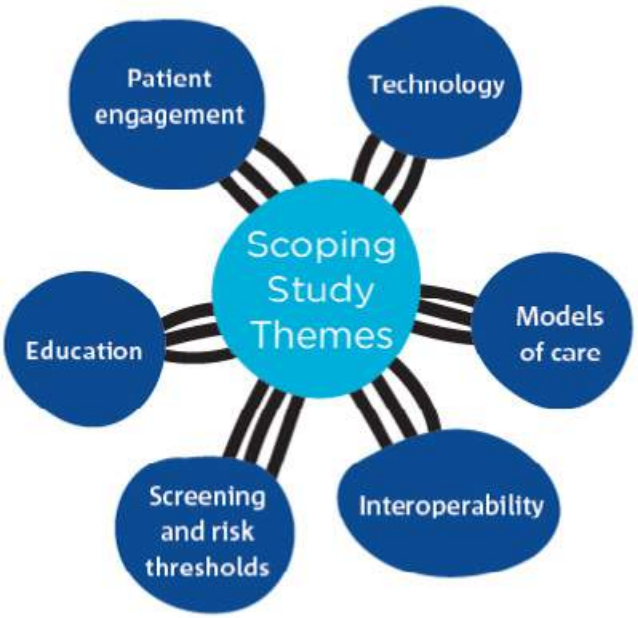
Hypertension scoping study: mobile health platform

Collaborator: Queensland Aboriginal and Islander Health Council (QAIHC)

QAIHC is a leadership and policy organisation established in 1990 and is the peak organisation body representing Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHO) in Queensland. Self-governance of primary health care for Indigenous people is recognised nationally and internationally as best practice. Community-control is a process which allows the local community to be involved in the priorities, protocols and procedures as determined by the community.

The use of smartphone and internet technology (mHealth) has shown encouraging results towards care delivery and management of a variety of health conditions from clinician and patient perspectives. However, there are currently no mHealth digital platforms developed for the management of cardiovascular disease specific to the needs of Indigenous people and the Indigenous community-controlled health sector's models of care.





Scoping Study Findings: Six overarching themes for hypertension mHealth deployment in the ATSICCHO setting.

A scoping study was undertaken to determine whether further consideration of hypertension m-health is a relevant priority with the Indigenous Health Sector and to provide valuable insights about the needs, preferences and priorities of how Indigenous people may wish to engage with m-health for hypertension management.

Six overarching themes were identified; technology, interoperability, screening risks and thresholds, education and patient engagement. There are two key findings from this scoping study. Results contribute narrative information about the perceived value that m-health may have in the contexts of ATSICCHO patients and Models of Care. The consultation process and subsequent findings have built a culturally respectful foundation to guide engagement, partnership, co-design and implementation of hypertension m-health with ATSICCHOs in their communities.

Read more on our mHealth platform in Health Services: Platform Technologies.

At home in Quandamooka: Smarter Safer Homes

Collaborator: Winnam Aboriginal and Torres Strait Islander Corporation (WATSIC)

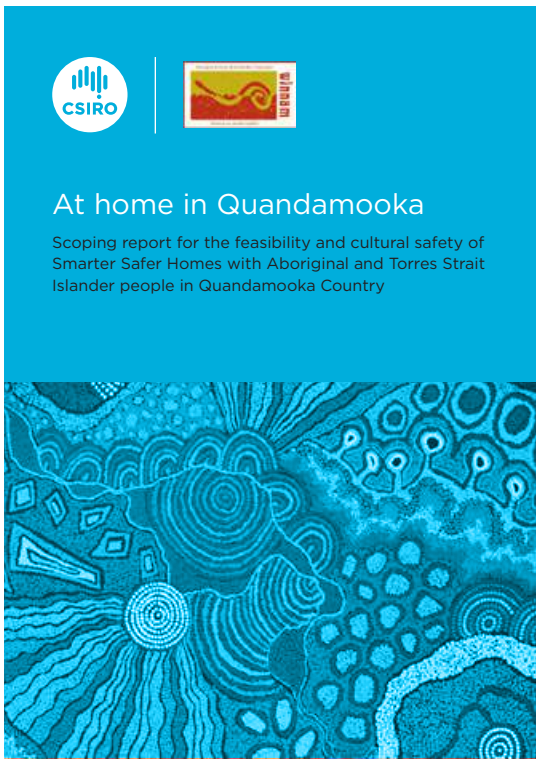
The Winnam Aboriginal and Torres Strait Islander Corporation (WATSIC) is an enterprising community organisation that is a holistic service provider for the Aboriginal and Torres Strait Islander community in the Wynnum and Bayside Suburbs of Brisbane. WATSIC is a 100 per cent community-based and controlled, not-for-profit corporation with approximately 40 properties that are used to provide affordable housing to local Aboriginal and Torres Strait Islander people. WATSIC also owns and operates the only residential aged-care facility in Brisbane that caters specifically for Aboriginal and Torres Strait Islander people: the Georgina Margaret Davidson Thompson Hostel in Morningside.

Historical and contemporary experiences of colonisation and racism have contributed to disadvantage experienced by Aboriginal and Torres Strait Islander people. Difficulties accessing culturally safe health and aged care compound these challenges. Many older Australians prefer the option of staying at home as they age.

We undertook a scoping study to look at the potential use of our Smarter Safer Homes (SSH) platform within the WATSIC aged care facility. The study considered cultural appropriateness and health applications of using SSH to support urban Aboriginal and Torres Strait Islander older people, through a series of meetings in November 2019 that sought the perspectives of WATSIC members and Georgina Hostel aged care staff.

Georgina Hostel staff were curious and receptive to the concept of the SSH platform and could see value in the collection of data to support the health and safety of the residents. WATSIC members emphasised the significance of their family connections, shared culture, historical impacts, their privacy, and health, which strongly influence their daily decisions. A trial must have a 'whole of community' approach and acknowledge the complexity of family situations and the historical experiences of many older Aboriginal and Torres Strait Islander people. Recommendations from the scoping study include that planning should proceed for a trial of the SSH platform for WATSIC members and Georgina Hostel.

Read more on our Smarter Safer Homes platform in Health Services: Platform Technologies.



Alice Springs residential thermal comfort monitoring trial

Collaborators: Tangentyere Council Aboriginal Corporation (TCAC)

This scoping project funded by CSIRO's Health and Biosecurity Indigenous Opportunities grant is the first step toward a broader climate change adaption and heat mitigation project in partnership with Tangentyere Council Aboriginal Corporation (TCAC) in Alice Springs.

This project's main objective was to undertake a scoping study with TCAC to investigate the viability of a collaboration with both TCAC and Central Australia Academic Health Science Network (CAAHSN), to develop a larger-scale long-term project in the future. Installation and demonstration of SSH sensors in three Town Camp community centres in Alice Springs was completed in February 2020. Sensors were deployed in these Town Camps for the purposes of demonstration only and in public areas with consent from the community leaders with CSIRO Ethics approval. The collection of sensor data is used for data transfer and quality assurance purposes only. Successful data upload to cloud storage using local satellite internet or 4G has been achieved. Access to real-time sensor data on temperature, humidity and power usage has been confirmed.

We have submitted a full ethics application to proceed with a feasibility trial to deploy sensors in suitable houses determined by TCAC in one Town Camp for the purpose of collecting temperature, humidity and power usage over 12 months.

Primary Care Data Quality Foundations project

There are national standards for the collection of health data for Indigenous peoples. The Primary Care Data Quality Foundations Project (see Health Informatics section) is a community-driven consensus programme to standardise primary care data using a standard data model (FHIR) and a terminology (SNOMED CT) to improve data quality, interoperability and population health data use.

The next phase of the programme is expanding to include the data requirements for recording social determinants of health, risk factors and information on family history. This project will explore how this data could be used to support health assessments such as the RACGP National Guide to a Preventative Health Assessment and the Medicare Health Assessment for Aboriginal and Torres Strait Islander People (MBS ITEM 715).

The AEHRC and Indigenous Health: postdoc and student highlights

Postdoctoral fellow

Dr Kaley Butten, AEHRC-QAIHC

Supporting women with diabetes in pregnancy from diagnosis to childbirth

In collaboration with the Mt Isa Hospital, North West Hospital and Health and Service, and Aboriginal and Torres Strait Islander Community Controlled Health Organisation (Gidgee Healing), we have initiated a feasibility study of the M♡THer platform for gestational diabetes mellitis at the Mt Isa Hospital. The M♡THer platform utilises a smartphone application and web-based portal to support mothers and clinicians to manage diabetes during pregnancy. While the platform has proven successful in urban locations and is implemented across a number of Brisbane hospitals, this project will evaluate the feasibility of the platform in regional and remote areas and consider the perceptions and uptake of the platform by Aboriginal and/or Torres Strait Islander people within the area. The study has received ethical approval from the Townsville Hospital and Health Service and CSIRO, and is currently awaiting Site Specific Approval for the Mt Isa Hospital before beginning recruitment. The project will provide much needed insight into the adoption of m-health technologies into regional areas and the potential barriers to successful utilisation going forward.

Read more in Health Services: Project Reports.

PhD Students

Andrew Goodman, The University of Queensland

Tailoring and trialling a mHealth intervention for the management of hypertension in an Aboriginal and Torres Strait Islander community

This project aims to utilise a mobile health (mHealth) system for the management of hypertension through information exchange integrated into existing Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHOs). Timely access to primary health care is critical in the current COVID-19 pandemic. This mHealth platform facilitates remote monitoring and timely health care support without unnecessary exposure to potential risks of attending health service clinics for routine review.

Andrew is a PhD Candidate with The University of Queensland, a recipient of the Heart Foundation Australian Aboriginal and Torres Strait Islander Award PhD Scholarship, and the CSIRO Indigenous Postgraduate Top Up Scholarship.

Read more in the AEHRC and Indigenous Health: Project Updates.

AEHRC staff Ray Mahoney and Marlien Varnfield with Kelly Dingli from QAIHC and Kiri Wodington from Gidgee Healing.

Georgina Hobson, The University of Queensland

Digital health as an avenue for dementia awareness and support with Aboriginal and Torres Strait Islander peoples

Use of digital health applications with First Nations populations is an emerging area of research. Exploration of the perspectives of key stakeholders within Aboriginal and Torres Strait Islander communities regarding the integration of a digital health platform will be conducted. Outcomes will inform the development of a framework to guide future research and deployment of digital health platforms with Aboriginal and Torres Strait Islander peoples for health conditions including dementia.

Georgina is a PhD Candidate with The University of Queensland and a recipient of a CSIRO Research Plus Scholarship with the AEHRC.

MPH Student

Jed Fraser, Queensland University of Technology

Indigenous youth health assessments: a narrative systematic review

The objective of this review was to investigate the effectiveness of Indigenous youth health assessments for improving the health and wellbeing of Indigenous youth living in Canada, Australia, New Zealand, the United States and Taiwan, and the Sami people. Results were limited due to the small number of studies and varying methodological quality. However, health assessments can be useful for picking up new diagnoses and detecting concerns regarding social determinants of health and social and emotional wellbeing. Future development of Indigenous youth health assessments needs to involve Indigenous young peoples' voices.

The Health System Analytics group

Group Leader: Dr Rajiv Jayasena

The Health System Analytics group delivers value-based performance and productivity analytics to hospitals, payers and healthcare organisations by optimising patient, clinician and resource flows, including intelligent decision support and evaluating the implementation of new and improved care models as routine healthcare.

The group's research agenda is focused on supporting and improving health service delivery by applying evidence-driven strategies to support improved health outcomes. Our research includes building analytics, prediction, optimisation, and operational and clinical decision support tools that can help hospitals and clinicians obtain a better understanding of where they can optimise delivery of health services. It also seeks to provide them with solutions that can help improve and streamline the delivery of care and improve patient outcomes.

The group focuses broadly on three areas of research: hospital patient flow and demand analytics; hospital avoidance; and evidence-based healthcare evaluations. Across these three areas the group tackles issues such as predicting demand for patients presenting to the health system; risk stratification to reduce re-admissions and preventable hospitalisations; evaluation of care models; measuring translation of evidence to practice, and more.

Health System Analytics' science and impact highlights for 2019/20

- Completed in-hospital trial at Logan Hospital to identify and inform care and discharge planning for inpatients at risk of 30-day re-hospitalisation.
- Delivered comprehensive patient flow analysis report to Logan Hospital to inform hospital redesign efforts aimed at improving day-to-day capacity management, bed utilisation, patient flow and emergency department access performance.
- Delivery of the HealthLinks Chronic Care Evaluation Year 3 Progress Report to the Victorian Department of Health and Human Services.
- Our environmental scan report on measures and methodologies for Board Safety and Quality Reporting for the Victorian Agency for Health Information was publicly released through the agency's website.
- A report on simulating emergency service capacity to match emergency case demand was delivered to WA Health and Fiona Stanley Hospital.
- Completion of scenario modelling as the basis for the Future of Healthcare Queensland report.
- A web-based bed prediction tool implemented within the operational environment of Bunbury Hospital (WA Country Health Service).

Health Implementation Science team

Team Leader: Mr Norm Good

The Health Implementation Science team undertakes research into evaluating health service interventions and/or improvements using a range of qualitative and quantitative methods. Due to the complexity of health systems and heterogeneity among patients we are constantly exploring new and novel approaches to measure the efficacy, effectiveness and adoption of models of care and patient outcomes.

Our team explores what strategies delivered through what platforms and supported by what policies would increase adherence, reduce hospitalisations, reduce cost and improve quality of life for people whose ongoing health outcomes are at risk.

Health Intelligence team

Team Leader: Dr Sankalp Khanna

The Health Intelligence team brings together skills in artificial intelligence, statistics and operations research to further the science behind helping the health system increase productivity and safety through optimising patient, clinician and resource flows and providing intelligent decision support. Working closely with clinicians and health system administrators, we have delivered significant impact in the space of patient flow analytics, and are well recognised as leaders in this research space.

Health System Analytics: platform technologies

Predicting bed demand

Predicting bed demand is a necessary step in developing real-time monitoring and assessment tools for improving health service delivery in hospitals. Improving efficiency has become an absolute imperative for Australian state governments in their delivery of health services. The issue is becoming more urgent as the population ages, resulting in a growing number of people requiring hospitalisation under increasingly tighter budgetary conditions as proportionately fewer people are gainfully employed to help fund these services. The need to ensure adequate hospital capacity is particularly crucial during crises such as the current coronavirus outbreak, other viral outbreaks such as influenza, and the pressures winter places on hospital operations.

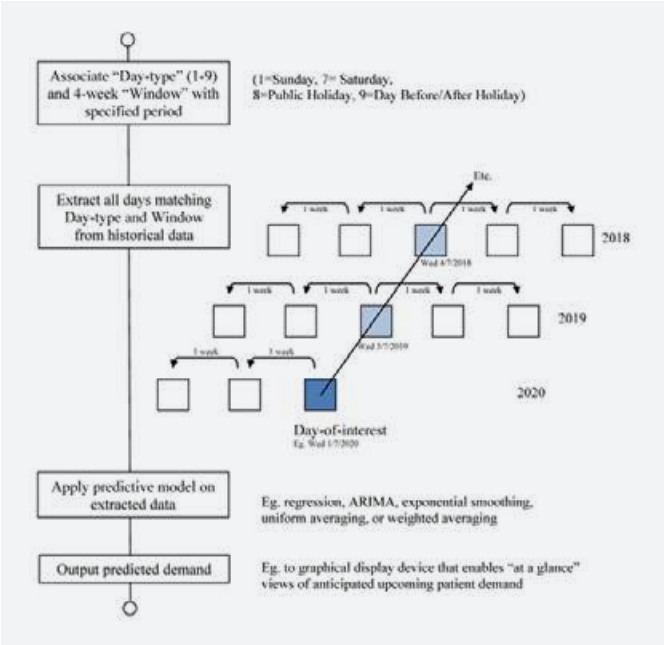
As suggested by the principle that you cannot manage what you cannot measure, the lack of accessible demand prediction impedes the efforts of planners and schedulers to improve the delivery of services. This platform technology relates to the embodiment of algorithms to predict ED presentations, inpatient admissions and separations, and operating theatre arrivals on any given day of the year, taking into account peak periods such as public holidays, to facilitate efficient use of available resources.

Initially developed in 2008 in partnership with Queensland Health, Griffith University and Queensland University of Technology, the models use a hospital's historical data to provide an accurate prediction of the expected daily patient load. Forecasts can be broken down by patient subgroups such as medical urgency, specialty, principal diagnosis, discharge disposition etc. The tool has been shown to have over 90 per cent accuracy in forecasting daily bed demand in a range of hospitals, and is used effectively for:

- staff resourcing
- scheduling of elective surgery
- identifying when demand is likely to exceed capacity
- detecting the start and duration of the annual winter bed crisis
- detecting disease outbreaks.

For patients, the system has delivered improved health outcomes such as:

- timely delivery of emergency care
- improved quality of care
- less time spent in hospital.



A rolling window approach to collect related historic observations for predicting demand on a target day of interest. For any day of interest, the algorithm collects historic observations on its corresponding day and surrounding weekly windows in preceding years.

We have continued to support and further develop the platform in response to demand from our users. In 2019-20 we extended this work by developing new prediction models for bed and operating theatre demand in Western Australia (read more in Health System Analytics: Project Reports). In future developments, we aim to make this technology available for use as a FHIR-enabled decision support tool that can directly communicate with FHIR-compatible electronic medical record software in hospital without the need for expensive customisation.

The value of this work has been recognised with several grants and internal and external awards.

Predictive analytics-driven patient monitoring and in-hospital care and discharge planning

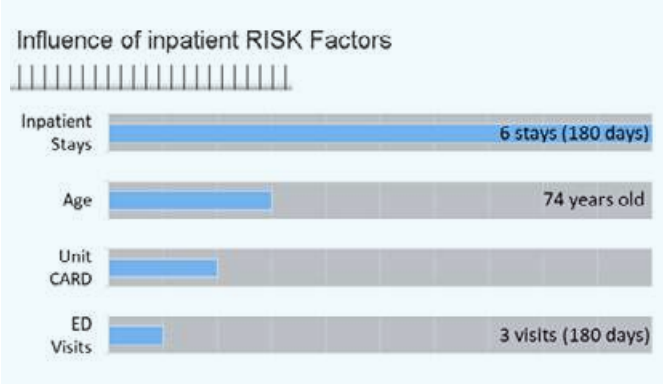
Strategies to reduce unplanned hospitalisations include interventions and integrated care in the community based around general practice (GP). Hospitals use in-hospital care planning and discharge planning to implement patient level strategies to reduce unplanned re-hospitalisations. However, identifying the patients who need these interventions can be a challenge.

We have developed explainable machine learning algorithms that use data captured in clinical and administrative systems to identify patients who would benefit from appropriate hospital avoidance interventions. We have also developed a web-based decision support interface for these algorithms that presents the top risk factors contributing most significantly to each patient's predicted risk level, to assist clinicians in care and discharge planning.

Previously, we also developed the Predictive Risk Model (PRM) used to identify eligible patients for the Australian Government's Health Care Homes (HCH) trial, an initiative to provide ongoing coordinated care for patients with chronic conditions in primary care clinics and Aboriginal Community Controlled Health Services across Australia. Over 170 GP practices nationally use the PRM, risk-stratifying and enrolling thousands of patients for the HCH trial.

In 2019-20, we completed a two-year in-hospital trial of decision support algorithms for identifying patient risk of readmission or re-presentation to the emergency department following discharge from hospital. We also participated in a demonstrator project for NSW Health where risk stratification algorithms we developed were employed for real-time risk profiling to provide clinical decision support in a NSW local health district. Another project is focused on predicting unexpected patient deterioration in the digital hospital setting. Read more on these projects in Health System Analytics: Project Reports and Project Updates.

We are currently extending algorithms for predicting patient risk of hospitalisation for deployment in the digital hospital setting for use across all Queensland hospitals for informing patient care and post-discharge interventions. We also propose extending this work to better estimate several other measures that are currently "guessed", "calculated", or "estimated" along various parts of the patient journey. These include estimated date of discharge, risk of death and risk of adverse outcome at an episode level. These algorithms can also be used to identify patient cohorts of interest, e.g. those that are high value or long length of stay. We also aim to make these algorithms available for use as FHIR-enabled decision support tools that can directly communicate with FHIR-compatible electronic medical record software in hospital without the need for expensive customisation.



Employing explainability on machine learning output to support clinical decision making. This de-identified report shows the patient has had six inpatient stays in the past 180 days, is aged 74 years, has had previous admission to the Cardiology Unit and three emergency department visits in the past 180 days. These represent the top four factors contributing to the patient's risk of readmission within 30 days post discharge. The blue bars represent relative influence of these risk factors.

Health System Analytics: project reports

Patient flow analysis at Logan Hospital

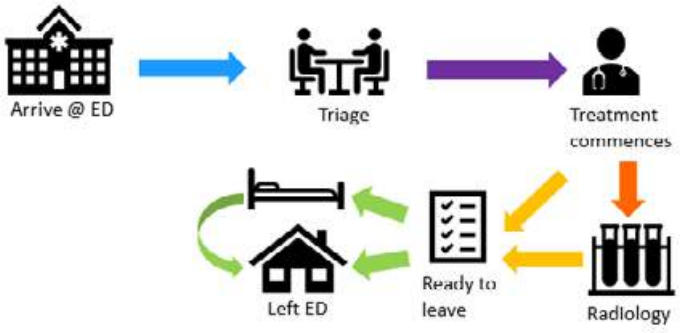
Collaborator: Metro South Hospital and Health Service, Queensland Health

This analytical research project was undertaken for and with Metro South Hospital and Health Service to identify strategies to improve bed access performance at Logan Hospital, a major metropolitan hospital in South East Queensland.

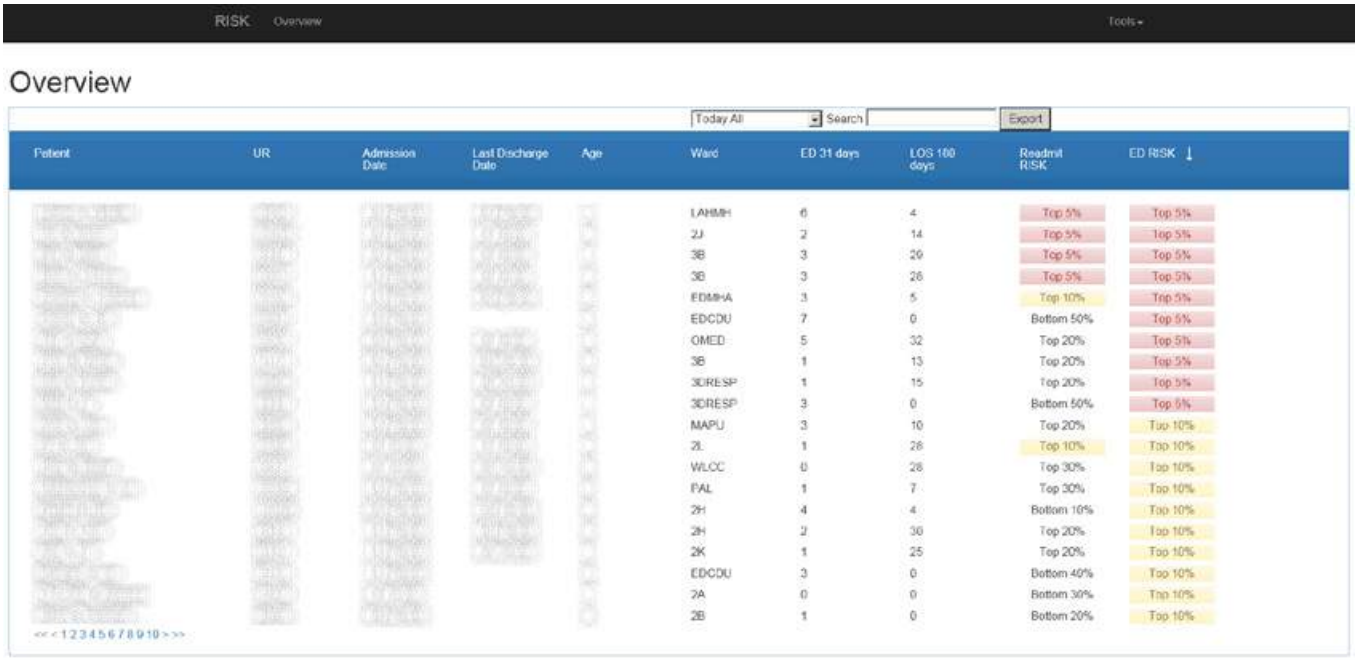
It involved evaluating the statistical relationship between time periods of care delivery and bed access performance indicators, including modelling:

- the ambulance-ED (emergency department) interface, determining the relationship between the number of ambulances at the door, the number of patients in ED, Patient Off Stretcher Time, and ED length of stay.
- ED flow, investigating the patient journey through the ED, and quantifying the impact of reducing treatment and departure delays on flow performance.
- Inpatient flow, to determine optimal bed occupancy targets to avoid flow bottlenecks, plausible discharge timing targets, and recommended bed stocks by specialty to achieve a given flow performance.

The modelling provided a hospital-wide view to capture relationships and interactions between flow metrics, to identify access issues and inform escalation strategies within the hospital system. Several strategies were identified to improve bed access performance at Logan Hospital. The findings from this system-wide modelling approach are expected to improve day-to-day capacity management-related decision making, leading to improvements in bed utilisation, patient flow and emergency department access performance. A better understanding of flow bottlenecks applied to day-to-day capacity management is expected to assist Logan Hospital executive with meeting performance targets and improving bed access for patients.



Waypoints explored in a patient's journey through the Logan Hospital ED.



Screenshot of the RISK tool showing risk of readmission within 30 days or re-presentation to ED within 30 days.

Risk stratification algorithms to quantify risk of rehospitalisation

Collaborators: Healthcare Improvement Unit and Logan Hospital, Queensland Health

Partnering with the Queensland Health's Healthcare Improvement Unit and Logan Hospital, we successfully completed a trial of a real-time web-based risk stratification algorithm in the admitted patient care setting to identify chronic disease patients with a high risk of re-hospitalisation to inform their care and discharge planning. Model development and validation involved employing routinely collected administrative and clinical datasets available in real time, and a web-based clinical decision support tool was built to provide risk groups and individual patient risk profiles to care teams.

Algorithms to predict unplanned re-admission within 30 days of discharge from hospital, and unplanned re-presentation to the ED within 30 days of discharge from hospital, were developed and validated on the Logan Hospital patient cohort and implemented within a password protected standalone web application hosted on a virtual machine on the Queensland Health network. Implementation of the tool was non-trivial, requiring significant liaison with eHealth Queensland and Metro South Clinical Informatics to establish a dedicated web service for the required data feeds. This was made available to various nurse practitioners engaged in the care of chronic disease patients for the duration of the trial. Quantitative and qualitative assessment was undertaken to evaluate whether the risk algorithm:

- improves the process of identifying patients at high risk of unplanned re-hospitalisation;
- reduces re-hospitalisation rates; and
- provides information to staff not readily available at the time of discharge planning.

Following the successful completion of the trial, we have been engaged by Queensland Health to develop and validate these algorithms for deployment in the digital hospital setting across all Queensland public hospitals. This work is underway.

Real time clinical decision support using FHIR

Collaborators: Alcidion and eHealth NSW

The deployment of electronic medical records (EMRs) at Australian hospitals is increasing the capture of high-quality patient data that can be used for patient care as well as safety, quality and research purposes. The increased adoption of standards – including terminologies such as SNOMED CT and common data models such as Fast Healthcare Interoperability Resources (FHIR) – greatly enhances the usefulness of information in EMR systems and improves interoperability of health information shared among healthcare providers and organisations.

Our rehospitalisation risk algorithm embedded within Alcidion's Miya flow dashboard.

The FHIR resources, which contain standard terminology, demonstrate the importance of agreed and standardised data models and terminologies, the cornerstone of knowledge representation. Leveraging these standards facilitates the deployment and scalability of real-time clinical analytics and decision support applications, and is a key research area for the Health System Analytics group.

A recent partnership project demonstrated the efficacy of this approach. Our predictive risk stratification algorithm developed was added into Alcidion's Miya Precision Real-Time FHIR Platform. We also supplied middleware that enabled data from the NSW Health EMR (from American company Cerner) to be sent as FHIR resources from the Alcidion Miya platform whenever certain trigger conditions were met, e.g. a new pathology report was received.

The proof-of-concept CSIRO algorithm then calculated a risk score based on the data in the FHIR observation resources and returned a FHIR resource into the Miya platform for display on dashboards to support real-time decision making. This work demonstrates the potential for improved detection and management of patients at risk of readmission.

A Healthy Horizon: megatrends and scenarios for the future of healthcare in Queensland out to 2040

Collaborators: CSIRO Data61 and Queensland Health

Queensland's healthcare sector is rapidly changing. Driven by the growing demand for healthcare services, changes in consumer and clinician expectations and emerging digital and health technologies, among other factors, the future horizon presents opportunities to revolutionise how the healthcare system operates by 2040. Understanding and keeping pace with emerging trends will be critical for ensuring current and future generations of Queenslanders continue to receive ever-improving standards of healthcare.

This report explores the 20-year future of healthcare in Queensland and identifies risks that, if not addressed, could cripple the ability of the future healthcare system to meet the needs of Queenslanders. This work was informed by consultations with government, academic and industry representatives, clinicians and health consumers.

This report identifies six 'megatrends' that have the potential to impact and reshape Queensland's healthcare system over the next 20 years. A megatrend reflects the convergence of multiple geopolitical, social, environmental, technological and economic trends that point to a deep-set trajectory of change that will unfold over coming decades. These megatrends are:

- An Unhealthy Climate
- Next-generation Consumers and Clinicians
- Getting Ahead of the Demand Curve
- Linking up the Healthcare System
- Health in a Technology Age
- Optimising Outcomes.

Four scenarios explore the different ways in which these megatrends could unfold over the next 20 years, taking into account the extent to which emerging digital and health technologies will be adopted by the sector and the degree to which future operational, strategic and policy decisions will be coordinated across the health portfolio. These scenarios from "low tech, health silos" to "high tech, health networks" are:

- Under Pressure
- Smart Hubs
- People Power
- A New Era.

To quantify the impact of these different healthcare futures, a set of health-related measures were modelled under each scenario. For example, in the Under Pressure scenario, healthcare expenditure is forecast to follow the status quo, reaching $64 billion (11% of gross state product) by 2040. On the other end of the spectrum, healthcare expenditure drops substantially by $18 billion under A New Era, reaching $46 billion (8% of gross state product) by 2040.

The megatrends and scenarios presented in the report provide a window to several plausible futures demonstrating that now is the time to shift the future direction and embrace a more integrated, data-informed, technology-enabled, patient-centred and outcomes-focused healthcare system in Queensland.

Operating Theatre Efficiency Modelling

Collaborator: Fiona Stanley Hospital, Western Australia

Operating theatres are one of the costliest components in hospital care, and improving theatre efficiency should be at the forefront of efforts to improve health service efficiency.

The focus of our work with the Fiona Stanley Hospital (FSH) in Western Australia throughout 2019-20 was to apply several statistical and machine learning approaches to predict the daily arrival of emergency and elective patients to theatre. This work is complete, and predictive accuracy has been quantified for elective/emergency breakdowns and for the 10 largest specialties by volume. Appropriate treatment of WA-specific public holidays has been included, allowing the models to be used prospectively for future dates of interest. Forecasts (plots and source data including 95% prediction intervals) have been provided to the hospital covering the months that followed the study period as a tangible component of the model development.

Models were also developed to predict if the current or following day would finish late. At a hospital level, overrun days can be predicted quite well using theatre patient cohort data up to midnight the day before (precision and recall >70%). Forecasting daily overruns is a binary classification problem, unlike forecasting predicted bed

demand which is based on the magnitude of error between forecast and observed counts. Four classifier approaches (Logistic Regression, Support Vector Machines, Naïve Bayes and Random Forests) were assessed using 10-fold cross-validation, where the data was partitioned into 10 subsamples to assess each model 10 times against new data not used in the model fitting. Predictive performance was described in terms of precision, recall and the F1-measure related to the model's ability to correctly pick true positives, and minimise false positives and false negatives. It is believed that predicting overruns in addition to predicting counts of theatre arrivals increases the value of this analytical exercise for end users from a day-to-day operational perspective.

In delivering on this study, we established a good working relationship with the Department of Anaesthesia and Pain Medicine and theatre data management staff. We worked together with FSH clinical collaborators throughout the project, collectively assessing the data and working through specific research questions based on relevance and importance to the surgery scheduling process in WA. To better understand scheduling processes, the team also included staff familiar with the dataset who provided invaluable comments on the measurement of surgery timestamps through FSH operating theatres, and focused on the factors responsible for causing inconsistencies in the measurement of efficiency-related metrics.

This project was awarded the CSIRO Health and Biosecurity Business Unit Award in 2019, recognising the use of deep digital and domain knowledge.

Bed demand prediction in WA

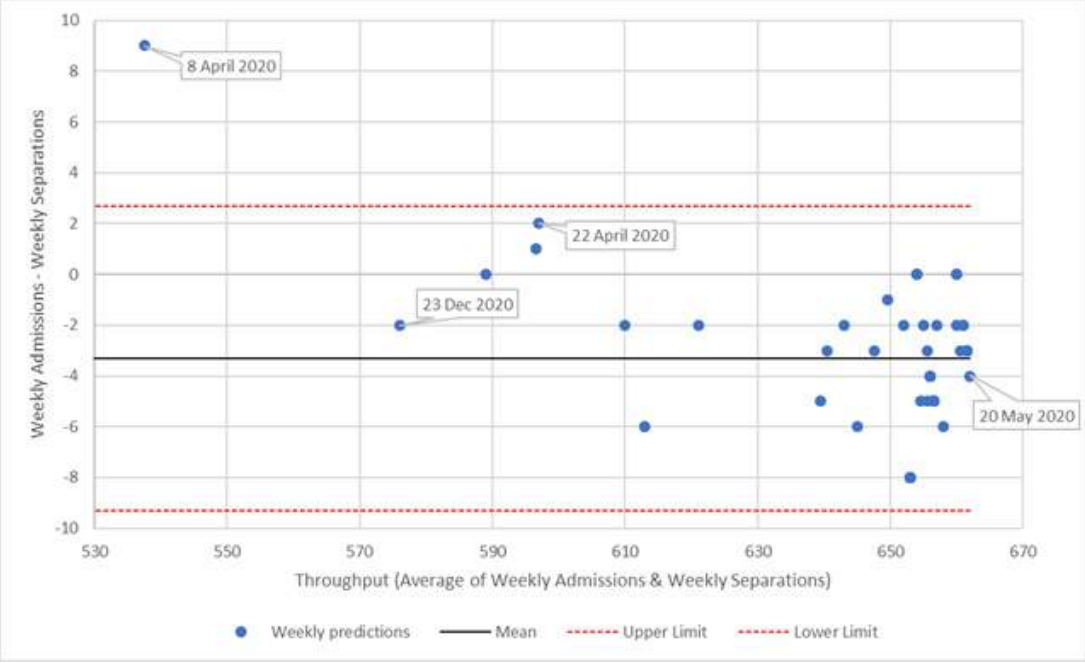
Collaborator: Western Australia Country Health Service

In 2019, we received funding from the Government of Western Australia (WA) acting through the WA Country Health Service to provide Bunbury Hospital with a model to forecast hospital bed demand which can assist in planning to meet daily demand for services and optimise service delivery. This understanding represents an early warning system of predicted bed demand for the hospital, so hospital managers can better prepare for high demand periods. Such a system can warn hospital decision makers of periods of increasing stress relating to future bed demand, thus providing them with information to best avoid or reduce the anticipated stress for their staff and patients.

The work is directly aligned with the 2019 WA Sustainable Health Review Report, particularly around capitalising on predictive analytics, big data, and moving towards the real-time use of data to unlock the potential benefits of the WA health system's rich information and transform healthcare. The validation performed in this project demonstrates it is possible to forecast daily bed demand within an accuracy of 90%. This level of forecast accuracy is for predicting daily estimates of emergency department and inpatient bed demand. When forecasting small patient subgroups within the data, sample sizes are smaller and forecast accuracy significantly differs to that for overall patient cohorts. As a tangible aspect of the modelling, we provided the hospital demand predictions for every day across 2020 for various cohorts such as presentations via ambulance and paediatric presentations.

In addition to day-to-day bed management, another application of predicting bed demand is looking at long-term patient flow movements and identifying potential shortfalls in hospital capacity. The project also showcased methods of determining long-term planning needs from the predictions: using smoothed net flow on a daily basis to identify trends; and forecasting at the weekly level and looking at differences between weekly forecasts of admissions and separations, which indicate on which specific weeks capacity issues may start occurring.

Mean difference plots of weekly separations and admissions used for identifying potential shortfalls in hospital capacity.



Periods where there is high throughput/turn-over (horizontal axis) and "large" admission number - weekly separation number (vertical axis) are indications of high hospital stress.

Health System Analytics: project updates

HealthLinks Chronic Care

Collaborator: Department of Health and Human Services Victoria

We are working in partnership with the Department of Health and Human Services Victoria (DHHS) on a co-sponsored system level evaluation of the HealthLinks Chronic Care (HLCC) initiative. The evaluation is based on the RE-AIM model and uses a comprehensive mixed methods approach including analysis of routinely collected hospital data, a quality of life patient survey conducted at three time points, workforce interviews conducted at two time points and costings data from across the trial period. The overall aim of the HLCC evaluation is to determine if flexible funding enables health services to develop and implement alternative models to inpatient acute care that provide better experiences and outcomes for patients with chronic conditions, at equal or lower cost.

So far the project has delivered two comprehensive annual reports, two six-monthly update reports and multiple presentations to the HLCC Clinical Collaborative and the Independent Hospital Pricing Authority.

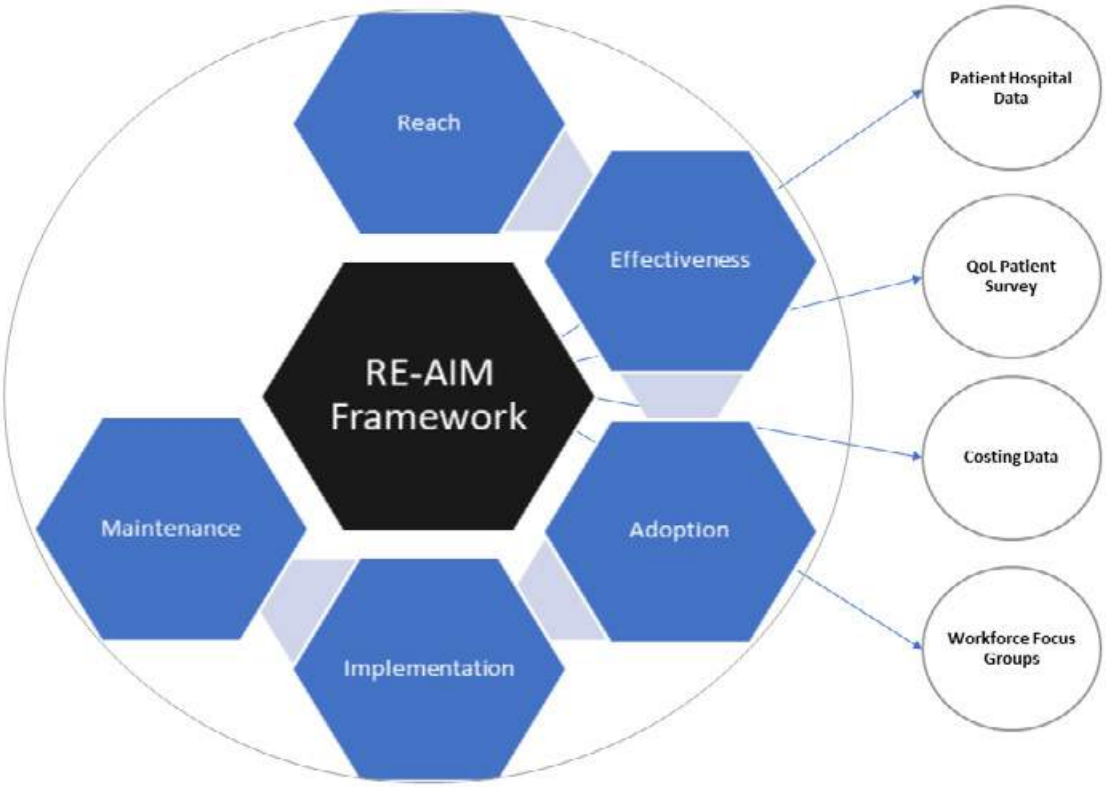
This is the third and final year of the project. The final report will be delivered to the DHHS in October 2020.

Predicting unexpected patient deterioration in a digital hospital

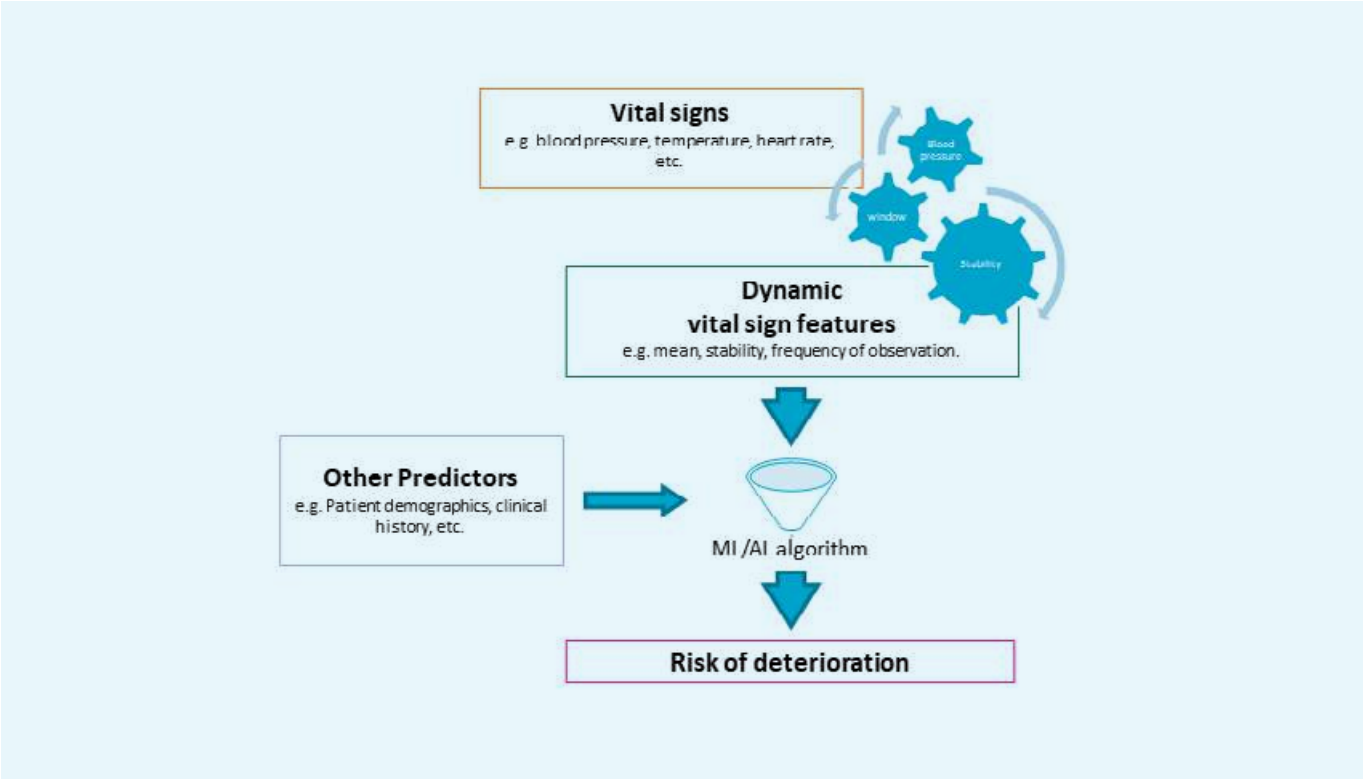
Collaborators: Clinical Excellence Division and Metro South Hospital and Health Service, Queensland Health

We are working with two Queensland Health Digital Hospitals (Princess Alexandra and Townsville Hospital) to improve detection of deteriorating patients. This project aims to reduce the incidence of unplanned adverse patient outcomes within the hospital by using data captured from medical devices and the iEMR.

This study aims to reduce unplanned intensive care unit admissions from a general ward, to reduce rapid response calls arising from a non-deteriorating patient, and to reduce the rate of serious injury, disability or death due to an adverse outcome while in hospital. This will include introducing customised vital signs thresholds programmed into a digital hospital's electronic medical record to suit individual patients using historic data, and predicting the likelihood of a patient deteriorating significantly before they become a candidate for critical or intensive care using a range of data sources.



Using the RE-AIM framework for evaluating the HealthLinks flexible funding model of care.



Analysis pipeline for real-time monitoring of patients' vital signs.

Predictive appointment notification tool

Collaborator: Austin Health in Victoria

We are working on a project with Austin Health in Victoria to better predict appointment loads for specialist clinics to provide realistic scheduling, increased productivity of staff, and timely care delivery for patients. The project's first main goal is to improve the appointments booking system currently used in the Austin Hospital by providing doctors with accurate real-time availability for their next appointment, providing additional visibility of delays to help manage the risk caused by delays, and allowing for better patient prioritisation during scheduling. The second goal is to provide a new tool to optimise clinic "templates" (i.e., the mix of appointment types) and explore the effect of "what if" scenarios on key performance indicators.

We are involved in various aspects: data preparation (data definition, data review and data cleaning), developing and validating models using queueing theory to predict queue lengths and waiting times, developing a prediction algorithm for their existing business-as-usual booking system, creating an optimisation functionality to optimise the mix of appointments in a clinic in each week, and creating an ability to play out "what if" scenarios of patient demand and clinician supply into the future. This is expected to help specialist clinics achieve quality and safety objectives while increasing patient satisfaction.

Syndromic surveillance for SA

Collaborator: SA Health's Commission for Excellence and Innovation in Health

In 2019-20, we began working with SA Health's Commission for Excellence and Innovation in Health in the area of syndromic surveillance. This project involved generating intelligence from data to inform operational decision making and response planning, and development of statistical models specific to SA for the monitoring of COVID-19 outbreaks. Pathology testing data related to COVID-19 was matched against emergency department and inpatient datasets to provide insight into the virus' impact on South Australian hospitals and characteristics of hospitalised COVID-19 patients. As coronavirus counts in the state have decreased following an initial first wave, influenza-like illness cases were analysed and used to develop initial outbreak detection models for application to syndromic surveillance.

The work supports SA Health's efforts to improve syndromic surveillance capability and assist hospitals in planning and responding to variations in hospital emergency demand.

Defining a new 30-day AMI mortality measure

Collaborator: Victorian Agency for Health Information

We were commissioned by the Victorian Agency for Health Information (VAHI) to develop a 30-day mortality measure for acute myocardial infarction which includes both in- and out-of-hospital mortality. This work was a continuation of earlier modelling work completed by CSIRO. This new work explored and recommended the most appropriate measurement period, threshold and frequency for reporting, as well as suggesting visualisation options to communicate hospital performance. As part of the project brief, we presented our recommendations for feedback and consideration to various key stakeholders including VAHI's Expert Advisory Group and the Safer Care Victoria Cardiac Clinical Network Insight Group.

The outputs from this project are being implemented by VAHI for reporting via VAHI's Program Report for Integrated Service Monitoring (PRISM) report. The PRISM report is targeted at the Department of Health and Human Services and health service executives and boards.

Board Safety Quality Reporting redesign

Collaborator: Victorian Agency for Health Information

This project assisted the Victorian Agency for Health Information (VAHI) to define the structure, metrics and visualisation of the Board Safety and Quality Report (BSQR) for all Victorian Health Services. The project team delivered an environmental scan report to inform VAHI's effort to redesign reporting to the boards of the 85 health services in Victoria. While the team was contracted to review available literature in the national and international context to identify strategic metrics suitable for inclusion, the focus was expanded to include various frameworks governing board level reporting and providing assistance with understanding several strategic measures. The team was also called upon to provide significant additional support, to assist VAHI plan their strategy for reporting metric selection, facilitate meeting with CSIRO contacts in other states and overseas to help the BSQR Expert Advisory Group (EAG) and VAHI leadership gain additional perspective, and provide advice and short reports to VAHI leadership and the EAG.

The feedback from EAG members and VAHI executive on the environment scan report were very positive and several EAG Board members acknowledged the body of work as thorough and requested bound hard copies of the report as a reference article. VAHI publicly released our report as a resource through their website. This project provided great exposure for the AEHRC and for our Victorian presence, where we were sitting alongside Victorian State Government executives to help define important metrics and how they should be positioned for reporting and benchmarking safety and quality across hospitals statewide.

The delivered work strongly impacts how safety and quality of care is monitored by Victorian hospitals to measure and drive improvement and provides an excellent opportunity to showcase CSIRO expertise in hospital performance and productivity research.

Supporting COVID-19-related modelling

Collaborator: Queensland Health, New South Wales Health

We worked with several state health agencies to support their COVID-19 response. We worked closely with Queensland Health on several versions of their demand forecasting model stood up in March 2019 to support planning and response. We are now working with them on analysing COVID-19 patient journeys and developing and validating models to support surveillance, monitoring. disease forecasting, and decision making as restrictions are eased and efforts are made to return to normal.

We were also engaged by New South Wales Health to provide independent expert advice on critical care demand models developed by their System Information and Analytics Branch for forecasting and scenario planning as part of their COVID-19 response.

Health System Analytics: postdoc and student highlights

Postdoctoral fellows

Dr Kay Mann

Kay is working on the "real-time" deteriorating patient prediction project. This project aims to develop a range of predictive statistical models for use in the clinical setting to optimally manage patients. Kay has developed a comprehensive data dictionary, and formalised a research analysis pipeline including the creation of time-series based vital sign features for input into models. Currently Kay is in the final stages of writing up a systematic review of the literature on real time vital sign research.

Dr Vahid Riahi

Vahid is working on a project for Austin Health in Victoria to improve their appointment booking system, to ensure correct prioritisation is given to patients in need of closer monitoring and to provide doctors with real-time information to support their decision-making in determining appropriate review schedules. To that end, Vahid analyses the historical data, creates system policies to determine whether patients should remain or be removed from the hospital waiting list, and builds algorithms to automate the appointment scheduling process.

PhD students

James Kemp, Centre for Big Data Research in Health, Faculty of Medicine, UNSW

AEHRC Industry PhD, scholarship UNSW. Fraudulent or inappropriate claims from healthcare providers can be costly for government health programs. With increasing numbers of claims, data analysis becomes a bottleneck in the process of detecting abnormal claims. Improving analysis methods could lower the cost of detection as well as increase detection rates. Deep learning algorithms are able to detect patterns in large volumes of data that may not be identified using conventional methods. This project will apply machine learning techniques, including deep learning, to whole-of-population Australian Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data sets held by the Australian Government Department of Health.

James has had his confirmation and is currently working on his first methods paper using association rule mining techniques to identify fraudulent and/or suspicious provider billing codes for select elective surgical procedures in public hospitals.

Kristin Edwards, James Cook University

Kristin is a PhD student jointly supervised by James Cook University and CSIRO. Her project forms a pilot study into aeromedical retrieval with the primary aim to develop analytics to support decisions, which leads to better health outcomes for patients requiring aeromedical retrieval. Kristin's research is motivated by her former career as a critical care nurse in America and Australia and wanting to provide better care and access for regional patients.

Marko Simunovic, Queensland University of Technology

Marko is a PhD student jointly supervised by QUT, LaTrobe University and CSIRO. He has an interest in combining epidemiology and big data to produce meaningful health related outcomes. His project aims to investigate spatiotemporal trends in asthma through Queensland and associations with grass pollen exposure, and to investigate whether temperate areas of South East Queensland are at increased risk of epidemic thunderstorm asthma compared to subtropical areas of Queensland. It is anticipated that this research will generate new knowledge to better understand epidemic asthma risks at state and national level. The outcomes will help inform public health strategy for mitigating risks of pollen-induced allergic respiratory disease in South East Queensland and the Darling Downs.

Australian Tele-Health Research and Development Group, Western Australia

The Australian Telehealth Research and Development Group (ATRDG) was established by CSIRO in conjunction with the Department of Health Western Australia in June 2012.

As part of our Health Services group, the ATRDG aims to develop a strong telehealth research and development program to address pressing and emerging areas of healthcare delivery, particularly in respect to the provision of high quality services to rural and remote populations, and to high-needs groups. The ATRDG aims to align and work with service providers and other stakeholders, and assist them in developing systems and technologies that result in better service delivery solutions and preventative health applications.

The ATRDG strives to be a world-leading telehealth research and development group, and aims to transform the way health services are delivered. The aim of this research is to improve health outcomes in Western Australia and increase the productivity and efficiency of health service delivery in the state.

In 2020 funding for projects in Perth were extended by a further 12 months by the WA Department of Health.

The AEHRC now has 13 staff in Perth as part of our ATRDG:

- The Artificial Intelligence in Tele-Health team, led by Shaun Frost, develops diagnostic and decision support systems for remote delivery of health services. Read more in the Health Services section.
- The Tele-Health Solutions team, led by Jana Vignarajan, develops and trials solutions that enable delivery of healthcare remotely and support research involving telehealth. Read more in the Health Services section.
- Our Health Intelligence team, with staff in Brisbane, Melbourne and Perth, partners with hospitals around Australia – including Fiona Stanley and Bunbury Hospitals – to provide tools to understand hospital performance; optimise patient, clinician and resource flows; and provide intelligent decision support. Read WA-specific project updates the Health System Analytics section.
- Our Health Informatics group – with staff in Brisbane, Sydney and Perth – aims to to improve the quality of health data to improve patient outcomes and health system performance and productivity. Staff in Perth contribute to a wide variety of Health Informatics group projects.
- Our Perth-based biostatistics staff work with our Perth-based collaborators as part of national and international research on Alzheimer's disease.

ATRDG highlights for 2019/20

- In collaboration with SMHS, the Tele-Health Solutions team developed the MICE (Medical Image Communication & Exchange) mobile health platform to transmit medical images, patient consent and clinical data in a secure and organised manner that keeps data and images in approved health care systems. The platform is now being used in burns, plastics, rural and emergency clinical settings. Read more about MICE in the Health Services: Platform Technologies section.
- The Artificial Intelligence in Tele-Health team completed a retinal imaging study investigating novel markers of hypertension (n=300). Preliminary analysis of correlation between fine vessel loss and hypertension mediated damage on kidney and large blood vessel, providing a capacity of non-invasive retinal imaging for cardiovascular risk. Read more in the Health Services: Project Updates section.
- In collaboration with Townsville Hospital, our Tele-Health Solutions team developed and evaluated a video streaming system for families to connect to the Neonatal Unit to see their premature born baby remotely. The "BabyCam" won the award for outstanding achievement at the Queensland Health Excellence Awards. Read more in the Health Services: Project Updates section.
- The Tele-Health Solutions team is developing technologies to support remote oral care. In a first step, this project has delivered a library of oral radiographic images with a ground truth database created. The deep learning-based machine learning model will be validated and tested against human grading. Read more in the Health Services: Project Reports section.
- Our Health Intelligence team undertook analysis and delivered a report on simulating emergency service capacity to match emergency case demand at Fiona Stanley Hospital. Read more in the Health System Analytics: Project Updates section.
- Our Health Intelligence team developed a web-based bed prediction tool within the operational environment of Bunbury Hospital with the WA Country Health Service. Read more in the Health System Analytics: Project Updates section.
- Amongst many other clinical terminology projects, our Perth-based clinical terminology staff developed a map between SNOMED CT and the Human Phenotype Ontology – now used by the Australian Genomics Health Alliance. Read more in the Health Informatics: Project Updates section.
- Our Perth-based biostatistics staff contributed to many of the Alzheimer's disease outcomes reported in the Biomedical Informatics: Project Updates section.

Vacation student projects

Project: Clinical text classification using large-scale pre-trained language models

Student: Anh (Andy) Pham, Queensland University of Technology

Supervisor: Thanh Vu

This project aimed to apply the state-of-the-art pre-trained language models, such as BERT, RoBERTa, BioBERT to clinical text classification tasks including cancer staging and ICD coding. A new component of our machine learning framework was created, which enables easy fine-tuning of a pre-trained language model with a clinical text classification task. The experimental results on several clinical datasets were collected and are currently in preparation for an academic paper submission.

Project: Identifying stroke subtype from diffusion MRI images using a deep learning approach

Student: Elaine Le Khon Luc, University of Queensland

Supervisor: Miranda Li

The aims of this project were to use deep learning methods to predict stroke subtypes from diffusion MRI images and to develop an augmented reality (AR) program to display the MRI images. A deep learning protocol was also developed to identify stroke from other diseases. Additionally, a new AR software has been developed to display MRI images, which can help remote communications between clinicians.

Project: Smart Activity Annotation Platform (SAAP): An innovative design to promote self-labelling ground truth collection for smart homes

Student: Chunyue Zheng, University of Sydney

Supervisor: Mahnoosh Kholghi

This project explored the application of gamification in the Smart Safer Home (SSH) project. The aim was to efficiently engage home residents in annotating their activities captured through ambient sensors. Firstly, a protocol was developed to generate a list of questions based on sensor data, and then a gamification app called "My Garden" was designed based on the general interests of senior citizens. A user experience study is required before deploying the My Garden app in SSH trials.

Project: Development of a gamification app for children with chronic pain

Student: Kausthubram Rajesh, University of Queensland

Supervisor: David Ireland

This project aimed to develop a game within the Pain ROADMAP mobile application to increase the compliance of child users. Pain ROADMAP is a data-collecting app for individuals with chronic pain which provides an 'Activity Pacing' based intervention for the management of chronic pain and medication use. This project was the implementation of an adventure game called 'The Case of Ebony Shadows'. In order to progress within the game, medication, activity and well-being data must be entered. The Pain ROADMAP app is now being deployed across Australia at different chronic pain clinics for a pilot study.

Project: Building disease models for synthetic patient data generation

Student: Kathryn Bird, University of Queensland

Supervisor: John Grimes

This project explored techniques for the generation of more sophisticated synthetic clinical data for use in testing health data analytics algorithms and generating statistically accurate models of patient populations. The synthetic patient data generation tool Synthea was enhanced to allow for family history to be generated as part of a patient's clinical record and exported as part of the FHIR representation. This has improved our ability to model congenital conditions and use this information within sophisticated patient cohort selection criteria and analytics use cases.

Project: Patient flow analysis and simulation

Student: Erin (Ezra) Kenny, University of Queensland

Supervisor: Hamed Hassanzadeh

This project investigated the application of simulation modelling towards optimising hospital bed configurations and patient flow. Various strategies for generating historically informed synthetic data were explored to help the simulation model to better mimic the patient flow through the target hospital over a longer future time frame. The findings of this project are reported in a conference manuscript.

Project: The power of family trees to discover new disease genes

Student: Heidi Chan, University of New South Wales

Supervisor: Natalie Twine

Identification of cryptic relatedness in a disease cohort can help uncover novel disease genes. The aim of this project was to apply our relatedness tool, TRIBES to a cohort of 800 individuals with either Alzheimer's disease (ADNI cohort) or healthy controls to identify any cryptic relatedness. The outcome of this project shows no relatives closer than 7th degree in either disease or control cohorts, and no difference in proportion of relatives between the cohorts. This result indicates that there is no recent family history of disease in this cohort and the disease is more sporadic in nature.

Project: Exploring the role of viral integration in cancer

Student: Susanna Grigson, Flinders University

Supervisor: Suzanne Scott

The main goal of this project was to simulate the integration of viral DNA into the genome of a host organism. These simulations are a useful tool for assessing the impact of viral integration, as well as assessing the accuracy of tools that detect viral integration. The outcome of this project was a workflow for simulating viral integration, as well as an examination of our tool for detecting viral integrations in various conditions. These data are being incorporated into a manuscript, which is currently in preparation.

Project: Unlocking the secrets in genomes using the power of visualisation

Student: Milindi Kodikara, RMIT

Supervisor: Arash Bayat

In this project, a python program was developed that parses the output of an epistasis analysis and turns it into a dynamic Cytoscape graph. Various visual elements have been used to simplify the complexity of the graph. The resulting software can be used for post epistasis analysis and help scientists to distinguish true biological interactions given a large number of statistical interactions. The achievements have been published in GitHub (github.com/aehrc/EpiExplorer) and have been expanded to be used in the Amazon Web Services cloud.

Project: Emotion monitoring system for telehealth and robot-assisted consultations

Student: Jenny Chiem, University of Sydney

Supervisor: David Silvera

This project developed a system to improve remote consultations (for example, via telehealth or telepresence robots) by providing clinicians with real-time information about a patient's emotions, using audio-visual data. The project brought together a number of machine learning techniques to achieve face detection and emotion classification. The accuracy of the model is approximately 73%. The efficacy of the new system to support remote consultations will be evaluated in future work.

Project: Machine learning for the automated analysis of sight-threatening retinal disease

Student: Dhaval Vaghjiani, University of Western Australia

Supervisor: Sajib Saha

This project developed a visualisation strategy so that the interworking of convolution neural networks for glaucoma detection can be visualised and the inherent image features contributing to disease detection can be understood. A set of interpretable notions representing five mutually exclusive ocular components to better comprehend the contributing image features involved in the disease detection process was also proposed. Extensive experiments were conducted on publicly available glaucoma datasets. The project not only developed an innovative system but also revealed interesting findings in the context. A manuscript is currently under review.

Publications 2019-2020

Journal Papers

1. S. Amadoru, V. Dore, C. McLean, F. Hinton, C. Shepherd, G. Halliday, C. Leyton, J. Hodges, C. Masters, V. Villemagne, C. Rowe, "Comparison of amyloid PET measured in Centiloid units with neuropathological findings in Alzheimer's disease", Alzheimer's Research & Therapy, vol. 12, pp. 1-8, Mar 2020.

2. D. Bauer, A. Tay, L. Wilson, D. Reti, C. Hosking, A. McAuley, E. Pharo, S. Todd, V. Stevens, M. Neave, M. Tachedjian, T. Drew, V. Vasan, "Supporting pandemic response using genomics and bioinformatics: a case study on the emergent SARS-CoV-2 outbreak", Transboundary and Emerging Disaeses, pp. online in press, May 2020.

3. A. Bayat, B. Hosking, Y. Jain, C. Hosking, N. Twine, D. Bauer, "BitEpi: A Fast and Accurate Exhaustive Higher-Order Epistasis Search", BioRxiv, vol. 1, pp. 11, Nov 2019.

4. J. Beaumont, S. Herve, O. Acosta, T. Kober, M. Tanner, J. Ferre, O. Salvado, J. Fripp, G. Gambarota, "Multi T1-weighted contrast MRI with fluid and white matter suppression at 1.5 T", Magnetic Resonance Imaging, vol. 63, pp. 217-225, Nov 2019.

5. S. Bradford, S. Nair, A. Statham, S. van Dijk, T. Peters, F. Anwar, H. French, J. von Martels, B. Sutcliffe, M. Maddugoda, M. Peranec, H. Varinli, R. Arnoldy, M. Buckley, J. Ross, E. Zotenko, J. Song, C. Stirzaker, D. Bauer, W. Qu, M. Swarbrick, H. Lutgers, R. Lord, K. Samaras, P. Molloy, S. Clark, "Methylome and transcriptome maps of human visceral and subcutaneous adipocytes reveal key epigenetic differences at developmental genes.", Scientific Reports, vol. 9, pp. 1, Jul 2019.

6. M. Braunstein, I. Oanceae, B. Barry, S. Darlington, J. Steel, D. Hansen, J. Battock, D. Cheung, G. Gan, B. Hooper, R. Lundin, D. Nicol, J. O'Brien, S. Whittington, C. Wilkinson, T. Wong, "The Development and Electronic Delivery of Case-Based Learning Using a Fast Healthcare Interoperability Resource System", JAMIA Open, pp. Online, Oct 2019.

7. C. Brighi, L. Reid, A. White, L. Genovesi, M. Kojic, A. Millar, Z. Bruce, B. Day, S. Rose, A. Whittaker, S. Puttick, "MR-guided focused ultrasound increases antibody delivery to non-enhancing high-grade glioma", Neuro Oncology Advances, vol. 2, pp. 1-12, Mar 2020.

8. C. Brighi, L. Reid, L. Genovesi, M. Kojic, A. Millar, Z. Bruce, A. White, B. Day, S. Rose, A. Whittaker, S. Puttick, "Comparative Study of Preclinical Mouse Models of High-Grade Glioma: The Importance of Reproducing Blood-Brain Barrier Heterogeneity", Theranostics, vol. 10, pp. 6361-6371, May 2020.

9. E. Brindal, G. Hendrie, J. Freyne, M. Noakes, "A Mobile Phone App Designed to Support Weight Loss Maintenance and Well-Being (MotiMate): Randomized Controlled Trial", JMIR mHealth and uHealth, vol. 7, pp. e12882, Sep 2019.

10. J. Buckley, R. Rai, G. Liney, J. Dowling, L. Holloway, P. Metcalfe, P. Keall, "Anatomical deformation due to horizontal rotation: Towards gantry-free radiation therapy", Physics in Medicine and Biology, vol. 64, pp. 175014-175026, Sep 2019.

11. R. Buckley, S. Sikkes, V. Villemagne, E. Mormino, J. Rabin, S. Burnham, K. Papp, V. Dore, C. Masters, M. Properzi, A. Schultz, K. Johnson, D. Rentz, R. Sperling, R. Amariglio, "Using subjective cognitive decline to identify high global amyloid in community-based samples: a cross-cohort study", Journal of Alzheimer's disease, vol. 11, pp. 670-678, Dec 2019.

12. S. Burnham, N. Fandos, C. Fowler, V. Dore, J. Doecke, R. Shishegar, T. Cox, J. Fripp, V. Pérez-Grijalba, C. Rowe, M. Sarasa, C. Masters, P. Pesini, V. Villemagne, "Longitudinal Evaluation of the Natural History of Amyloid-Beta in Plasma and Brain", Brain Communications, vol. 2, pp. fcaa041, Apr 2020.

13. M. Cespedes, J. McGree, C. Drovandi, K. Mengersen, J. Fripp, J. Doecke, "Relative rate of change in cognitive score network dynamics via Bayesian hierarchical model reveal spatial patterns of neurodegeneration", Statistics in Medicine, pp. 1-19, May 2020.

14. J. Choi, D. Lee, L. O'Connor, S. Chalup, J. Welsh, J. Dowling, P. Greer, "Bulk Anatomical Density Based Dose Calculation for Patient-Specific Quality Assurance of MRI-only Prostate Radiotherapy", Frontiers in Oncology, vol. 9, pp. 1-10, Oct 2019.

15. C. Dang, N. Yassi, K. Harrington, Y. Xia, Y. Lim, D. Ames, S. Laws, M. Hickey, S. Rainey-Smith, H. Sohrabi, J. Doecke, J. Fripp, O. Salvado, P. Synder, M. Weinborn, V. Villemagne, C. Rowe, C. Masters, P. Maruff, "Rates of age- and amyloid β-associated cortical atrophy in older adults with superior memory performance", Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring, vol. 11, pp. 566-575, Aug 2019.

16. K. Dhiman, V. Gupta, V. Villemagne, D. Eratne, P. Graham, C. Fowler, P. Bourgeat, Q. Li, S. Collins, A. Bush, C. Rowe, C. Masters, D. Ames, E. Hone, K. Blennow, H. Zetterberg, R. Martins, "Cerebrospinal fluid neurofilament light concentration predicts brain atrophy and cognition in Alzheimer's disease", Alzheimer's & Dementia, vol. 12, pp. e12005, Feb 2020.

17. J. Doecke, L. Ward, S. Burnham, V. Villemagne, Q. Li, S. Collins, C. Fowler, E. Manuilova, M. Widmann, S. Rainey-Smith, R. Martins, C. Masters, t. AIBL Research Group, "Elecsys CSF biomarker immunoassays demonstrate concordance with amyloid-PET imaging", Alzheimer's Research & Therapy, vol. 12, pp. 1-10, Mar 2020.

18. A. Elias, T. Cummins, F. Lamb, V. Dore, R. Tyrrell, R. Williams, J. Rosenfield, M. Hopwood, V. Villemagne, C. Rowe, "β-amyloid, tau and 18F-fluorodeoxyglucose Positron Emission Tomography in Posttraumatic Stress Disorder", Journal of Alzheimer's Disease, vol. 73, pp. 163-173, Jan 2020.

19. M. Estai, Y. Kanagasingam, M. Mehdizadeh, J. Vignarajan, M. Tennant, E. Kruger, R. Norman, B. Huang, H. Spallek, M. Irving, A. Arora, "Teledentistry as a Novel Pathway to Improve Dental Health in School Children: A Research Protocol for a Randomised Controlled Trial", BMC Oral Health, vol. 20, pp. 11, Jan 2020.

20. R. Finnegan, E. Lorenzen, J. Dowling, L. Holloway, D. Thwaites, C. Brink, "Localised delineation uncertainty for iterative atlas selection in automatic cardiac segmentation", Physics in Medicine and Biology, vol. 65, pp. 035011-035022, Feb 2020.

21. S. Frost, D. Xiao, M. Mehdizadeh, S. Burnham, C. Dehghani, J. Vignarajan, Y. Kanagasingam, "Effect of Pupil Dilation with Tropicamide on Retinal Vascular Parameters", Ophthalmic Epidemiology, vol. 2019, pp. 1-8, Jul 2019.

22. M. García-Galant, L. Reid, K. Pannek, "Study protocol of a randomized controlled trial of home-based computerized executive function training for children with cerebral palsy", BMC Pediatrics, vol. 20, pp. x, Jan 2020.

23. J. George, A. Pagnozzi, S. Bora, R. Boyd, P. Colditz, S. Rose, R. Ware, K. Pannek, J. Bursle, J. Fripp, K. Barlow, K. Iyer, S. Lieshman, R. Jendra, "Prediction of childhood Brain Outcomes in infants born preterm using neonatal MRI and concurrent clinical biomarkers (PREBO-6): study protocol for a prospective cohort study", BMJ Open, vol. 12, pp. e036480, May 2020.

24. M. Gonzalez-Garcia, N. Ghafouryan Gomish Bashi, F. Fatehi, M. Varnfield, P. Iyngkaran, A. Driscoll, C. Neil, D. Hare, B. Oldenburg, "A Review of Randomized Controlled Trials Utilizing Telemedicine for Improving Heart Failure Readmission: Can a Realist Approach Bridge the Translational Divide?", Clinical Medicine Insights: Cardiology, vol. 13, pp. 1-13, Jul 2019.

25. J. Goos, T. Dilling, M. Davydova, A. Cho, S. Puttick, A. Gupta, W. Price, J. Quinn, M. Whittaker, J. Lewis, T. Davis, "Delivery of polymeric nanostars for molecular imaging and endoradiotherapy through the enhanced permeability and retention (EPR) effect", Theranostics, vol. 10, pp. 567-584, Jan 2020.

26. J. Goos, M. Davydova, T. Dilling, A. Cho, A. Gupta, W. Price, S. Puttick, M. Whittaker, J. Quinn, T. Davis, J. Lewis, "Design and Preclinical Evaluation of Nanostars for the Passive Pretargeting of Tumor Tissue", Nuclear Medicine and Biology, vol. 84, pp. 63-72, Mar 2020.

27. P. Greer, J. Martin, P. Hunter, P. Pichler, J. Choi, L. Best, J. Smart, T. Young, M. Jameson, T. Afinidad, C. Wratten, J. Denham, L. Holloway, M. Sidhom, S. Sridharan, R. Rai, P. Raniga, J. Dowling, "A multi-center prospective study for implementation of an MRI-only prostate treatment planning workflow", Frontiers in Oncology, vol. 9, pp. Article 826, Aug 2019.

28. B. Harrington, Y. He, P. Conroy, S. Puttick, T. Khan, T. Kryzna, T. Cuda, K. Robbins, B. Arachchige, S. Stehbens, P. Pollock, S. Reed, J. Weroha, P. Haluska, C. Salomon, R. Lourie, L. Perrin, R. Law, J. Whisstock, J. Hooper, "Anti-CDCP1 immune-conjugates for detection and inhibition of ovarian cancer", Theranostics, vol. 10, pp. 2095-2114, Jan 2020.

29. H. Hassanzadeh, A. Nguyen, K. Verspoor, "Quantifying Semantic Similarity of Clinical Evidence in the Biomedical Literature to Facilitate Related Evidence Synthesis", Journal of Biomedical Informatics, vol. 100, pp. 1-13, Oct 2019.

30. H. Hassanzadeh, S. Karimi, A. Nguyen, "Matching Patients to Clinical Trials Using Semantically Enriched Document Representation", Journal of Biomedical Informatics (JBI), vol. 105, pp. 103406, Mar 2020.

31. Z. Houston, J. Bunt, K. Chen, S. Puttick, C. Howard, N. Fletcher, A. Fuchs, J. Cui, Y. Ju, G. Cowin, X. Song, A. Boyd, S. Mahler, F. Caruso, L. Richards, K. Thurecht, "Assessing permeation of nanomedicines into brain tumours: deconvolving the effect of leaky vasculature versus tumour size", ACS Central Science, vol. 6, pp. 727-738, Apr 2020.

32. S. Jamadar, F. Sforazzini, P. Raniga, N. Ferries, B. Paton, M. Bailey, A. Brodtmann, P. Yates, S. Ward, R. Woods, E. Storey, J. McNeil, G. Egan, "Sexual dimorphism of resting-state network connectivity in healthy ageing", Journals of Gerontology: Psychological Sciences, vol. 74, pp. 1121–1131, Oct 2019.

33. Jimmy, G. Zuccon, B. Koopman, "Payoffs and Pitfalls in using Knowledge-Bases for Consumer Health Search", Information Retrieval, vol. 22, pp. 350–394, Aug 2019.

34. S. Johnatty, C. Stewart, D. Smith, A. Nguyen, J. O'Dwyer, T. O'Mara, P. Webb, A. Spurdle, "Co-existence of leiomyomas, adenomyosis and endometriosis in women with endometrial cancer", Scientific Reports, vol. 10, pp. Article 3621, Feb 2020.

35. M. Kolic, E. Baglin, S. Titchener, J. Kvansakul, C. Abbott, N. Barnes, W. Kentler, K. Young, J. Walker, J. Yeoh, D. Nayagam, C. Luu, L. Ayton, M. Petoe, P. Allen, "A 44 channel suprachoroidal retinal prosthesis: interim functional vision results", Association for Research in Vision and Ophthalmology, vol. 61, pp. 2199, Jun 2020.

36. T. Kryza, T. Khan, S. Puttick, C. Li, K. Sokolowski, B. Tse, T. Cuda, N. Lyons, M. Gough, J. Yin, A. Parkin, E. Deryugina, J. Quigley, R. Law, J. Whisstock, A. Riddell, A. Barbour, D. Wyld, P. Thomas, S. Rose, C. Snell, M. Pajic, Y. He, J. Hooper, "Effective targeting of intact and proteolysed CDCP1 for imaging and treatment of pancreatic ductal adenocarcinoma", Theranostics, vol. 10, pp. 4116-4133, Mar 2020.

37. A. Largent, A. Barateau, J. Nunes, J. Castelli, C. Lafond, P. Greer, J. Dowling, J. Baxter, H. Saint-Jalmes, O. Acosta, R. de Crevoisier, "Comparison of Deep Learning-Based and Patch-Based Methods for Pseudo-CT Generation in MRI-Based Prostate Dose Planning", International Journal of Radiation Oncology, Biology, Physics, vol. 105, pp. 1137-1150, Dec 2019.

38. M. Lee, W. Tong, T. Nebl, L. Pearce, T. Pham, A. Golbaz-Hagh, S. Puttick, S. Rose, T. Adams, C. Williams, "Dual site-specific labelling of an antibody fragment through Sortase A and π-clamp conjugation", Bioconjugate Chemistry, vol. 30, pp. 2539–2543, Sep 2019.

39. J. Li, A. Wutherich, S. Dey, R. Lane, A. Sina, J. Wang, Y. Wang, S. Puttick, K. Koo, M. Trau, "The Growing Impact of Micro/Nanomaterial-Based Systems in Precision Oncology: Translating "Multi-Omics" Technologies", Advanced Functional Materials, pp. 1-37, Feb 2020.

40. J. Liddle, A. Sundraraj, D. Ireland, S. Bennett, T. Stillerova, P. Silburn, "Impact of deep brain stimulation on people with Parkinson's disease: A mixed methods feasibility study exploring lifespace and community outcomes", Hong Kong Journal of Occuptational Therapy, vol. 32, pp. 97-107, Dec 2019.

41. V. Lifke, G. Kollmorgen, E. Manuilova, T. Oelschlaegel, L. Hillringhaus, M. Widmann, C. von Arnim, M. Otto, R. Christenson, J. Powers, L. Shaw, O. Hansson, J. Doecke, Q. Li, C. Teunissen, H. Tumani, K. Blennow, "Elecsys® Total-Tau and Phospho-Tau (181P) CSF assays: Analytical performance of the novel, fully automated immunoassays for quantification of tau proteins in human cerebrospinal fluid", Clinical Biochemistry, vol. 72, pp. 30-38, Oct 2019.

42. A. Malhotra, T. Sepehrizadeh, T. Dhollander, D. Wright, M. Castillo-Melendez, A. Sutherland, Y. Pham, M. Ditchfield, G. Polglase, M. de Veer, G. Jenkin, K. Pannek, R. Shishegar, S. Miller, "Advanced MRI analysis to detect white matter brain injury in growth restricted newborn lambs", Neuroimage Clinical, vol. 24, pp. 101991, Aug 2019.

43. J. Martin, P. Keall, S. Siva, P. Greer, D. Christie, K. Moore, J. Dowling, D. Pryor, P. Chong, N. McLeod, A. Raman, J. Lynam, J. Smart, C. Oldmeadow, C. Tang, D. Murphy, J. Millar, K. Tai, L. Holloway, P. Reeves, A. Hayden, T. Lim, T. Holt, M. Sidhom, "TROG 18.01 Phase III Randomized Clinical Trial of the Novel Integration of New prostate radiation schedules with adJuvant Androgen Deprivation - NINJA", BMJ Open, vol. 9, pp. e030731, Aug 2019.

44. C. McKenzie, R. Bucks, M. Weinborn, P. Bourgeat, O. Salvado, B. Gavett, "Cognitive reserve predicts future executive function decline in older adults with Alzheimer's Disease pathology but not age-associated pathology", Neurobiology of Aging, vol. 88, pp. 119-127, Apr 2020.

45. A. Nguyen, J. O'Dwyer, T. Vu, P. Webb, S. Johnatty, A. Spurdle, "Generating high-quality data abstractions from scanned clinical records: Natural language processing-assisted extraction of endometrial carcinoma pathology features as proof of principle", BMJ Open, vol. 10, pp. 1-9, Jun 2020.

46. E. Ovtchinnikov, R. Brown, C. Kolbitsch, E. Pasca, C. da Costa-Luis, A. Gillman, B. Thomas, N. Efthymiou, J. Mayer, P. Wadhwa, M. Ehrhardt, S. Ellis, J. Jorgensen, J. Matthews, C. Prieto, A. Reader, C. Tsoumpas, M. Turner, D. Atkinson, K. Thielemans, "SIRF: Synergistic Image Reconstruction Framework", Computer Physics Communications, vol. 249, pp. 107087, Apr 2020.

47. A. Pagnozzi, J. Fripp, S. Rose, "Quantifying deep grey matter atrophy using automated segmentation approaches: A systematic review of structural MRI studies", NeuroImage, vol. 201, pp. 116018, Jul 2019.

48. A. Pagnozzi, K. Pannek, J. Fripp, S. Fiori, R. Boyd, S. Rose, "Understanding the impact of bilateral brain injury in children with unilateral Cerebral Palsy", Human Brain Mapping, pp. online in press, Mar 2020.

49. D. Patrick, J. Doecke, J. Irwin, K. Hanigan, L. Simms, M. Howlett, G. Radford-Smith, "Regional transfer patients are three times as likely to undergo colectomy compared with metropolitan presenting patients with acute severe ulcerative colitis: results from an observational cohort study", Internal medical Journal of Australia, vol. 50, pp. 823-829, Oct 2019.

50. T. Porter, S. Burnham, L. Milicic, G. Savage, P. Maruff, Y. Lim, Q. Li, D. Ames, C. Masters, S. Rainey-Smith, C. Rowe, O. Salvado, D. Groth, G. Verdile, V. Villemagne, S. Laws, "Utility of an Alzheimer's Disease risk-weighted polygenic risk score for predicting rates of cognitive decline in preclinical alzheimer's disease: a prospective longitudinal study", Journal of Alzheimer's Disease, vol. 66, pp. 1193-1211, Aug 2019.

51. L. Reid, M. Cespedes, K. Pannek, "How Many Streamlines are Required for Reliable Probabilistic Tractography? Solutions for Microstructural Measurements and Neurosurgical Planning", NeuroImage, vol. 211, pp. 116646, May 2020.

52. C. Roberts-Yates, D. Silvera, "Better education opportunities for students with intellectual disabilities and autism spectrum disorder through digital technology", International Journal of Special Education, vol. 34, pp. 14, Nov 2019.

53. D. Rolls, S. Khanna, N. Lloyd, A. Reeson, R. Jayasena, C. McCormick, S. Hakkenness, "Before-after evaluation of patient length of stay in a rehabilitation context following implementation of an electronic patient journey board", International Journal of Medical Informatics, vol. 134, pp. 8, Dec 2019.

54. S. Saha, Y. Kanagasingam, "Automated detection and classification of early AMD biomarkers using deep learning", Scientific Reports, vol. 9, pp. 1-9, Jul 2019.

55. S. Saha, A. Pagnozzi, P. Bourgeat, J. George, D. Bradford, P. Colditz, R. Boyd, S. Rose, J. Fripp, K. Pannek, "Predicting motor outcome in preterm infants from very early brain diffusion MRI using a deep learning convolutional neural network (CNN) model", NeuroImage, vol. 215, pp. N/A, Apr 2020.

56. L. Sakzewski, Y. Bleyenheuft, R. Boyd, I. Novak, C. Elliott, S. Reedman, C. Morgan, K. Pannek, J. Fripp, P. Golland, D. Rowell, M. Chatfield, R. Ware, "Protocol for a Multi-site Randomised Trial of Hand Arm Bimanual Intensive Training Including Lower Extremity Training for Children with Bilateral Cerebral Palsy: HABIT-ILE Australia", BMJ Open, vol. 9, pp. e032194, Sep 2019.

57. C. Santiago de Araujo, T. Beckie, M. Varnfield, N. Sarrafzadegan, A. Babu, S. Baidya, J. Buckley, S. Chen, A. Gagliardi, M. Heine, J. Khiong, A. Mola, B. Radi, M. Supervia, M. Trani, A. Abreu, J. Sawdon, P. Moffatt, S. Grace, "Promoting patient utilization of outpatient cardiac rehabilitation: A joint International Council and Canadian Association of Cardiovascular Prevention and Rehabilitation position statement", International Journal of Cardiology, vol. 298, pp. 1-7, Jan 2020.

58. L. Shaw, O. Hansson, E. Manuilova, C. Masters, J. Doecke, Q. Li, S. Rutz, M. Widmann, A. Leinenbach, K. Blennow, "Method comparison study of the Elecsys® β-Amyloid (1–42) CSF assay versus comparator assays and LC-MS/MS", Clinical Biochemistry, vol. 72, pp. 7-14, Oct 2019.

59. E. Shen, A. Lord, J. Doecke, K. Hanigan, J. Irwin, R. Cheng, G. Radford-Smith, "Development of a Diagnostic Algorithm for Crohn's Disease", Journal of Crohn's and Colitis, vol. 51, pp. 281-290, Jan 2020.

60. R. Shishegar, I. Harding, L. Corben, M. Delatycki, E. Storey, G. Egan, N. Georgiou-Karistianis, "Longitudinal increases in cerebral brain activation during working memory performance in Friedreich ataxia: 24-month data from IMAGE-FRDA", The Cerebellum, vol. 19, pp. 182-191, Apr 2020.

61. D. Silvera, S. Hussain, J. Li, "Emerging Technologies for Precision Health: An insight into sensing technologies for health and wellbeing", Smart Health, vol. 15, pp. 19, Mar 2020.

62. Z. Stark, T. Boughtwood, P. Phillips, J. Christodoulou, D. Hansen, J. Braithwaite, A. Newson, C. Gaff, A. Sinclair, K. North, "Australian Genomics: a federated model for integrating genomics into healthcare", The American Journal of Human Genetics, vol. 105, pp. 7-14, Jul 2019.

63. A. Sweeny, G. Keijzers, J. O'Dwyer, G. Arendts, J. Crilly, "Predictors of a long length of stay in the emergency department for older people", Internal Medicine Journal, vol. 50, pp. 572-581, May 2020.

64. S. Tran, D. Nguyen, S. Ngo, X. Vu, L. Hoang, Q. Zhang, M. Karunanithi, “On Multi-resident Activity Recognition in Ambient Smart-Homes”, Artificial Intelligence Review, pp. 1, Dec 2019.

65. V. Villemagne, V. Dore, S. Burnham, “The trinity of tau, trauma and time”, Lancet Neurology, vol. 18, pp. 715-717, Aug 2019.

66. J. Walker, M. Petoe, M. Kolic, J. Oorloff, N. Habili, E. Baglin, J. Kvansakul, S. Titchener, P. Allen, N. Barnes, “A novel vision processing method for detection and avoidance of well and poorly color-contrasted obstacles for prosthetic vision”, Investigative Ophthalmology & Visual Science, vol. 61, pp. 2205-2205, Jun 2020.

67. E. Wallace, J. Mathias, L. Ward, J. Fripp, S. Rose, K. Pannek, “A fixel-based analysis of micro- and macro-structural changes following adult traumatic brain injury”, Human Brain Mapping, vol. 41, pp. 2187-2197, Jan 2020.

68. A. White, C. Langton, M. Wille, J. Hitchcock, O. Cayre, S. Biggs, I. Blakey, A. Whittaker, S. Rose, S. Puttick, “Ultrasound-Triggered Release from Metal Shell Microcapsules”, Journal of Colloid and Interface Science, vol. 554, pp. 444-452, Oct 2019.

69. N. Yassi, S. Hilal, Y. Xia, Y. Lim, R. Watson, H. Kuijf, C. Fowler, P. Yates, P. Maruff, R. Martins, D. Ames, C. Chen, C. Rowe, V. Villemagne, O. Salvado, P. Desmond, C. Masters, “Influence of comorbidity of cerebrovascular disease and amyloid-β on Alzheimer’s disease”, Journal of Alzheimer’s Disease, vol. 73, pp. 897-907, Feb 2020.

70. B. Yu, L. Zhou, L. Wang, Y. Shi, J. Fripp, P. Bourgeat, “Ea-GANs: Edge-aware Generative Adversarial Networks for Cross-modality MR Image Synthesis”, Transactions on Medical Imaging, vol. 38, pp. 1750-1762, Jul 2019.

71. Z. van Havre, P. Maruff, V. Villemagne, N. White, K. Mengersen, J. Rousseau, J. Doecke, “Identification of pre-clinical Alzheimer’s Disease in a longitudinal study of ageing with overfitted finite mixture models”, The Journal of Alzheimer’s Disease, vol. 73, pp. 683-693, Jan 2020.

72. S. Burnham, S. Loi, J. Doecke, V. Dore, V. Fedyashov, V. Villemagne, C. Masters, “The dawn of robust individualised risk models”, The Lancet Neurology, vol. 18, pp. 985-987, Nov 2019.

73. H. Ding, F. Fatehi, A. Maiorana, N. Ghafouryan Gomish Bashi, W. Hu, I. Edwards, “Digital Health for COPD care: review of the current state of play”, Journal of Thoracic Medicine, vol. 11, pp. S2210-S2220, Nov 2019.

74. J. Dowling, A. Rosenfeld, J. Waldie, I. Feain, “Opportunities in space life sciences”, Australasian Physical & Engineering Sciences in Medicine, vol. 42, pp. 663–664, Sep 2019.

Conference Publications and Presentations

1. D. Bradford, J. Pearson, D. Gorse, A. Metke Jimenez, H. Leroux, K. Dallest, D. Bunker, D. Hansen, “Understanding the Barriers to Genomic Healthcare in Queensland Through an Information Management Lens”, HIC 2019, Melbourne, 12-14 August 2019.

2. A. Gillman, A. Rashidnasab, R. Brown, N. Dowson, B. Thomas, F. Fraioli, S. Rose, K. Thielemans, “PCA regression for continuous estimation of head pose in PET/MR”, Nuclear Science Symposium and Medical Imaging Conference, Manchester, UK, 26/10/19.

3. D. Ireland, A. Nicole, “Pain ROADMAP: A mobile platform to support activity pacing for chronic pain”, Health Informatics, Melbourne, 13/08/2019.

4. L. Iwaya, J. Li, S. Fischer-huebner, R. Åhlfeldt, L. Martucci, “E-Consent for Data Privacy: Consent Management for Mobile Health Technologies in Public Health Surveys and Disease Surveillance”, MedInfo 2019, Lyon, France, 26-30 Aug 2019.

5. Jimmy, G. Zuccon, B. Koopman, G. Demartini, “Health Cards for Consumer Health Search”, SIGIR, Paris, France, July 21–25, 2019.

6. A. Largent, J. Nunes, H. Saint-Jalmes, J. Baxter, P. Greer, J. Dowling, R. de Crevoisier, O. Acosta, “Pseudo-CT generation for MRI-only radiotherapy: Comparative study between a generative adversarial network, a UNET network, a patch-based, and an atlas based methods”, IEEE International Symposium on Biomedical Imaging, Venice, Italy, 8-11 April 2019.

7. M. Li, S. Burnham, J. Fripp, Y. Li, X. Li, A. Fazlollahi, P. Bourgeat, “Identification of Functional Connectivity Features in Depression Subtypes Using a Data-Driven Approach”, Graph Learning in Medical Imaging, Shenzhen, China, October 17, 2019.

8. H. Ngo, A. Metke Jimenez, D. Truran, M. Kemp, M. Lawley, “Can Wikipedia be used to derive an open Clinical Terminology?”, HIC 2019, Melbourne, 12-14 August 2019.

9. A. Nguyen, H. Hassanzadeh, Y. Zhang, J. O’Dwyer, D. Conlan, M. Lawley, J. Steel, K. Loi, P. Rizzo, “A decision support system for pathology test result reviews in an emergency department to support patient safety and increase efficiency”, The 17th World Congress of Medical and Health Informatics (MedInfo), Lyon, France, 26-30 August 2019.

10. C. Redd, M. Varnfield, M. Karunanithi, “Development of a Wearable Sensor Network for Quantification of Infant General Movements for the Diagnosis of Cerebral Palsy”, IEEE Engineering in Medicine and Biology Conference, Berlin, Germany, July 2019.

11. S. Saha, Y. Kanagasingam, “Retinal Blood Vessel Segmentation: A semi-supervised approach”, Iberian Conference on Pattern Recognition and Image Analysis, Madrid, Spain, July 1-4, 2019.

12. S. Saha, Y. Kanagasingam, “An Efficient Binary Descriptor to Describe Retinal Bifurcation Point for Image Registration”, Iberian Conference on Pattern Recognition and Image Analysis, Madrid, Spain, 1-14 July 2019.

13. S. Saha, Y. Kanagasingam, “Haar Pattern Based Binary Feature Descriptor for Retinal Image Registration”, International Conference on Digital Image Computing: Techniques and Applications, Perth WA, Australia, 02/12/2019 to 04/12/2019.

14. P. Shayegh Boroujeni, Y. Li, J. Zhang, Q. Zhang, “Semi-supervised text classification with deep convolutional neural network using feature fusion approach”, Wed Intelligence 2019, Thessaloniki, 2019-10-14.

15. M. Vacher, J. Doecke, “Biostatistics to tackle new challenges: from plant cells to brain diseases”, 40th Annual Conference of the International Society for Clinical Biostatistics, Belgium, 14/07/2019.

16. M. Varnfield, K. Rajesh, S. Gibson, L. Gwillim, S. Polkinghorne, “Health-e Minds: a participatory personalised and gamified mHealth platform to support healthy living behaviours for people with mental illness”, IEEE EMBS, Berlin, 23-27 July 2019.

17. T. Vu, A. Nguyen, N. Brown, J. Hughes, “Identifying Patients with Pain in Emergency Departments using Conventional Machine Learning and Deep Learning”, Australasian Language Technology Association (ALTA), Sydney, Australia, 5 December 2019.

18. Q. Zhang, M. D’Souza, U. Balogh, V. Smallbon, “Indoor Localization through Efficient BLE Fingerprinting with UWB Sensors”, IEEE Smart World Congress 2019, United Kingdom, August 19.

19. N. Barnes, M. Petoe, M. Kolic, N. Habili, J. Oorloff, W. Kentler, E. Baglin, S. Titchener, P. Allen, J. Walker, “Novel vision processing method facilitates color-contrast obstacle detection in participants implanted with a suprachoroidal retinal prosthesis”, The Eye and The Chip World Research Congress on Artificial Vision, Michigan, US, 10/11/2019.

20. D. Bauer, A. O’Brien, O. Luo, N. Twine, A. Bayat, L. Wilson, P. Szul, R. Dunne, B. Hosking, “The dawn of cloud-native bioinformatics”, Bioinformatics Winter School, Sydney, 3 June 2019.

21. D. Bauer, A. O’Brien, N. Twine, A. Bayat, L. Wilson, P. Szul, R. Dunne, B. Hosking, A. Tay, Y. Jain, S. Scott, D. Reti, C. Hosking, “Serverless Beacon: Helping take genomic analysis from the cloud to the clinic(27/08/19, Sydney)”, ServerlessDays Sydney, Sydney, 28 August 2019.

22. D. Bauer, A. O’Brien, O. Luo, N. Twine, A. Bayat, L. Wilson, P. Szul, R. Dunne, B. Hosking, “Cloud computing and artificial intelligence transforms bioinformatics research”, InCoB2019, Jakarta, Indonesia, 9 - 11 Sept 2019.

23. D. Bauer, A. O’Brien, N. Twine, A. Bayat, L. Wilson, P. Szul, R. Dunne, B. Hosking, A. Tay, Y. Jain, S. Scott, D. Reti, C. Hosking, “Cloud computing and artificial intelligence transforms bioinformatics research (10/12/19, Sydney)”, Conference on Genome Informatics GIW/ABACBS, Sydney, 9-10 December 2019.

24. D. Bauer, A. O’Brien, N. Twine, A. Bayat, L. Wilson, P. Szul, R. Dunne, B. Hosking, A. Tay, Y. Jain, S. Scott, D. Reti, C. Hosking, “Serverless Bioinformatics helping to fight the COVID19 pandemic (02/04/20, Sydney)”, Serverless Meetup, Sydney, 02/04/2020.

25. D. Bauer, A. O’Brien, N. Twine, A. Bayat, L. Wilson, P. Szul, R. Dunne, B. Hosking, A. Tay, Y. Jain, S. Scott, D. Reti, C. Hosking, “How Technology Can Help Fight Covid-19 Crisis (12/05/20, India)”, Virtual Tech Summit, India, 12/05/2020.

26. A. Bayat, N. Twine, L. Wilson, A. O’Brien, P. Szul, R. Dunne, D. Bauer, “Variable Depth Forest: A More Random Random-Forest for heterogeneous disease genetics”, ISMB, Switzerland, July 2019.

27. A. Bayat, B. Hosking, Y. Jain, N. Twine, D. Bauer, “BitEpi: A Fast Higher-Order Epistasis Exhaustive Search Algorithm Boosted with Bitwise Operations”, AGTA, Melbourne, October 2019.

28. J. Beaumont, G. Gambarota, S. Herve, O. Acosta, O. Salvado, J. Fripp, “Effect of the transmitted bias-field on partial volume estimation of MP2RAGE data at 7T”, 2019 Alzheimer’s Association International Conference® (AAIC®) Satellite Symposium, Sydney, September 25th-27th, 2019.

29. P. Bourgeat, V. Dore, S. Williams, D. Ames, C. Masters, J. Fripp, C. Rowe, V. Villemagne, “Correcting for PET scanner changes in longitudinal studies”, AAIC 2019, Los Angeles, USA, 14-18 July 2018.

30. H. Ding, M. Gonzalez-Garcia, M. Varnfield, A. Krumins, Y. Martin, F. Bourke, L. Gilroy, L. Collins, M. Karunanithi, “Limited functional capacity and physical activity associated with patient withdrawals from cardiac rehabilitation”, European Society of Cardiology (ESC), Paris - France, Saturday 31 August 2019.

31. V. Dore, P. Bourgeat, R. Martins, D. Ames, C. Masters, S. Burnham, C. Rowe, O. Salvado, J. Fripp, V. Villemagne, “Automated reporting of tau PET quantification on brain surface”, NNIDR, Hobart, 12 Juen 2019.

32. G. Farr-Wharton, J. Li, J. Freyne, S. Hussain, D. Bradford, "Value-based Healthcare in Action: clinician experiences of a digital rehabilitation platform supporting Orthopaedic patients", Health By Tech 2020, Twente, Netherland, 14-15 Jun 2020.

33. N. Good, K. Mann, S. Khanna, D. Cook, "Going Fully Digital: Opportunities and Challenges for Research.", Health Informatics Conference, Melbourne, 12-14/08/2019.

34. B. Hosking, D. Bauer, A. O'Brien, L. Wilson, A. Bayat, N. Twine, P. Szul, R. Dunne, A. Tay, D. Reti, S. Scott, Y. Jain, "Serverless Beacon: Helping take genomic analysis from the cloud to the clinic", Health Data Analytics 2019, Sydney, 16-17 October 2019.

35. S. Khanna, D. Rolls, J. Boyle, Y. Xie, R. Jayasena, M. Hibbert, M. Georgeff, "Developing a Predictive Risk Model for Health Care Homes", HIC 2019, Melbourne, 12-14 August 2019.

36. S. Khanna, D. Rolls, J. Boyle, Y. Xie, R. Jayasena, M. Hibbert, M. Georgeff, "Developing the Predictive Risk Algorithm for the Australian Government Health Care Homes Trial", 2019 Digital Health Week NZ, Hamilton, New Zealand, 18-22 November 2019.

37. M. Kholghi, M. Lupton, A. Fazlollahi, Q. Zhang, M. Breakspear, J. Fripp, S. Rose, O. Salvado, M. Karunanithi, N. Martin, C. Guo, "Sleep as a risk factor of Alzheirmer's disease", AAIC Satellite Symposium 2019, Sydney, 25-27 September 2019.

38. M. Li, J. Fripp, S. Burnham, V. Dore, P. Bourgeat, "Identifying Alzheimer's Disease Brain Atrophy Subtypes by Deep Learning", ISMRM 2020, Sydney, Australia, 18-23 April 2020.

39. K. Pannek, J. George, R. Boyd, P. Colditz, S. Rose, J. Fripp, "Fixel-based morphometry reveals associations between brain micro- and macrostructure of preterm infants at term and neurodevelopmental outcomes at 2 years", American Academy of Cerebral Palsy and Developmental Medicine, Anaheim, California, USA, 18-21 September 2019.

40. C. Paola, S. Saha, T. Rantalainen, Y. Kanagasingam, S. Aris, F. McIntyre, B. Hands, N. Hart, "Feasibility of automatically evaluating motion artefact from Peripheral Quantitative Computed Tomography Scans using a deep learning approach", Australian and New Zealand Bone and Mineral Society Annual Scientific Meeting, Darwin, Australia, 27/10/2019-30/10/2019.

41. R. Raman, S. Saha, S. Frost, R. Khan, T. Sharma, Y. Kanagasingam, "Assessment of vessel parameters as a micro vascular biomarker using a web-based Retinal Vessel Analysis System (VASP)", The Association for Research in Vision and Ophthalmology ARVO, Not applicable due to COVID, May 2020.

42. L. Reid, M. Prior, "CONSULT – A Fully Automated Imaging Pipeline for Identifying the Optic Radiation", Royal Australian and New Zealand College of Radiologists Annual Scientific Meeting, Auckland, 17-20 October 2019.

43. S. Saha, J. George, P. Colditz, R. Boyd, S. Rose, J. Fripp, K. Pannek, "Prediction of cognitive and motor outcome of preterm infants from diffusion MR brain images using a deep learning convolutional neural network (CNN) model", Combined AACPDM 73rd Annual and IAACD 2nd Triannual Meeting (AACPDM, 2019), Anaheim, California, Sep 18- Sep 21, 2019.

44. S. Saha, A. Pagnozzi, P. Bourgeat, J. George, D. Bradford, P. Colditz, R. Boyd, S. Rose, J. Fripp, K. Pannek, "Comparison of the predictive potential of gestational age and brain MRI data for very early prediction of motor outcome in preterm infants using artificial intelligence (AI) techniques", AusACPDM, Perth, Australia, 11-14 March 2020.

45. S. Scott, C. Hallwirth, J. Kerr, A. O'Brien, A. Tay, D. Reti, B. Hosking, D. Bauer, I. Alexander, L. Wilson, "Identifying viral integration sites in tumour NGS data", Westmead Research Showcase, Westmead, 11/09/2019.

46. S. Scott, C. Hallwirth, J. Kerr, A. O'Brien, A. Tay, D. Reti, B. Hosking, D. Bauer, I. Alexander, L. Wilson, "Finding viral integration sites in cancer sequence data", Australian Genomic Technologies Association Conference, Melbourne, 7-9 October 2019.

47. K. Shen, P. Chatterjee, Y. Xia, K. Goozee, J. Fripp, S. Burnham, R. Martins, "White Matter Hyperintensity and β-amyloid burden in a preclinical cognitively normal cohort", Alzheimer's Association International Conference, Los Angeles, USA, July 14-18, 2019.

48. R. Shishegar, F. Lamb, J. Robertson, S. Laws, T. Porter, V. Dore, P. Maruff, G. Savage, C. Rowe, C. Masters, M. Weiner, V. Villemagne, S. Burnham, "Harmonizing longitudinal measures of cognition across AIBL and ADNI (two of the largest global studies on Alzheimer's)", Optimising Multistudy Integrative Research, Wellcome Genome Campus Conference Centre, UK, 18-20 September.

49. R. Shishegar, V. Dore, P. Bourgeat, S. Laws, P. Maruff, R. Martins, D. Ames, C. Rowe, C. Masters, V. Villemagne, S. Burnham, "Implementation of the NIA-AA Research Framework: Toward a Biological Definition of Alzheimer's Disease in AIBL", Alzheimer's Association International Conference® (AAIC®) Satellite Symposium, Sydney, Australia, 25 September-27 September.

50. R. Shishegar, T. Cox, D. Rolls, V. Dore, F. Lamb, J. Robertson, S. Laws, T. Porter, P. Maruff, G. Savage, C. Rowe, C. Masters, M. Weiner, V. Villemagne, S. Burnham, “Using imputation to harmonize longitudinal measures of cognition across two large cohorts: AIBL and ADNI”, AAIC, Amsterdam, 26–30 July 2020.

51. R. Shishegar, T. Cox, D. Rolls, V. Dore, F. Lamb, J. Robertson, S. Laws, T. Porter, P. Maruff, G. Savage, C. Rowe, C. Masters, M. Weiner, V. Villemagne, S. Burnham, “Harmonizing longitudinal measures of cognition across two large cohorts: AIBL and ADNI”, Australian Dementia Forum, Adelaide, 31 May - 2 June.

52. A. Tay, B. Hosking, S. Scott, D. Reti, A. O’Brien, D. Bauer, L. Wilson, “Detecting foreign DNA using genomic signatures”, Synthetic Biology Australasia (SBA) 2019, Queensland, 14-16 October.

53. A. Tay, B. Hosking, S. Scott, D. Reti, A. O’Brien, D. Bauer, L. Wilson, “Detecting foreign DNA using genomic signatures”, Australasian Genomic Technologies Association (AGTA) 2019, Victoria, 7/9 October.

54. N. Twine, L. Henden, P. Szul, E. McCann, K. Williams, I. Blair, D. Bauer, “Novel software ‘tribes’ enables distant relationship and disease variant discovery in amyotrophic lateral sclerosis”, Intelligent Systems for Molecular Biology (ISMB), Basel, Switzerland, 21-25 July 2019.

55. T. Vu, A. Nguyen, “Explainable deep learning for healthcare text analytics”, Health Informatics Conference, Melbourne, Australia, 12-14/8/2019.

56. L. Reid, J. Fripp, “Fully-Automated Delineation of the Optic Radiation”, ISMRM Annual General Meeting, Sydney, 18 April 2020. (Accepted Jan 2020).

57. M. Vacher, T. Porter, L. Milicic, M. Peretti, V. Dore, V. Villemagne, S. Laws, J. Doecke, “Identification of genetic markers linked to accelerated brain volume changes in Aβ positive population”, Alzheimer’s Association International Conference, Amsterdam, 26/07/2020. (Accepted Jun 2020).

Book Chapters

1. M. Cespedes, J. McGree, C. Drovandi, K. Mengersen, L. Reid, J. Doecke, J. Fripp, “A Bayesian hierarchical approach to jointly mode cortical thickness and covariance networks”, Kerrie Mengersen, Christian Roberts & Pierre Pudlo, Wiley & French Mathematical Society, Jun 2020, pp. 1-418.

2. F. Fatehi, M. Taylor, L. Caffery, A. Smith, “The use of telemedicine in the clinical management of adults in remote and rural areas”, Kerry Atkinson, Wiley, Aug 2019, pp. 439-461.

3. D. Silvera, S. Brown, “Cross-collaborative approach to socially-assistive robotics: A case study for humanoid robots in therapeutic intervention for autistic children”, Oliver Korn, Springer, Jul 2019, pp. 165-186.

4. A. Smith, M. Taylor, F. Fatehi, L. Caffery, “Telemedicine for the delivery of specialist paediatric services”, Kerry Atkinson, Wiley, Aug 2019, pp. 462-487.

5. S. Tran, Q. Zhang, “Towards Multi-resident Activity Monitoring with Smarter Safer Home Platform”, Feng Chen, Springer, Aug 2019, pp. 12.

Reports

1. J. Boyle, H. Hassanzadeh, S. Khanna, S. Louise, R. Sparks, "Interim Report - Theatre Efficiency Modelling Agreement G02019ATRDG: Support for the Australian Telehealth Research and Development Group", CSIRO Internal Report Number: EP198667, Dec 2019.

2. J. Boyle, S. Khanna, D. Rolls, D. Ireland, "Risk Stratification Algorithms to Quantify Risk of Rehospitalisation - Results of a trial of a web-based risk stratification algorithm", CSIRO Internal Report Number: EP203054, May 2020.

3. J. Boyle, H. Hassanzadeh, S. Louise, S. Khanna, R. Sparks, "Theatre Efficiency Project – Final Activity Report; a deliverable for Agreement G02019ATRDG: Support for the Australian Telehealth Research and Development Group", CSIRO Internal Report Number: EP204961, Jun 2020.

4. J. Boyle, R. Sparks, "Progress Report - SA Syndromic Surveillance Initial Pilot Activities", CSIRO Internal Report Number: EP204281, Jun 2020.

5. D. Bradford, D. Ireland, "'Hear' to Help Co-development of Chat bot to facilitate participation in tertiary education for students with Autism and related conditions", CSIRO Internal Report Number: EP193591, May 2020.

6. D. Bradford, L. Currie, P. Valencia, J. Galvin, A. Schieber, D. Haddon, "Sensor Systems to Augment Safety in 767 Wings Major", CSIRO Internal Report Number: EP203082, Jun 2020.

7. C. Bull, M. Fenech, J. Doecke, "Cellular Nutrition Project In vitro Studies (Stage 2) - Final Report", CSIRO Internal Report Number: EP202218, Apr 2020.

8. S. Frost, "Retia Imaging of Retinal Aβ Plaques in Alzheimer's disease NVI007 – End of Data Collection Report", CSIRO Internal Report Number: EP194153, Aug 2019.

9. S. Frost, "WA Health Report - Retinal Imaging in Resistant Hypertension", CSIRO Internal Report Number: EP198669, Dec 2019.

10. H. Hassanzadeh, S. Louise, S. Khanna, J. Boyle, "Patient Flow Analysis at Logan Hospital - Understanding bottlenecks in flow and bed access performance, Final Report", CSIRO Internal Report Number: EP203055, May 2020.

11. Y. Jain, D. Bauer, N. Twine, "The Dawn of cloud-native Bioinformatics, MLCB, Basel Switzerland", CSIRO Internal Report Number: EP203037, Sep 2019.

12. Y. Jain, D. Bauer, N. Twine, "The dawn of cloud-native Bioinformatics - IGIB-CSIR, India", CSIRO Internal Report Number: EP203041, Jan 2020.

13. Y. Jain, D. Reti, D. Bauer, "F50 data analysis", CSIRO Internal Report Number: EP20690, Feb 2020.

14. Y. Jain, B. Hosking, D. Bauer, "Serverless architecture for genomic variant annotation", CSIRO Internal Report Number: EP201910, Apr 2020.

15. J. Li, Y. Xie, S. Khanna, R. Jayasena, "Safety and Quality Reporting at a Board Level: Environmental Scan", CSIRO Internal Report Number: EP194201, Jul 2019.

16. S. Louise, D. Rolls, S. Khanna, N. Good, R. Jayasena, "Methodology and Risk Adjustment for a New AMI 30-day Mortality Measure", CSIRO Internal Report Number: EP194335, Jul 2019.

17. S. Louise, D. Rolls, R. Sparks, S. Khanna, R. Jayasena, "Measurement and Reporting for a new AMI 30-day Mortality Measure", CSIRO Internal Report Number: EP195462, Jul 2019.

18. D. McMurtrie, "Australian Terminology National Release Centre Future Tooling Analysis", CSIRO Internal Report Number: EP201240, Feb 2020.

19. C. Naughtin, E. Schleiger, K. Mann, S. Le, N. Good, D. Hansen, "A Healthy Horizon: Megatrends and scenarios for the future of healthcare in Queensland out to 2040", CSIRO Internal Report Number: EP20202, Dec 2019.

20. D. Rolls, N. Good, S. Khanna, R. Jayasena, "Critical Care Demand Modelling for COVID-19: A Second Review", CSIRO Internal Report Number: EP203080, May 2020.

21. J. Vignarajan, Y. Kanagasingam, M. Mehdizadeh, "Medical Image Communication Exchange (Final Report)", CSIRO Internal Report Number: EP198668, Dec 2019.

22. J. Walker, "Local Background Enclosure / Depth Vision Processing for Orientation and Mobility in an Indoor Setting: A Randomised Control Trial for the 44 Channel Fully Implantable Device", CSIRO Internal Report Number: EP204184, Jun 2020.

23. J. Boyle, R. Sparks, H. Hassanzadeh, S. Khanna, S. Louise, "Bunbury Hospital Bed Predictions Model - Development and Validation of Bed Prediction Algorithms at Bunbury Hospital", CSIRO Internal Report Number: EP201731, Mar 2020. (Created Mar 2020).

24. S. Frost, "Report on ransomware attack on Remote-I database", CSIRO Internal Report Number: EP196064, Aug 2019. (Created Aug 2019).

25. S. Khanna, D. Rolls, N. Good, R. Jayasena, "Critical Care Demand modelling for COVID-19", CSIRO Internal Report Number: EP201881, Apr 2020.

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Ms Sal Martin, Project Support Service Centre Officer

Ms Kaz Roebuck, Project Support Service Centre Officer

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Janis Nolde, Postgraduate Student

Future Science Platform

Prof Stephen Rose, Future Science Platform Leader

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Miss Chunue Zheng, University of Sydney

Mr Kausthubram Rajesh, University of Queensland

Ms Kathryn Bird, University of Queensland

Ezra Kenny, University of Queensland

Ms Heide Chan, University of NSW

Ms Susanna Grigson, Flinders University

Ms Milindi Kodikara, RMIT

Ms Jenny Chiem, University of Sydney

Mr Dhaval Vaghijiani, University of Western Australia

Visitors

Prof Mark Braunstein, Georgia Institute of Technology, Atlanta, USA July 2018 - December 2018, June 2019

Dr Charles Baker, Visiting Scientist June 2014 - current

Dr Shekhar Chandra, Visiting Scientist August 2011 - current

Erica Wallace, Visiting Scientist July 2011 - current

Dr Alison White, The University of Queensland January 2019 to December 2019

Christine Guo, Visiting Scientist June 2016 - current

Dr Lyndal Henden, Visiting Scientist October 2018 - current

Kun Huang, Site Visitor December 2019 - current

Dr Mao Li, Visiting Scientist Mar 2019 - current

Sandrine, Chan Moi Fat, Visiting Scientist October 2018 - current

Dr Jennifer Fifita, Visiting Scientist October 2018 - current

Dr Emily McCann, Visiting Scientist October 2018 - current

Dr Alyce Russel, Visiting Scientist from ECU Jan-Feb 2020

Support staff

Finance - Kellie Tighe

HR - Laurie Mackenzie

Finance Support - Katie Forestier / Kim Tran

Contract Support - Sandy Farnworth

HSE Support - Megan Tilley

Business Development Support - Dr Peter Kambouris

Special Purpose Financial Report

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE
(An unincorporated joint venture)

SPECIAL PURPOSE FINANCIAL REPORT

30 JUNE 2020

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

DIRECTORS DECLARATION

The directors have determined that the unincorporated joint venture is not a reporting entity and that this special purpose financial report should be prepared in accordance with the terms of the joint venture agreement and the accounting policies outlined in Note 1 to the financial statements.

The directors declare that the accompanying Statement of Comprehensive Income, Statement of Financial Position, Statement of Cash Flows, Statement of Changes in Joint Venture Funds and Notes to the Financial Statements present fairly the unincorporated joint venture's financial position as at 30 June 2020 and its performance for the year ended on that date in accordance with the terms of the joint venture agreement and the accounting policies described in Note 1 to the financial statements.

This declaration is made in accordance with a resolution of the Board.

Director

Victoria
Date: 25.08.2020

Director

Brisbane
Date: 25/08/2020

Director

Victoria
Date: 25/08/2020

Director

Brisbane
Date: 26/08/2020

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INDEPENDENT AUDITOR'S REPORT

TO THE DIRECTORS OF THE AUSTRALIAN E-HEALTH RESEARCH CENTRE

Report on the Audit of the Financial Report

Opinion

We have audited the accompanying special purpose financial report of The Australian E-Health Research Centre ("the unincorporated joint venture"), which comprises the statement of financial position as at 30 June 2020, and the statement of comprehensive income, statement of changes in joint venture funds and statement of cash flows for the year then ended, notes comprising a summary of significant accounting policies, other explanatory information and the directors' declaration.

In our opinion, the accompanying financial report presents fairly, in all material respects, the financial position of the unincorporated joint venture as at 30 June 2020 and its financial performance and its cash flows for the year then ended in accordance with the accounting policies described in Note 1 to the financial statements.

Basis for Opinion

We conducted our audit in accordance with Australian Auditing Standards. Our responsibilities under those standards are further described in the *Auditor's Responsibilities for the Audit of the Financial Report* section of our report. We are independent of the unincorporated joint venture in accordance with the ethical requirements of the Accounting Professional and Ethical Standards Board's APES 110: *Code of Ethics for Professional Accountants* (the Code) that are relevant to our audit of the financial report in Australia. We have also fulfilled our other ethical responsibilities in accordance with the Code.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of Matter – Basis of Accounting

We draw attention to Note 1 to the financial statements which describes the basis of accounting. The financial report has been prepared to assist The Australian E-Health Research Centre to meet the requirements of the Joint Venture Agreement with Commonwealth Scientific and Industrial Research Organisation and the State Government of Queensland. As a result the financial report may not be suitable for another purpose. Our opinion is not modified in respect of this matter.

Responsibilities of the Directors' for the Financial Report

The directors of the unincorporated joint venture are responsible for the preparation and fair presentation of the financial report in accordance with the joint venture agreement and the accounting policies described in Note 1 to the financial report. The directors are also responsible for such internal control as they determine is necessary to enable the preparation and fair presentation of the financial report that is free from material misstatement, whether due to fraud or error.

In preparing the financial report, the directors are responsible for assessing the unincorporated joint venture's ability to continue as a going concern, disclosing, as applicable, matters relating to going concern and using the going concern basis of accounting unless the directors either intends to liquidate the unincorporated joint venture or to cease operations, or has no realistic alternative but to do so.

Auditor's Responsibilities for the Audit of the Financial Report

Our objectives are to obtain reasonable assurance about whether the financial report as a whole is free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with the Australian Auditing Standards will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of this financial report.

As part of an audit in accordance with Australian Auditing Standards, we exercise professional judgement and maintain professional scepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.
- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the unincorporated joint venture's internal control.
- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by the unincorporated joint venture.

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- Conclude on the appropriateness of the unincorporated joint venture's use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the association's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor's report to the related disclosures in the financial report or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the association to cease to continue as a going concern.
- Evaluate the overall presentation, structure and content of the financial report, including the disclosures, and whether the financial report represents the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the directors regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit

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Peter Bray

Peter Bray
Partner

Chatswood

Dated: 27 August 2020

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John O’Dwyer

1964-2020

Photo courtesy of Marilla O’Dwyer, photographer Paul Clacher.

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