Australian e-Health Research Centre

The Australian e-Health Research Centre

Annual Report
2021–2022

Queensland Government

Contents

The Australian e-Health Research Centre

The Australian e-Health Research Centre (AEHRC) is the largest digital health research program in Australia with over 100 scientists and engineers and a further 30 higher degree research students.

As CSIRO's national digital health research program, AEHRC have offices across Brisbane, Sydney, Melbourne, Canberra, Adelaide and Perth. AEHRC is globally unique in covering the full value chain in health care, from basic science all the way up to delivering technology and services into the healthcare system.

Established in 2003 with initial funding from the Queensland 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 extended in 2017 and again in 2022 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, including mobile health, tele-health and sensing technologies.

With 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 engages the research capability of our five research groups – health data semantics and interoperability, 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:

- transform health with data and artificial intelligence
- transform healthcare delivery with virtual care
- enable efficiencies in healthcare systems
- innovate and develop digital technologies for precision healthcare

Our research program is informed through strong partnerships with the health industry, including clinicians, researchers, health service executives and the health IT vendor community.

Over half our staff are located in the STARS Hospital on the Herston Health Precinct, while in Sydney we are excited to be moving onto the Westmead Health Precinct. In Melbourne we are located at Parkville and in Perth we are located on the Kensington CSIRO site. Our locations enable us to develop strong relationships with the state-based health departments, clinicians and academics.

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 with the Human Health and Biosecurity programs in CSIRO Health and Biosecurity and with the wider CSIRO health research.

Foreword by the Chair and CEO

CSIRO and Queensland Health recently finalised an agreement for five years of renewed funding of the Australian e-Health Research Centre. The AEHRC was established in 2003 and the new agreement will take the centre through to 2027.

Over the next five years the AEHRC will continue to be an important contributor to the digital enhancement of Australia's health system.

The 2021–2022 Annual Report gives an overview of the many achievements of the Australian e-Health Research Centre in the last year of the 2017–2022 funding agreement between Queensland Health and CSIRO. The AEHRC has met – and often exceeded – the aims we set at the beginning of the agreement.

With broader reaching digitalisation comes increasing data to support care. The AEHRC is using this data escalation and the accompanying rise in compute power through cloud-based systems to enable a new generation of artificial intelligence and machine learning tools for decision support in everything from precision medicine to building digital twins to analysing the health system.

Connected care is another goal in digitising our health system and a central focus of much of our research this year. With connected care comes the improved assurance that patients are supported as they traverse the health system and, increasingly, can be treated either at home or in the community. AEHRC's work in virtual care models of care – including through mobile health, tele-health and connected sensors and medical devices – demonstrates how connected devices and interoperable data improve health outcomes and system efficiency.

The AEHRC works with Queensland Health across the program – in health data and text analytics, interoperability and connected care, mobile health and tele-health, genomics and medical imaging. Our scientists continue to work with clinicians and service providers across the many parts of Queensland Health. The past year has seen eHealth Queensland establish a Queensland Clinical Terminology Service using our Ontoserver technology. This will be an enterprise service used across Qld Health. We have also further developed the Queensland One Health Antimicrobial Resistance (AMR) Hub; undertaken a pilot study of a mobile phone-based service for the Prince Charles Hospital Heart Failure Service and developed new ways of visualising patient health journeys by analysing COVID related health system data.

Our teams continue to work with eHealth Queensland, Clinical Excellence Queensland, many Queensland Health and Hospital Services and Cancer Alliance Queensland. With the new agreement we are now discussing several new projects. We'd like to thank all our Queensland Health partners for their great engagement and collaboration.

The past 12 months has seen our scientists deliver multiple national projects, including: completing a 12-month Smart Home random control trial among 200 older people – one of the largest trials undertaken in Australia; developing a framework and implementation roadmap to support participants from the National Disability Insurance Scheme (NDIS) with new AI-enabled assistive technologies; supporting the collection of data for a range of national cohorts and trials, including for the Australian Dementia Network and continued work with the Australian Digital Health Agency and the National Clinical Terminology Service.

To support our growth nationally we are working with other health systems around Australia. This year we delivered an evaluation of the HealthLinks Chronic Care program with the Victorian Department of Health; we are trialling the use of our M♡THer platform (developed to support women with gestational diabetes) for pregnancy hypertension support with 3 major NSW hospitals; and we've completed a retinal imaging study at Royal Perth Hospital to inform cardiovascular risk.

The AEHRC is an increasingly prominent part of Australia's health and medical innovation system. AEHRC scientists lead or contribute to over 20 NHMRC and MRFF initiatives – detailed later in the annual report. An example of our contribution to this research is in cerebral palsy – where we demonstrated the value of early MRI scans in providing measures to accurately predict two-year outcomes for motor, cognitive, and to a lesser extent, language scores, in babies born very premature. We also work with industry – for example we worked with several small and medium sized entities (SMEs) to bring cloud computing to cancer therapeutics work and undertake a study of newborn screening using targeted re-sequencing.

Internationally we've delivered a new mapping tool to SNOMED international for use by member countries; progressed the international adoption of our clinical terminology server; contributed image processing and data analysis to international Alzheimer's disease research and developed new ways of surveillance of infectious disease for the Indonesian health system.

We also work with the broader CSIRO community to contribute to a wide variety of scientific initiatives. This year CSIRO supported the AEHRC in developing a plan to extend our work in virtual care and to use our genomics technology for an organisational wide gene editing tool.

The past year also saw increased commercial success. Our FHIR terminology server, Ontoserver, is now used around the world, with several reseller agreements in place with technology companies. It was also great this year to see the ongoing success of Cardihab – a spin out from AEHRC six years ago.

The 2021–22 AEHRC Annual Report provides an overview of our research– including our research groups, platform technologies, project reports and project updates. This year we are proud to report on over 80 projects across our five research groups – more than we can possibly highlight in this foreword.

The renewal of the joint venture between CSIRO and Queensland Health, along with the growing maturity of AEHRC research and development, positions the centre for significant further growth over the next five years.

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' 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 start-up 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.

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.

Previously, Prof McNeil has worked at 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

(Until March 2022)

Dr Rob Grenfell, a public health physician, was the Director of CSIRO's Health and Biosecurity business unit until October 2021.

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.

Kirsten Rose

As Executive Director, Future Industries, Kirsten is a member of the CSIRO Executive Team. In this role, she leads a portfolio which comprises the Agriculture and Food, Health and Biosecurity, Manufacturing, and Services Business Units of CSIRO.

Kirsten is a respected leader in technology and innovation, with a career spanning 30 years in the US, UK and Australia. Prior to joining CSIRO, she was Head of Innovation, Sustainable Operations at BHP, where she had global responsibility for bringing together innovation and technology to drive material improvements in key sustainability-related challenges.

Her previous positions include Director of the Founder Institute, an entrepreneur training and start-up launch program, State Manager for the Australian Institute of Company Directors and CEO of the Sustainable Energy Association of Australia.

Kirsten actively supports the innovation ecosystem through non-executive director and advisory board roles, as well as mentoring, and enjoys helping entrepreneurs commercialise their ideas.

Michael Roberson

(From March 2022)

Dr Michael Robertson has been Acting Director for the Health and Biosecurity Business Unit since October 2021. Michael has been at CSIRO for 29 years, where he has held a range of leadership roles including Deputy Director of Agriculture and Food, and Acting Director of Health and Biosecurity.

He has been integral to furthering research in digital agriculture, and championing CSIRO's Missions, which are large-scale, impact focussed scientific and collaborative research initiatives aimed at making significant breakthroughs. His research background is in crop agronomy, farming systems and simulation modelling.

Richard Symons

Minutes Secretary

Rebecca Mok

Finance Manager, CSIRO

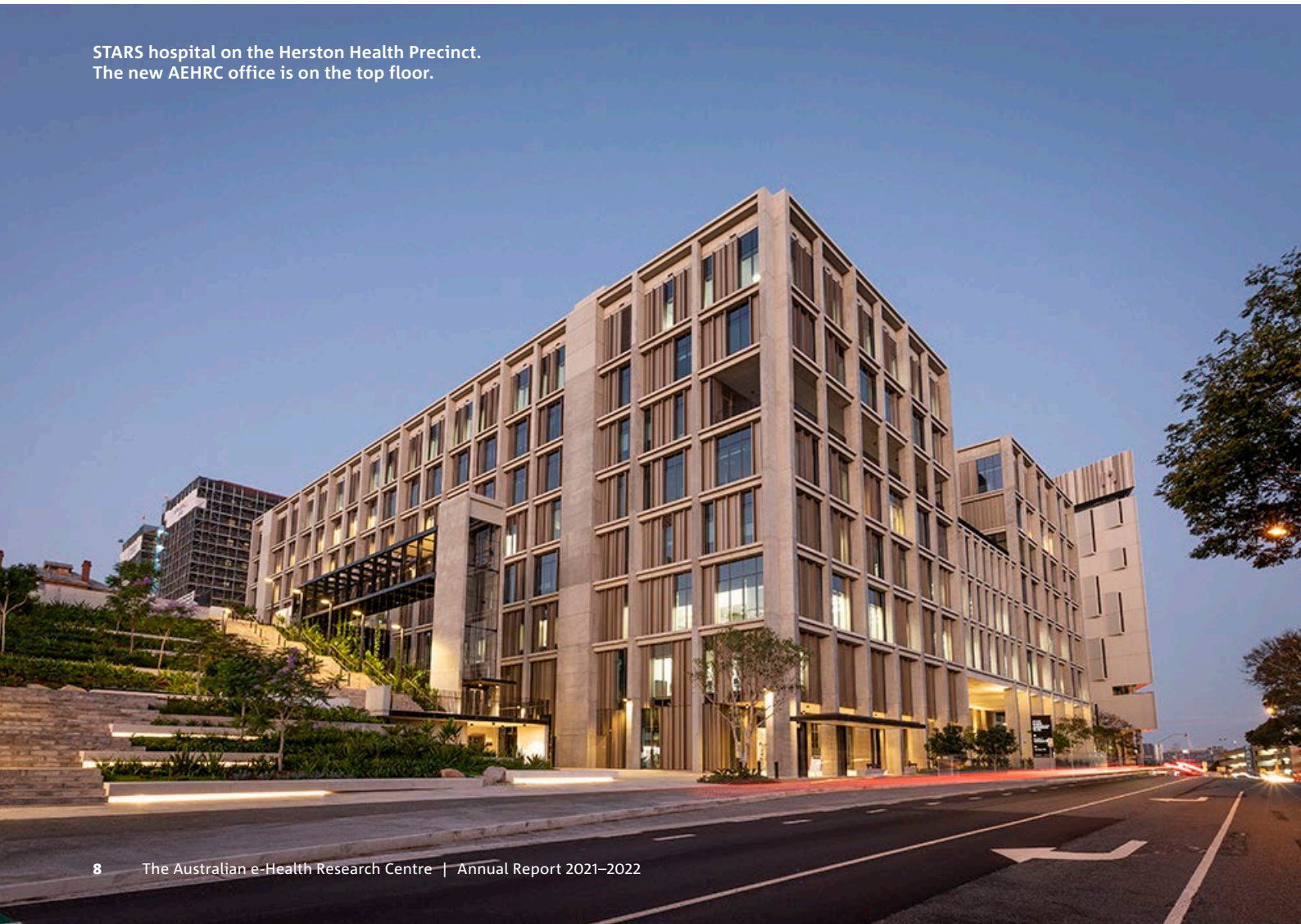
Meetings

- 13th August 2021
- 3rd November 2021
- 17th May 2022

AEHRC around Australia

Since its formation in 2003, the Australian e-Health Research Centre has established a central role in the Australian digital health ecosystem. We continue to work closely with Queensland Health and Hospital Services, but our national remit means we work around Australia and internationally. Nationally we continue to work with several state and federal health agencies – including the Commonwealth Department of Health and the Australian Digital Health Agency.

Over the past 12 months CSIRO has supported our moves into new offices around Australia. In Brisbane the team have settled in well to our offices on the 7th floor of the new STARS Hospital at the Herston Health Precinct; our Melbourne and Perth staff have moved into refurbished offices in Parkville and Kensington respectively; and recently our Sydney staff enjoyed a relocation to new offices in the Westmead Innovation Precinct.



STARS hospital on the Herston Health Precinct. The new AEHRC office is on the top floor.

Queensland

Our AEHRC headquarters is in the new STARS Hospital on the Herston Health Precinct. We collaborate broadly across Queensland Health – including with eHealth Queensland and Clinical Excellence Queensland, as well as with clinicians and hospitals in hospital and health services including Metro North, Metro South, Gold Coast, Townsville, North West and Children's Health Queensland. We also collaborate with many universities – including University of Queensland, Queensland University of Technology, James Cook University, Griffith University and Sunshine Coast University.

All our research groups work with Queensland collaborators, who are acknowledged throughout this report.

New South Wales

Our NSW based staff have recently moved into the Westmead Innovation Quarter as part of the new home for CSIRO Health and Biosecurity in Sydney. Sydney-based staff bring expertise across the whole program – including in transformational bioinformatics, health services and health informatics.

We have several long-term collaborators – especially with the Australian Institute for Health Innovation and the applied sciences group and Faculty of Medicine and Health Science at Macquarie University, the Children's Medical Research Institute (CMRI) at Westmead and the Ingham Institute at Liverpool Hospital.

Over the past 12 months we have worked with NSW Pathology and eHealth NSW and are currently developing multiple projects with NSW Hospitals as we expand our work with NSW Health.

Our NSW Health engagement is led by our Deputy Research Director Jill Freyne and Transformational Bioinformatics group leader Denis Bauer.

Western Australia

Our Perth based staff recently moved into refurbished offices on the Kensington CSIRO campus.

As part of our Health Services group, our Perth based tele-health research and development teams address pressing and emerging areas of healthcare delivery, particularly in respect to the provision of quality services to rural and remote populations and high-needs groups.

Our tele-health project reports are in our Health Services group section where we detail our collaborations with Fiona Stanley and Royal Perth Hospitals, as well as the University of Western Australia. Our tele-health research team also works around Australia – including leading a project in Queensland with the Northern Australian CRC.

Perth is also home to team members from other groups. We work with hospitals including Fiona Stanley and Bunbury on Health System Analytics group projects and our Biomedical Informatics group has several projects with collaborators including Alzheimer's Australia and Edith Cowan University.

Our WA Health engagement is led by Perth based team leaders, Shaun Frost and Jana Vignarajan.

Victoria

Our Melbourne based staff moved into refurbished offices at the CSIRO Parkville site and are part of several different groups – including Health System Analytics, Biomedical Informatics and Health Data Semantics and Interoperability.

We have significant long-standing collaborations in Melbourne – including with the Florey Institute and Austin Health in the Australian Imaging Biomarker Lifestyle (AIBL) Study of Ageing. The AEHRC has been CSIRO's lead partner in the Melbourne Genomics Health Alliance (MGHA). AEHRC staff are embedded within the MGHA program and at Austin Health. We also engage with Victorian Clinical Genetics Services (VCGS), Murdoch Institute, Peter MacCallum Cancer Centre (PeterMac) and Walter and Elisa Hall Institute (WEHI).

Our Victorian Health engagement is led by our Health System Analytics Group Leader Rajiv Jayasena.

AEHRC 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, as well as 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.

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 they engage with their health. Through clinical trials, these technologies have been evaluated and demonstrate a quantifiable impact on individuals, care teams and carers. These outcomes have contributed to the body of evidence required to see large scale adoption and innovation in digital health service delivery. Jill contributes to a range of research focussed initiatives through non-executive director and advisory board roles.

Dr Michael Lawley

Group Leader, Health Data Semantics and Interoperability

Dr Michael Lawley is Senior Principal Research Scientist and Group Leader with the Australian e-Health Research Centre. Michael leads the Health Data Semantics and Interoperability 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 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 and machine learning and statistical techniques for precision health (prediction, staging, prevention and treatment), including in combination 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 leads the Transformational Bioinformatics Group and is an internationally recognised expert in machine learning and cloud-based genomics. She is an Adjunct Associate Professor at Macquarie University and AWS Data Hero, determined to bridge the gap between academia and industry. 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 research has led to the discovery of novel disease genes for Motor Neuron Disease and has informed the COVID-19 vaccine development. She keynotes international 10,000-attendee IT, LifeScience and Medical conferences and has attracted more than $38M in funding to further health research and digital health. She develops open-source bioinformatics software that has commercial impact through cloud-deployment. She was recognized as Brilliant Women in Digital Health 2021 and Women in AI 2022.

Dr Mohan Karunanithi

Group Leader, Health Services (Until September 2021)

Dr Mohanraj Karunanithi has been part of the Australian e-Health Research Centre since 2004 and led our Health Services group over the past seven years. Mohan made an enormous contribution to CSIRO and to the Australian e-Health Research Centre over this time. Mohan has established a world leading mobile health capability – with the successful spin out of Cardihab – and over the past 7 years established a health internet-of-things capability with a focus on aged care. Across many of these projects Mohan ran some amazing trials with great outputs.

Mohan has also developed some fantastically talented people over his time at CSIRO who will carry on his work in developing innovative health service delivery models using technology.

Dr Marlien Varnfield

Group Leader, Health Services (From October 2021)

Marlien Varnfield obtained a BSc Honours degree from the Faculty of Natural Sciences and MSc (focusing on periodontal diseases) from the Faculty of Dentistry, University of Pretoria, South Africa. Her PhD research at the Department of Epidemiology & Preventive Medicine, Monash University, Australia, focused on evaluating the potential for large scale implementation of health-care interventions utilising Information and Communication Technologies.

Marlien has developed the AERHC Mobile Health research area over many years and is now leading our Health Services group.

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 led research in primary and acute healthcare reform and in new models of care for chronic disease management.

Rajiv leads the AEHRC's Health Systems Analytics group, comprising research teams specialising on 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 leads activities as Group Leader through programs undertaken by teams nationally as well as internationally in South America (Chile).

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

Even despite the threat of a rain event in Brisbane, a surge in COVID cases and the screen fatigue many are experiencing in the post-COVID world, attendance at the 18th annual AEHRC colloquium was strong. The event was held virtually and across four physical sites nationally — including our new Westmead site — on 10 May 2022. In total nearly 450 registered to attend, 284 of those in person.

Our annual colloquium demonstrates our role as trusted and knowledgeable experts in the global digital health ecosystem, bringing together established innovations in data analysis, interoperability, precision medicine and virtual care, as well as fledgling projects that are sure to take digital health by storm. One of the broad themes of this year's showcase was the focus on closing the gap for Indigenous Australians, with many presentations focussed on innovations in telehealth and filling knowledge gaps about rural and remote communities. Along with featuring the exciting science being developed at AEHRC, the Colloquium also provided a stage for the work of some of our collaborators in the aged care, maternal health, interoperability and precision health.

AEHRC digital health initiatives

The morning session highlighted many AEHRC projects with our collaborators and demonstrated the impact of our science. The session started with talks about our health service delivery research. First up was a joint presentation by the AEHRC's Marlien Varnfield and Joanne Laurie, obstetric medicine specialist at Mater Mothers' about the uptake, implementation and future of the MoTHer platform for helping women manage their gestational diabetes. Following this was Sarah Docherty, Senior Project Manager for Developing Northern Australia, and AEHRC's Justin Boyle, who presented on our project in delivering tele-ophthalmology services for diabetic retinopathy to remote Northern Australia.

We then presented our health data research – with Teresa Wozniak discussing the Hotspots surveillance system – currently being trialled in the Northern Territory to track antimicrobial resistance (AMR) surveillance. The final two talks from AEHRC were about our precision health research. Ying Xia showcased her team's work on using FEOBV PET as a direct and quantitative tool to assess region-specific cholinergic denervation in the detection of Alzheimer's disease. Glenn Bennett, CMO of Gene Path Labs and AEHRC's Letitia Sng presented on targeted genomics for newborn testing.

The final talk of the morning session was from Damien Green, Deputy Director General of eHealth QLD who outlined some of the strategies for digital health in Queensland and talked about the importance of research partners such as AEHRC for Queensland Health.

Health interoperability

The second session provided an opportunity for AEHRC to demonstrate our global impact in health interoperability. It opened with a pre-recorded presentation by Ian Townend and Nicholas Oughtibridge, chief and lead architects respectively of the NHS who spoke of their experience of driving interoperability in the UK and the role of AEHRC's Ontoserver technology. Reuben Daniels, Enterprise Architect for eHealth Queensland presented the Queensland's Clinical Terminology Service – a new statewide enterprise service using the Ontoserver technology.

Herbert Down, from the Australian Digital Health Agency, added to this session on interoperability with a view from the Agency on Australia's Digital Interoperability Strategy, part of the National Digital Health Strategy. David O'Driscoll, from Erintide and AEHRC's Kylynn Loi then took us on a tour of the Australia's antimicrobial resistance data ecosystem – with a report to be launched shortly. Parnesh Raniga, from the AEHRC imaging team, outlined his team's work on integrating artificial intelligence into imaging workflows using FHIR.

As has become custom at the colloquium – we finished the session with vibrant panel featuring Grahame Grieve, Kate Ebrill, Narelle Doss, Herbert Down and outgoing Telstra Health CMO Vincent McCauley on the challenges and opportunities of interoperability in healthcare.

Emerging AEHRC research

The final session, chaired by Marlien Varnfield, featured some of the newer AEHRC projects which are starting to get uptake and impact, including work from our postdoctoral researchers and PhD students. Georgina Chelberg talked about her PhD findings about dementia care for Indigenous people in rural and remote Australia – and the potential role for digital health. Vera Buss, another of our PhD students, showcased her tracker app for cardiovascular disease.

This was followed by talks from two of our Perth based scientists. Shaun Frost took the audience through his work on eye imaging for the detection of cardiovascular disease. Michael Vacher presented his findings on the use of polygenic risk scores in the prediction of risk for Alzheimer's dementia.

We finished the day with some excellent AI talks. Bowen Xing showed his work in using MRI and AI in the detection and monitoring of paediatric lung disease. And Jacky Hung, Principal Project Officer at QLD Health, and our own Hamed Hassanzadeh showcased their work on visualising patient's journey through the health system.

Great networking!

The colloquium was rich with opportunities for discussion between AEHRC scientists and engineers and other attendees. It was also great to have people beaming in from around Australia. Special thanks to Marianne Chalk for doing a great job (as usual) in making the day run super smoothly!

News and Communications

AEHRC in the news

This year, AEHRC was a beneficiary of the post-COVID media interest in all things digital. We shared our research findings and key engagements with partners and governments through coverage in both mainstream and industry platforms.

News coverage highlights

- In the first half of 2022, there were two major announcements: one on AMR and the other on VariantSpark and COVID variant analysis. Both received international and national media attention in press and TV.
- There were multiple interviews: David Silvera had a radio interview for 4CRB Gold Coast, in robotics in aged care for a show called: Your Retirement Years. https://www.odysseycommunities.com.au/news/your-retirement-year-episode-29/, Dana gave a pre-recorded interview with Triple J's Hack (6/4/21) on ethics of chatbots and robots as companion bots, David Hansen & Georgina Hobson were interviewed for Wild Health, Denis was interviewed for The Economist podcast Healthcare Redefined, our Indigenous research featured on CSIRO's webpages https://blog.csiro.au/indigenous-science-solutions/
- There were several blog features: Happi Mind project reported in Canberra Weekly (Liz CW) https://canberraweekly.com.au/clinical-trial-targets-dementia-risk-in-middle-aged/, EDNA was featured in a blog by Melbourne Genomics Alliance
- Our femtech research was featured in the CSIROScope blog
- aehrc.csiro.au went live – 8th October
- Internal comms: our vacation student Megan Ferguson was featured in a MyCSIRO blog, Denis Bauer represents the AEHRC in the CSIRO wide Impossible Without You HR campaign
- A short film about MoTHer was featured at the American Diabetic Association 2022 Summit

Government and partner engagement highlights

- CSIRO joined the Westmead precinct and held a successful research showcase to mark the event. The showcase was attended by Larry and the other CSIRO board members as well as executives from some of Australia's leading healthcare organisations. News was featured on our website and via CSIRO's Twitter and LinkedIn accounts.
- We reached key stakeholders through eHealth Queensland's *National Digital Health Update* newsletters, with stories on our Indigenous health projects, diabetic foot sock, AMR and more.
- Justin, Jana and Sajib were part of a collaborative project with the Fred Hollows Foundation that were finalists the WHO Innovation Challenge – one blog and a media announcement followed from this
- The collaborative report by us, Telstra Health, DHCRC and AIDH on gender and diversity in digital health was released: **Report reveals gender disparity in Australia's digital health sector (telstrahealth.com)**

Awards

Our teams were again successful in being nominated for or winning several awards this year.

- MICE platform was the finalists at the WAITTA incite awards under 'innovating government'. Maryam and Madonna attended the gala cocktail event on 23 July with the external collaborators from Fiona Stanley hospital. The project missed the spotlight this time but the project team is still buzzing and will keep innovating!
- A team of postdocs (Aaron, Hollie, Ash, Bowen, Leo) participated in ImageCLEF – an international challenge to build the best AI system for medical imaging tasks. The team came 3rd in the image captioning and 1st in the TB detection task.
- Dr Denis Bauer won the Women in AI in Innovation Award
- Denis and Kate E won Telstra Health's Brilliant Women in Digital Award
- Denis was the AI first runner up of the overall award for AU/NZ
- Andrew – lighting pitch (1 min.) and poster presentation at the Qld Cardiovascular research network (QCVRN) symposium at the Sunshine Coast university hospital (SCUH) Friday 22nd Oct. awarded first place
- Justin, Jana and Sajib are winners in the WHO Innovation Challenge for their work with the Fred Hollows Foundation on diabetic eye disease in Viet Nam.

CSIRO recognition

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

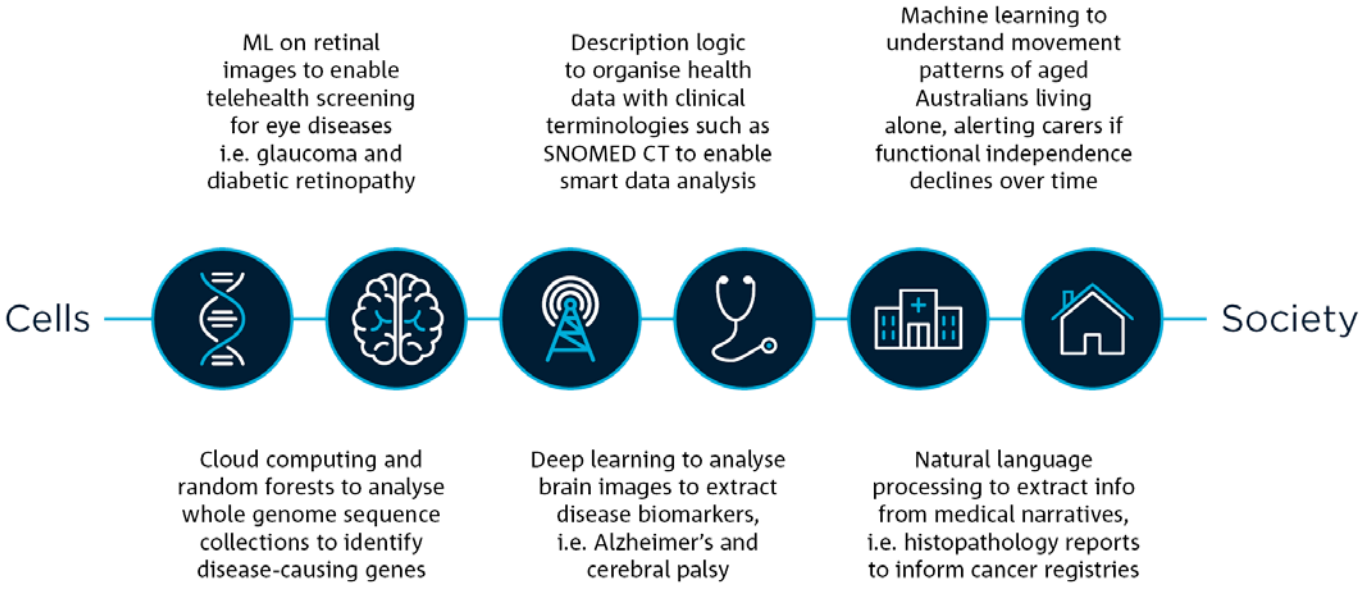
- Dr Ray Mahoney, Andrew Goodman, Jed Fraser, Georgina Chelberg and Dr Kaley Butten received The CSIRO Aboriginal and Torres Strait Islander Engagement Impact Excellence Medal – the award recognises achievements of our people in relation to Aboriginal and Torres Strait Islander engagement, participation, service delivery and research services.
- Medal for Diversity and Inclusion: The CALD Assist team, for developing a communication tool for use with culturally and linguistically diverse patients to reduce inequity in healthcare delivery.
  Team members: Jill Freyne, David Silvera, Dana Bradford, Karen Harrap and Vanessa Smallbon.
- Laurence Wilson was finalist in CSIRO awards for COVID work with Vasan and ACDP
- Hamed and Ash, along with the entire H&B EMCR Committee & Westmead collaborators won the 2021 H&B Collaboration Award for delivering the 2021 H&B EMCR Workshop
- Sajib received the Julius Career Award (JCA) 2022

Artificial Intelligence in Healthcare

A large proportion of AEHRC projects now have some artificial intelligence(AI) or machine learning (ML) component; some developing new methods, others applying state-of-the-art methods to new problems. Recent advances in cloud computing, along with increased data availability, have resulted in increasing application of AI and ML technologies across our society, including in health.

Broadly, all our AI work falls within four broad areas:

- **Knowledge representation and reasoning:** how we represent or classify health 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.



The AEHRC contributes to several AI and ML initiatives, including CSIRO's MLAI Future Science Platform and the Macquarie University-led Australian AI Alliance in Healthcare. We contributed to many projects in these areas. To highlight our work in AI and ML, this year we released a report titled *Exemplars of AI in Healthcare at AEHRC,* providing a comprehensive overview of our work, as well is a introductory primer to AI in health.

For more visit aehrc.csiro.au/ai/

AEHRC wins international competition in machine learning

This year AEHRC scientists from our medical imaging and health data semantics teams participated in the ImageCLEF Medical 2022 challenge – an international medical AI competition.

The good news is–their hard work has paid off and we have placed 1st and 3rd in two projects comprising the competition, which features participants from around the globe!

Our team came 1st in the 'detect tuberculosis from 3D chest CT images' task and 3rd in the 'predict concepts from medical images/ generate captions from medical images'.

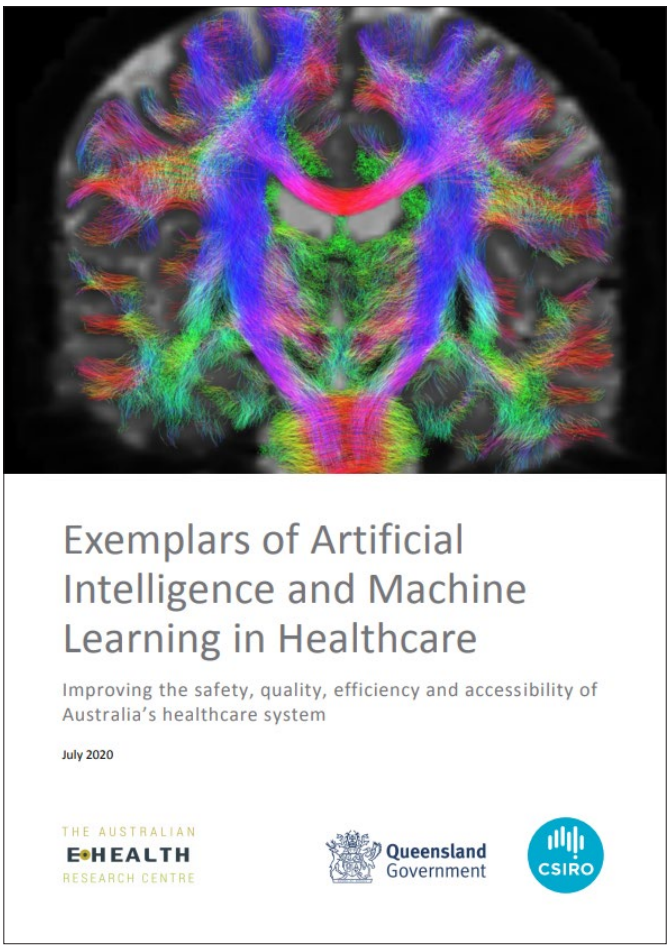
This year, the aim of the competition was to broaden the evaluation of technologies for annotation, indexing and retrieval of visual data.

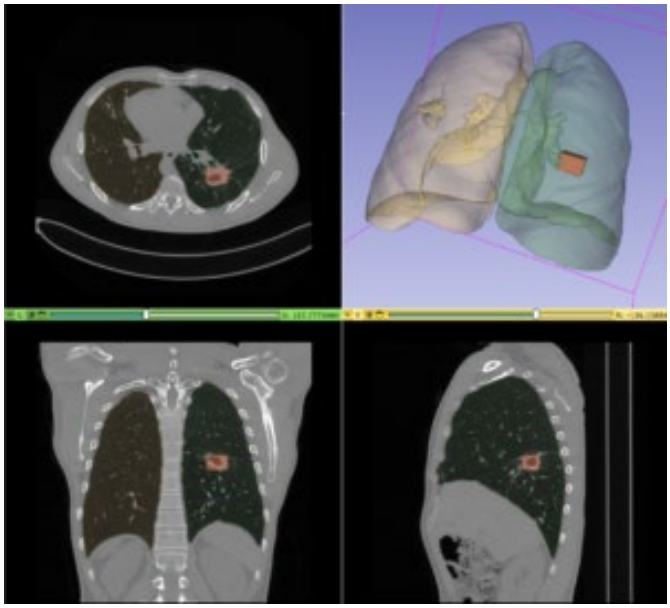
It's hoped this will provide information access to large collections of images in various usage scenarios and application domains: medical, nature, Internet and social media around the world.

Participants came from a large variety of fields including information retrieval (e.g., text, vision, audio, multimedia, social media, sensor data), machine learning, deep learning, data mining, natural language processing, image and video processing; with special emphasis on the challenges of multi-modality, multilinguality, and interactive search.

Congratulations to the entire team: Hollie Min, Ash Gillman, Aaron Nicolson, Leo Lebrat, Bevan Koopman, Bowen Xin and Jason Dowling.

The results of the campaign are published in the working notes proceedings, published by CEUR Workshop Proceedings (CEUR-WS.org). Selected contributions are invited for publication in next year's Springer Lecture Notes in Computer Science (LNCS), together with the annual lab overviews.





Automated detection of TB lung cavern regions on CT imaging. Image: Bowen Xin

Advances in use of AI and ML @ AEHRC

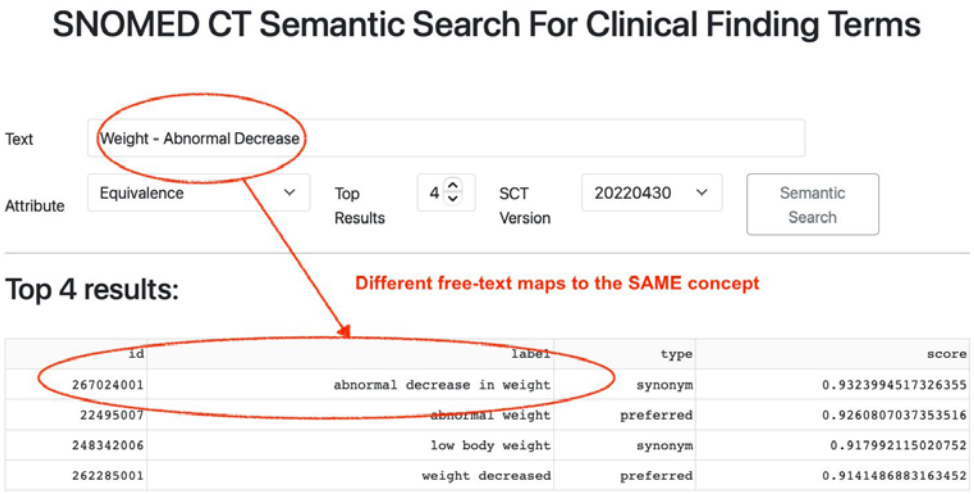
Here we highlight some of the AI and ML techniques that underpin our projects.

Knowledge representation and reasoning

Machine Learning to Match and Search Medical Terminologies.

Problem: Medical Terminologies such as SNOMED CT are extensive and highly curated sources of medical concepts. Finding concepts in large clinical ontologies can be challenging when queries use different vocabularies. A search algorithm that overcomes this problem is useful in applications such as concept normalisation and ontology matching, where concepts can be referred to in different ways, using different synonyms.

Solution: To handle this problem, we developed a deep learning based approach to build a semantic search system for large clinical ontologies. We propose a Triplet-BERT model and a method that generates training data directly from the ontologies. The figures below show an example of the model finding the right SNOMED CT concept even though the query is authored in different ways. The method is generic in nature and can be used for both finding concepts given a text query and matching concept between different ontologies. Experiments searching SNOMED CT showed that our Triplet-BERT model outperforms all the existing common approaches to this problem. In particular, the method was effective at mapping 'hard' queries – those that had little or no common terms with relevant concepts. Triplet-BERT can be used as the basis for both automatic ontology matching algorithms and searching tools to assist humans building ontology maps.



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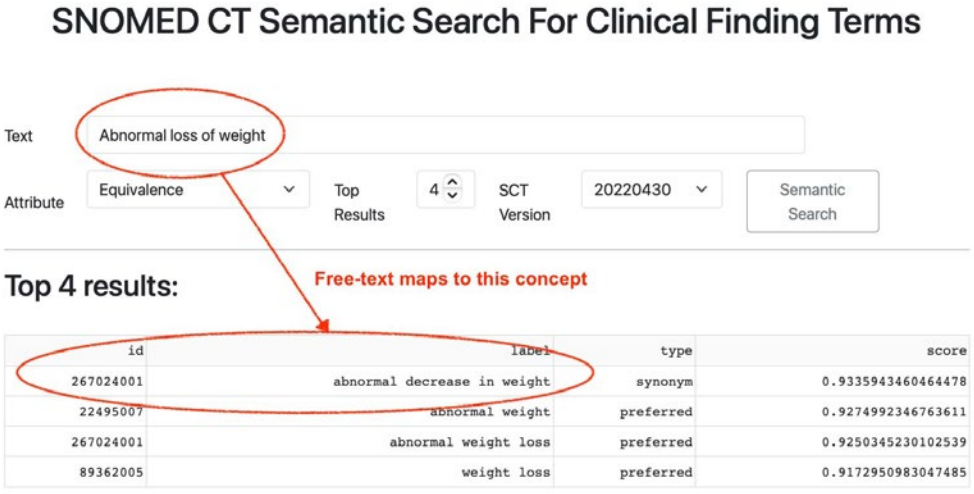


id	label	type	score
267024001	abnormal decrease in weight	synonym	0.9335943460464478
22495007	abnormal weight	preferred	0.9274992346763611
267024001	abnormal weight loss	preferred	0.9250345230102539
89362005	weight loss	preferred	0.9172950983047485

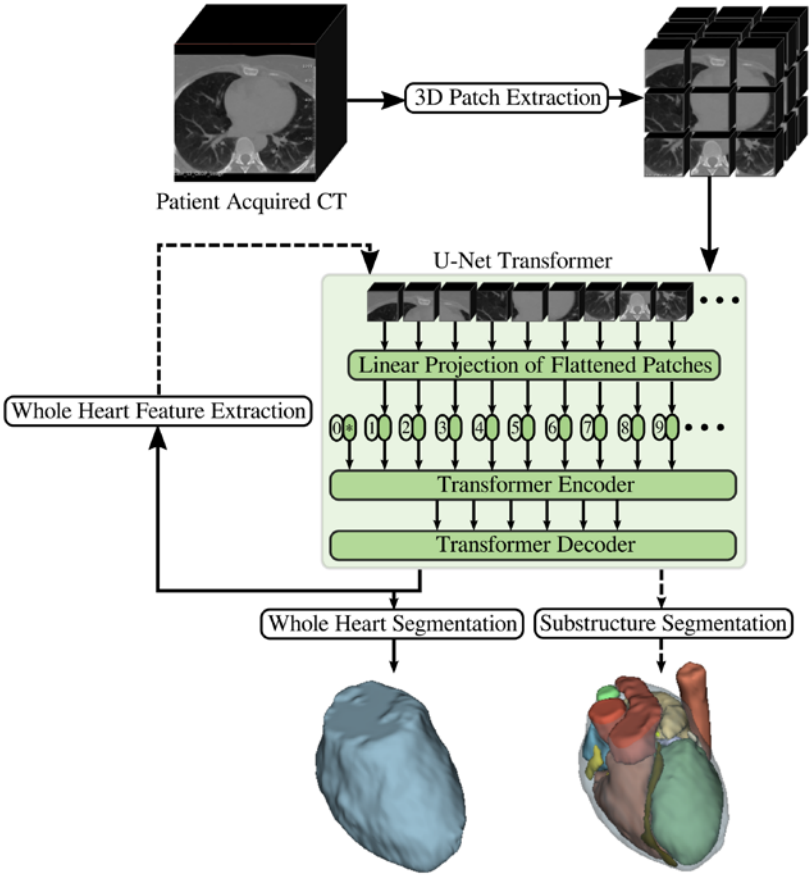
Imaging and vision

Cascaded vision transformer network for cardiac substructure segmentation in CT

Problem: Computed Tomography (CT) is a widely used imaging modality for detecting coronary artery disease. The accuracy of CT is dependent on operator skill, image quality and reader experience. This study aimed to assess the utility of a novel machine learning (ML) technique to detect cardiac substructures in CT.

Solution: A novel ML technique, Cascaded Vision Transformer Network (CVTN), was developed using twenty retrospectively obtained non-contrast thorax CT scans from patients undergoing radiotherapy treatment for breast cancer in Liverpool and Macarthur Cancer Therapy Centers, NSW, Australia. Images were contoured by three independent observers to delineate the whole heart, cardiac chambers, cardiac valves, LADCA, great vessels and coronary arteries. Ground-truth contours were defined using a majority vote, with 20-fold cross validation adopted to assess the utility of the proposed CVTN model.

Improved segmentation accuracy of the whole heart, 0.956 ± 0.013 (DSC), and an average improvement of 2.32% and 1.57% across the chambers compared with benchmark multi-atlas and deep learning models was obtained, respectively. CVTN was presented at the Society of Cardiovascular CT annual conference, Las Vegas, 2022.



Proposed CVTN pipeline. Image: Gregg Belous

Automated detection of cardiac substructures in CT. Image: Gregg Belous

Human language understanding

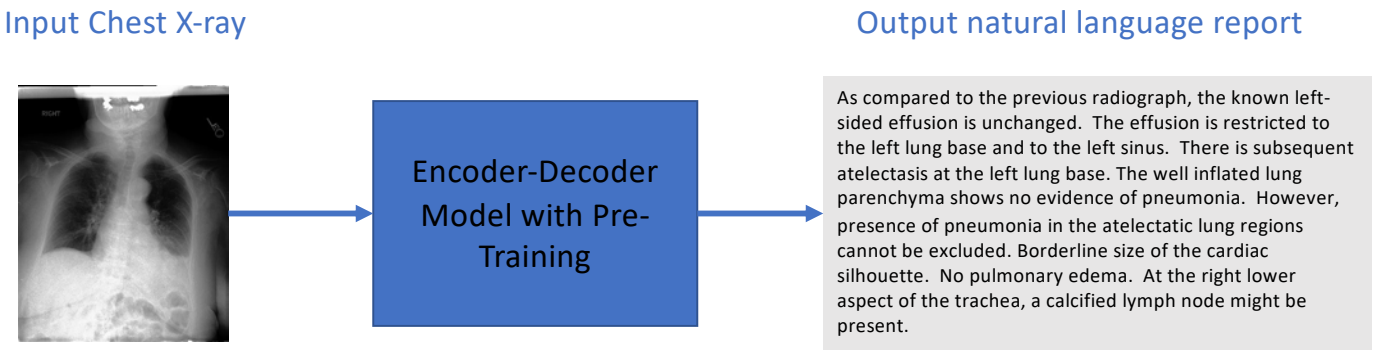
Automatically generated natural language reports for chest X-ray images.

Problem: Radiology departments produce large number of chest X-rays each year. Automatically generating a report from a patient's chest x-Rays is a promising solution to reducing clinical workload and improving patient care. However, current report generators – which are predominantly deep learning models – lack the diagnostic accuracy to be deployed in a clinical setting.

Solution: To improve automated report generation, we investigate a technique known as pre-training, that is exposing the deep learning model to large amounts of external data, both x-rays, reports and medical literature.

Once pre-trained, the model has some of the important 'background knowledge' it needs to then be trained specifically on the task of chest x-ray report generation. The actual architecture we use is a Vision Transformer to encode the x-rays images and a medical BERT model to decode the image to a natural language report.

The reports generated are more diagnostically accurate and have a higher similarity to radiologist reports than previous approaches. By leveraging pre-training, the model brings automatic chest x-ray report generation one step closer to the clinical setting.



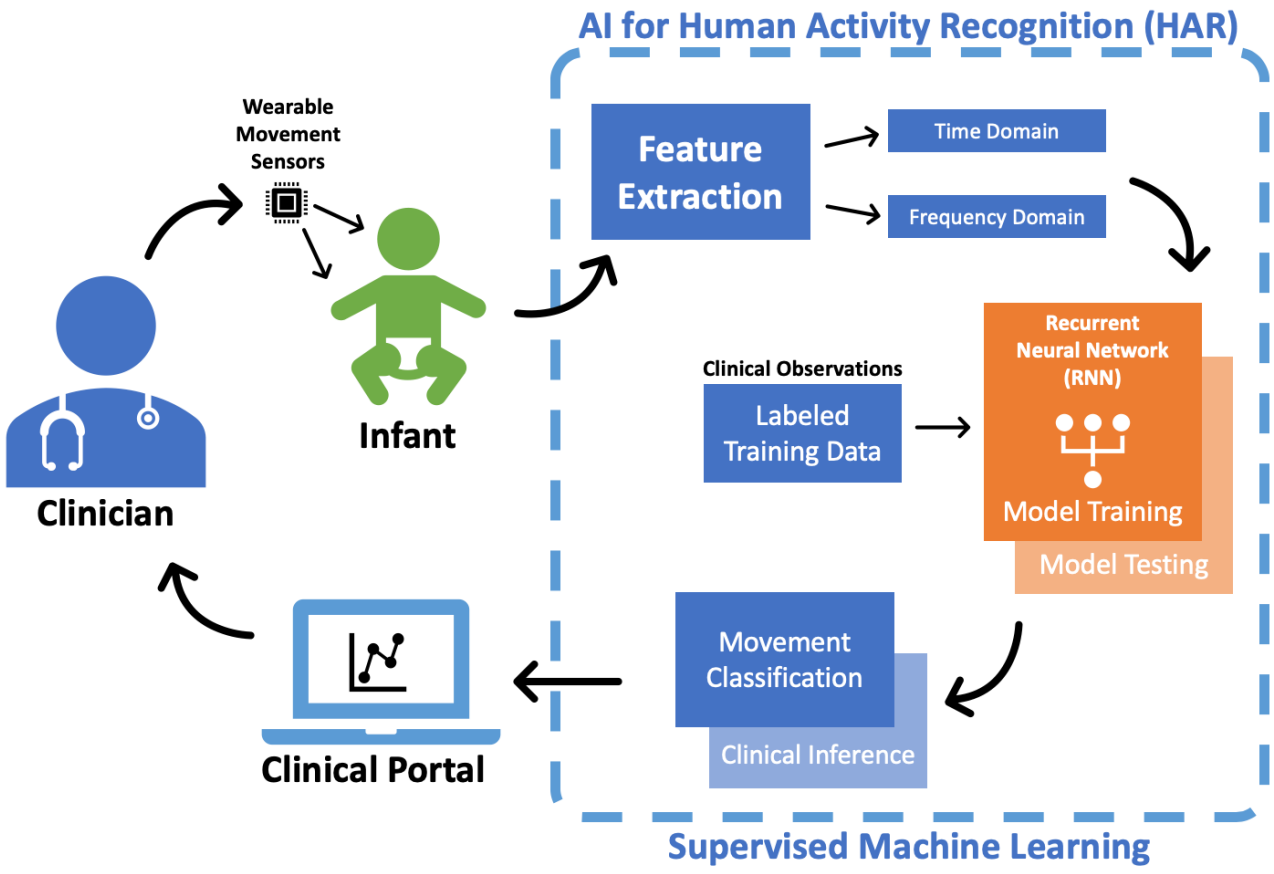
Conceptual overview of our multimodal analysis software. An input chest x-ray is fed into our pre trained model and an automated radiology summary is generated.

Predictive analytics and data-driven intelligence

Movement classification for early diagnosis of cerebral palsy and related neurodevelopmental disorders

Problem: Cerebral palsy (CP) is the most common movement disability in childhood, affecting one in 700 children in Australia. Despite the underlying causal neural injury being present around the time of birth, diagnosis only occurs at the 18-month mark. While early diagnosis is valuable for early treatment, it is difficult to objectively measure and classify an infant's physical movement over time. To solve this, we have developed a suite of miniature wearable movement sensors that can be used to measure motor development in infants from 3–5 months of age, towards early identification of infants at risk of CP.

Approach: The sensors use an inertial measurement unit to measure absolute orientation of the hands, feet, head, and trunk of the infant without the need for clinical supervision. Time series sensor orientation data have been used to develop a recurrent neural network (RNN) to classify infant movement along a developmental motor trajectory to determine whether the infant is at high risk for CP. Time and frequency domain movement characteristics are extracted and used as input features for the RNN, while clinical observations of the same movements from neonatal physiotherapists are used to create a labelled training dataset. This approach allows us to use a validated clinical metric to train the classification algorithm, thereby expanding neonatal motor assessments beyond the traditional medical environment while maintaining their diagnostic utility.

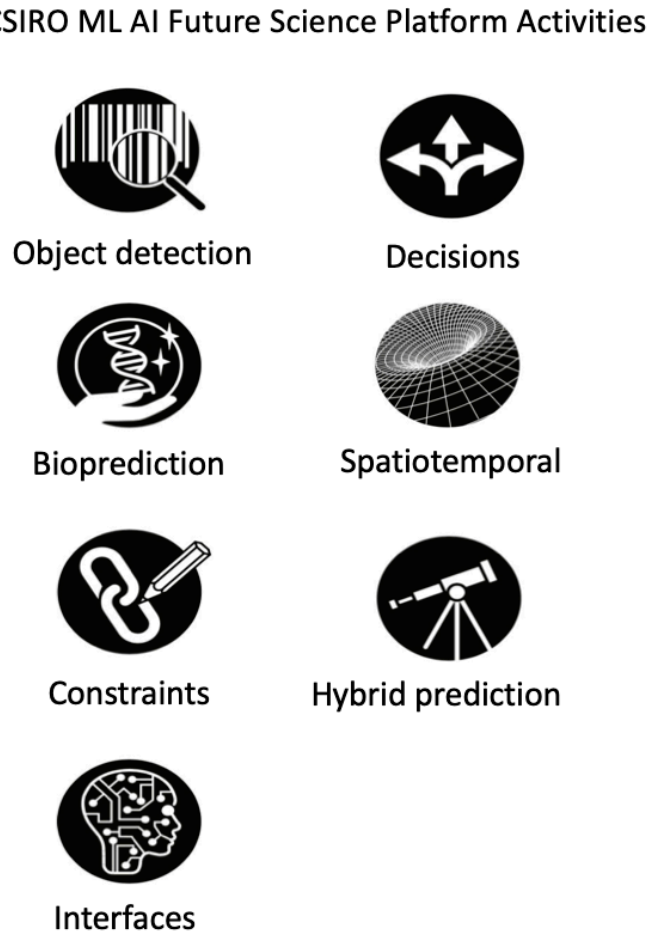


Data workflow for automated classification of infant movements indicating high risk of cerebral palsy.

AEHRC and CSIRO's ML and AI Future Science Platform

CSIRO has made a significant investment in AI through the Machine Learning and Artificial Intelligence Future Science Platform (FSP) – a cross-organisational initiative looking at AI across all domains which includes the hire of approximately 50 new postdoctoral research fellows.

We're involved in both the inception of this FSP, as well as hosting several dedicated postdocs in this initiative. The FSP consists of multiple high-level activity areas.



AEHRC has significant involvement in three FSP activities.

The **object detection activity** is developing a general feature extraction platform, and methods to automate data labelling and synthetic data generation, for image and image-like data. We plan to combine image and natural language processing expertise to better search, classify and exploit mixed image/text health data. Post-doc Dr Aaron Nicolson is dedicated to this project, which has:

- Research and evaluate new models for Chest X-Ray report generation that take into account a patients current and past imaging examinations.
- Developed computationally efficient strategy to encode medical images and their associated reports into a single model capable of search for images given text and text given an image.
- Participated in ImageCLEF – an international medical image processing competition. Participated in two sub-tasks: 1) image report generation where AEHRC placed 3rd; and 2) tuberculosis detection where AEHRC placed 1st among a cohort of international teams from academia and industry.
- Presented our work on medical report generation at the MARS2022 conference.

The **decisions activity** looks at AI-based decision making, reinforcement learning, active annotation and Bayesian optimisation; verifiable, explainable, ethical MLAI. 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. Here we have:

- Developed deep learning models for automated wellbeing assessment based on smart home data (manuscript under internal review; target journal is Journal of Biomedical and Health Informatics).
- Presented smart home research at FSP MLAI MARS Conference 2022.
- Development of novel deep reinforcement learning techniques to address the elective surgery scheduling problem. A manuscript describing this work has been submitted to the 19th Pacific Rim International Conference on Artificial Intelligence (PRICAI 2022) and is under review.
- Successful completion of ACORN-funded project to develop improved approaches for predicting elective surgery operation duration. A manuscript describing this work has been submitted to the Journal of Medical Systems (IF: 4.92) and is under review.

The **bioprediction activity** transforms biological production systems. We are using our VariantSpark tools to predict genomic traits in humans and plants.

AEHRC involvement in CSIRO initiatives

CSIRO employs multiple funding mechanisms to facilitate the development of new technologies to support Australian industry and government. AEHRC has been successful in securing funding for several projects through these mechanisms.

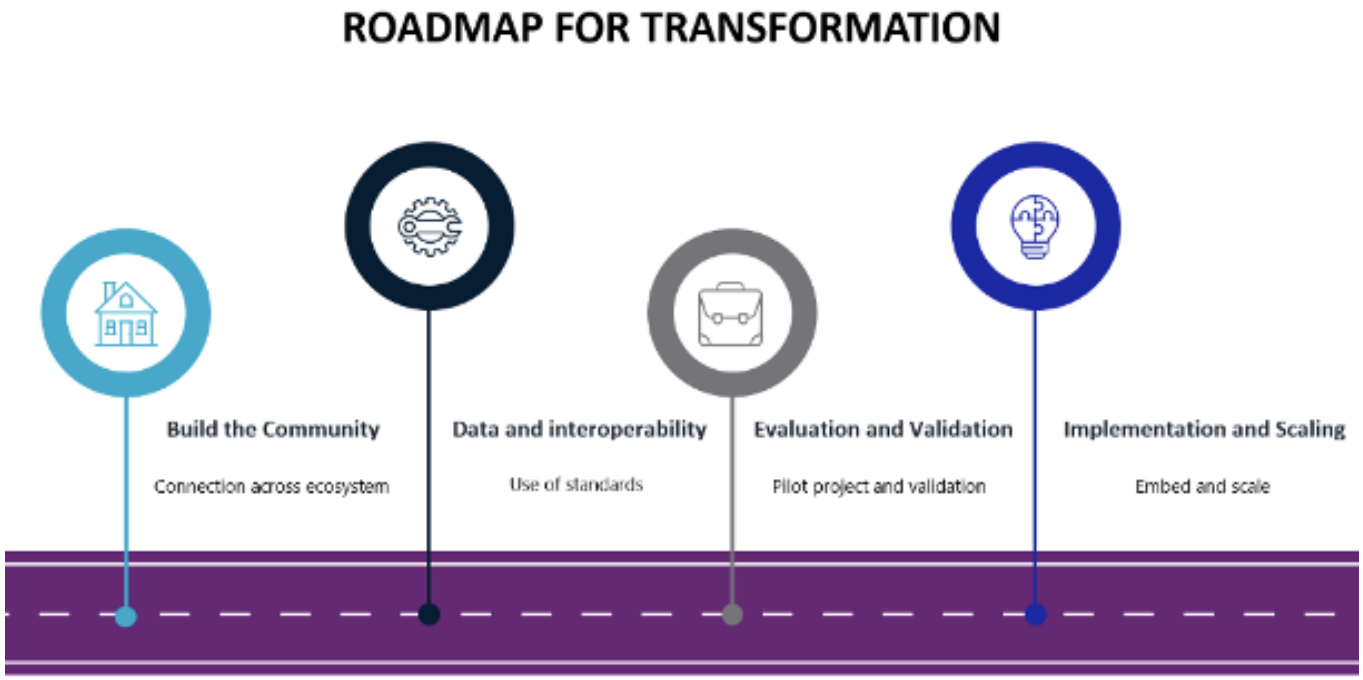
Virtual Care Initiative

Virtual care has the potential to elevate healthcare by improving efficiencies across the system, leading to better quality experiences and delivery of care from service providers and clinicians. True virtual care provides continuous, connected and coordinated care across the continuum via digital and telecommunications technology. At the heart of effective virtual care is a system responsive to patient needs, where clinicians provide the best care possible, supported by the latest digital tools and technologies.

For the last 17 years, AEHRC has undertaken research and development to enable Australia's preparation for virtual care. As such, we are uniquely positioned to establish a national agenda of digital innovation to transform healthcare delivery for all Australians, via our virtual care APAIR initiative.

The initiative will facilitate an integrated, ecosystem-wide growth process driven by a national roadmap for transformation. The roadmap identifies four innovation pillars that underpin transformative initiatives in virtual care including problem space definition, stakeholder community engagement, infrastructure and data models, success metrics and sustainability. The framework is supported by a set of integrated functions, processes and tools guided by the healthcare and technology industry to achieve harmonised interoperability for healthcare.

Over the past 12 months this funding has supported AEHRC to grow multiple new relationships and undertake a number of initiatives—described in the Health Services, Health Data Semantics and Interoperability and Health System Analytics groups.



CRISPR initiative

Genome editing is a central capability for domains ranging from human health to biosecurity and nutrition. As diverse as the application areas, so are the molecular protocols to perform these edits. The H&B-led APAIR initiative was funded with $1.3M to identify the best commercial and technical approaches to have 'freedom to operate' and create products for a wide range of domains. However, designing the optimal experimental set-up for all these molecules is time-consuming and cost-intensive because of the manual testing involved.

As part of the APAIR initiative, AEHRC has developed a framework for predicting the optimal experimental set-up in-silico, thereby reducing time and cost substantially. This framework will be based on AEHRC-developed approaches (GT-Scan suite) that have been published in the premier genome editing journals (e.g. *The CRISPR Journal*) and cited over 200 times.

Bluetongue virus study

Australian bluetongue virus (BTV) outbreaks can have a significant economic impact on Australia's livestock trade industry and the BTV-free status in Victoria is vital for some export markets. CSIRO's Australian Centre for Disease Preparedness (ACDP) requested funding to develop an enhanced surveillance tool for BTV using machine learning (ML) and visualised using the Nextstrain platform.

As part of the bluetongue virus APAIR we identified different clades of the virus active in Australia and differentiated this to other virus forms from the Indo-Malayan and European region. The resulting ML models will predict the various defined clusters using genomic sequences of BTV and in combination with Nextstrain analyses, provide enhanced characterisation of the BTV genome.

This work is packaged into an automated BTV database with a devised nomenclature system for individual virus isolate descriptors of the genetic composition. This will subsequently be used to interrogate specific clades and isolate features for disease-causing potential and real-time surveillance of BTV incursion in Australia.

CSIRO Future Science Platforms

CSIRO's Future Science Platforms (FSPs) are an investment in science that underpins innovation. FSPs 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 FSPs, detailed below, with projects described throughout this report.

Precision Health FSP

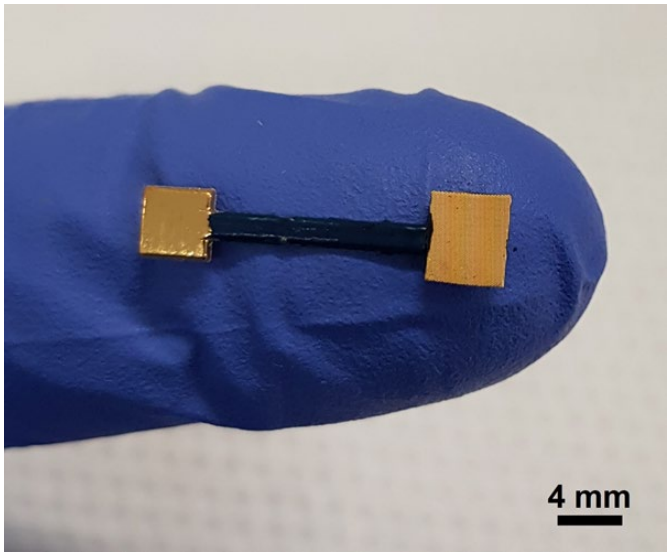
Australia's current healthcare system is focused on treating illnesses, but to keep up with our ageing population and the rise of chronic conditions like obesity the focus needs to switch to keeping healthy people healthy. The Precision Health FSP focuses on creating an integrated platform that can be 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 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 will usher 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 timely, customised and specific health and medical interventions. 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 for the diagnostic application of neural exosomes in the early detection of neural injury.



Optical image of Si-MNA patch

Machine Learning and Artificial Intelligence (MLAI) FSP

The MLAI FSP will develop capacity and platforms in key areas of machine learning and artificial intelligence. Further information about our involvement in this FSP is in the AI section.

Autonomous Sensors FSP

The new funded Autonomous Sensors FSP aim to accelerate the generation of new tools to enable growth of digital decision making within domains; combining fundamental sensor research with autonomous engineering solutions to provide new advanced sensing and platform technologies for the environmental monitoring, health monitoring, mining, agriculture, and manufacturing domains.

The AEHRC brings to the AS FSP a wealth of experience in health domain applications such as internet of things (IoT)-based smart home systems, clinical data processing, wearable sensors applications, and development of mobile health platform development.

AEHRC undertook a pilot project with the Autonomous Sensors FSP to investigate the use of ultra-wideband (UWB) radar sensor as an environmental fall detection sensor to monitor falls in the home of older people. This UWB sensor prototype was specifically designed and developed through a collaboration between AEHRC and CSIRO Mineral Resources.

The Health Data Semantics and Interoperability Group

Group Leader: Dr Michael Lawley

Our team answers the call for real-time clinical information to be shared between individual health practitioners, healthcare provider organisations and state and territory health departments to improve patient outcomes and health system performance.

We develop and apply innovative tools and techniques for evidence-based solutions and strategies to support improved health outcomes. As catalysts in developing the maturity of Australia's digital health ecosystem, we use, promote, and enhance health IT standards to improve the quality of, and unleash the value in, health data, including electronic health records and administrative data sets.

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 Data Semantics and Interoperability group science and impact highlights for 2021/22

- Ontoserver, our clinical terminology server is now the national clinical terminology server for five countries, most recently New Zealand and Scotland. Additionally, we have signed and are about to sign several reseller agreements with international organisations that will be announced shortly.
- The collaborative mapping tool, Snap2Snomed is now in operation and used by SNOMED licensees around the world to map local and legacy terminologies to SNOMED CT.
- Queensland One Health Antimicrobial Resistance (AMR) Hub project documented for the first time Australia's antimicrobial use and resistance data landscape; and demonstrated a suite of SMART on FHIR technologies to support antimicrobial stewardship in emergency departments (e.g., microbiology test result reviews, patient summaries of infections and AMR, and antibiograms).
- Medtex cancer notifications software improvements to Cancer Alliance Qld incorporating ICD-O updates and specific synoptic and stage factor extraction for colorectal, prostate, lung, pancreas, uterine and recurrent cancers.
- Consultation and delivery of a medicine terminology product strategy for the NHS incorporating dm+d, the UK Drug Extension, national/international interoperability use cases, and potential FHIR projection of medicines information. This translated to further prototyping work to demonstrate how the UK Drug Extension can be remodelled using SNOMED International's drug model, and generated from dm+d to ensure synchronisation.

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 Leaders: Jim Steel (until January 2022)

Dion McMutrie (from January 2022)

The Health Data and FHIR team is a team of engineers with expertise in using FHIR to build and integrate digital health systems. We develop a range of tools to accelerate and promote 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 Health Data Engineering team is a dedicated team of software engineers who work with scientists across the AEHRC translating our science into solutions for our customers and partners.

Health Data Interoperability team

Team Leaders: Dr Alejandro Metke (until January 2022)

Dr Bevan Koopman (from January 2022)

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

Interoperability Products and Services Lead

Kate Ebrill

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

Health Data Semantics and Interoperability: Platform Technologies

Our technologies enable 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®.

These include:

- FHIR-native terminology and classification tools: Ontoserver, Snapper, Snorocket, Shrimp, Atomio, Ontocloak, and SnoMAP
- OpenSource FHIR tools: RedMatch; Pathling
- Natural language processing tools: Medtex
- Search engines for medical reports and literature
- Chat bots to tackle a range health focussed topics

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. 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 the world-leading clinical terminology server implementing FHIR terminology services and supporting syndication–based content distribution.

Over the last year Ontoserver has continued to receive many new updates including:

- Pre-adoption of FHIR R5 features where no backward compatibility issues exist
- Support for concrete domains as released by SNOMED International since July 2021
- Improved SNOMED CT language reference set handling and support for preferredForLanguage to provide improved language handling
- Support for concept sub properties in CodeSystems through FHIR extensions
- Extended support for new SNOMED CT expression constraint language features
- Support for csv, tsv, scsv formats for ValueSet $expand operations

ontoserver.csiro.au

Ontocloak

Ontocloak is an authorisation server for controlling access to Ontoserver and other related services.

Atomio

Atomio is a syndication service for managing distribution content.

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 that enables diagnoses to be recorded using SNOMED CT-AU and 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 Data Semantics and Interoperability: Project Updates.

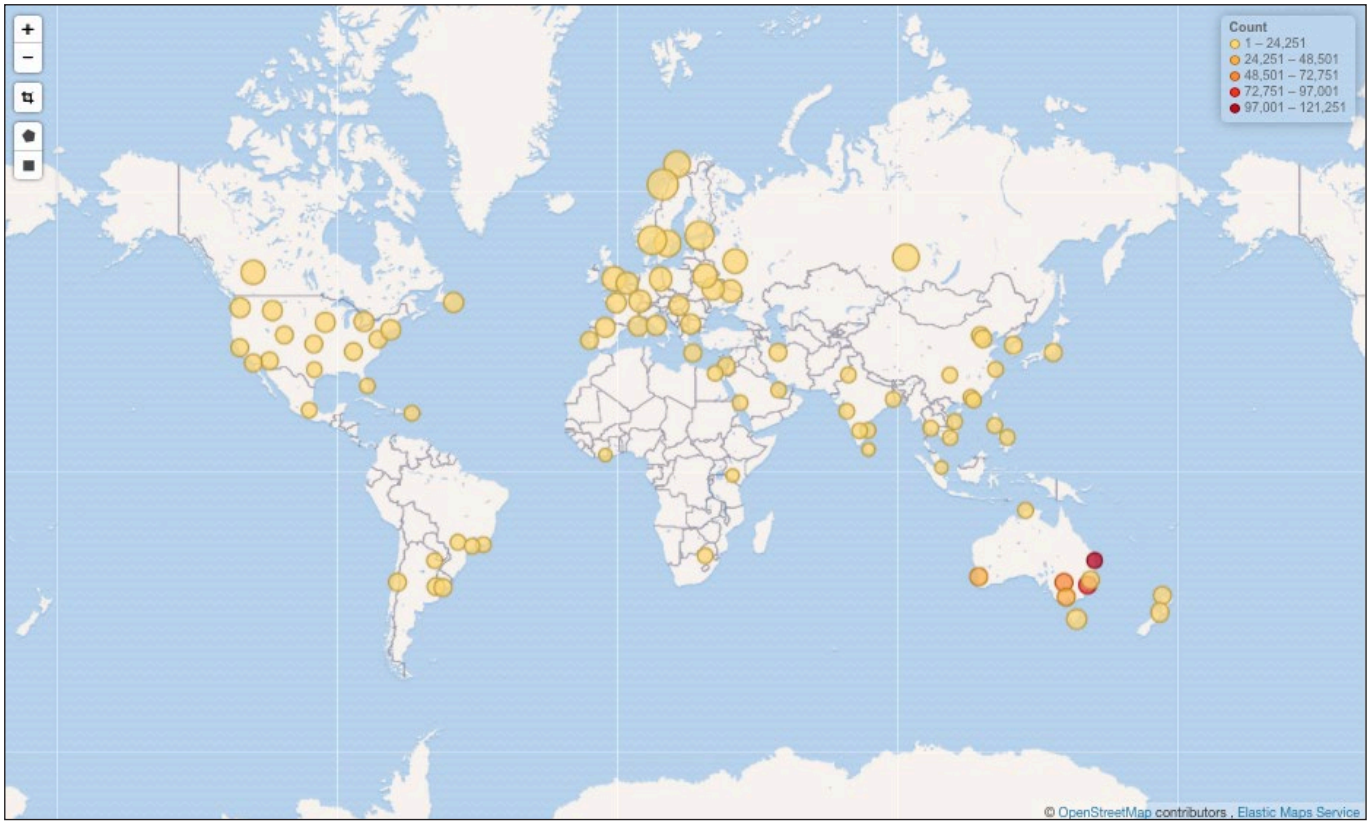
Snorocket

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.

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 used worldwide. Ontoserver is also licenced commercially by users in Australia, New Zealand, Switzerland, Germany, England, Wales and the United States, with evaluation licences in use across the United States, ASEAN region and South America. In the last 12 months NHS Digital, NHS Wales and Nictiz (Netherlands) all went live with Ontoserver as their national terminology server, along with vendors in NZ, US and UK.

Supporting open-source technology

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

REDCap is one of the most popular tools for the capture of research data. We developed two plugins 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 to turn a text field into an autocomplete-style field backed by a FHIR terminology server. This module improves REDCap out of the box capabilities, by enabling 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.

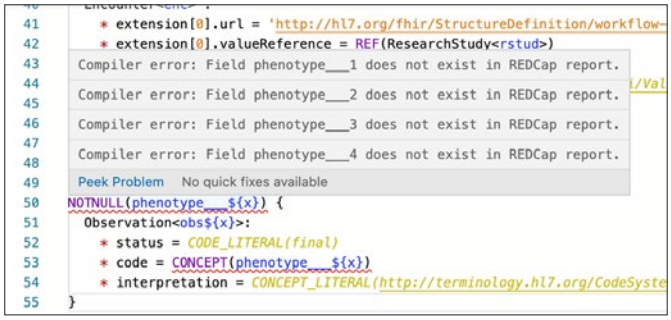
2. The **Pedigree Editor External Module** leverages the open-source version of the pedigree drawing tool released by Phenotips to capture pedigrees electronically in REDCap and represent them in FHIR format. Prior to the plugin, it was impossible to capture a diagram electronically. Most users would instead upload scanned versions of pedigree drawings.

Read more in Health Data Semantics and Interoperability: Project Reports.

Redmatch

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

Clinical trials and studies increasingly use electronic systems to capture data required for a range of analysis, such as the effectiveness of a new treatment or its economic value. However, these tools 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 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 the need to write code. This functionality can be used to standardise clinical data captured in different REDCap systems.



Redmatch: Web editor

Read more in Health Data Semantics and Interoperability: Project Reports.

Leveraging the HAPI FHIR Server

A number of projects across 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 simplifies the use of **HL7® FHIR®** within data analytics. It is built on Apache Spark, and includes language libraries and a server implementation.

Pathling was designed to assist with these primary use cases:

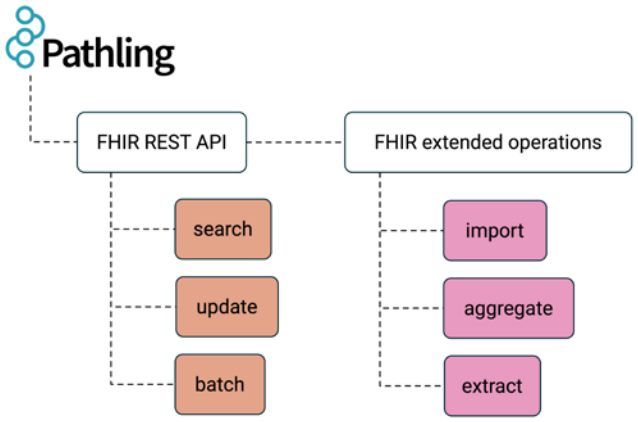
- **Exploratory data analysis** – Exploration of hypotheses, assessment of assumptions, and selection of appropriate statistical tools and techniques.
- **Patient cohort selection** – Selection and retrieval of patient records based on complex inclusion and exclusion criteria.
- **Data preparation**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

Pathling uses **FHIRPath** expressions for the aggregation and transformation of data, along with powerful and expressive search queries. This makes it easier to select and transform FHIR data as compared to a generalised query language such as SQL, and it also allows us to extend the functionality of the FHIR API to make it more capable for analytic use cases.

Pathling also integrates with the FHIR Terminology Services API to enable advanced terminology functionality within queries, at query time and at scale. This allows users to access terminological information and join it to clinical data in arbitrary ways, including advanced support for SNOMED CT and its expression constraint language.

Language libraries are available in the Python, Java and Scala languages, allowing for deep integration into existing applications and data science workflows. The server implementation provides a standard FHIR interface to analytic query operations and is suitable for the delivery of web and mobile applications.

You can learn more about Pathling at https://pathling.csiro.au/.



Pathling: operations provided as part of the FHIR API

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 with rich, valuable information that 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 learns 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.

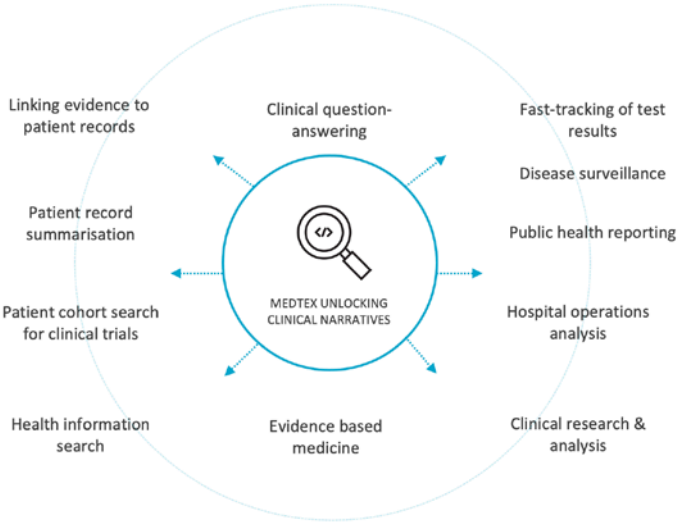
Analysis engines using Medtex technology have been developed to:

- 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
- 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 is used to deliver solutions to healthcare practitioners from cancer registries, and hospital radiology and emergency medicine departments including:

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

Read more in Health Data Semantics and Interoperability: Project Reports.



Medtex: Unlocking clinical narratives

Search engines for health data

With a rapid increase in health data – in all its myriad of forms – the need to effectively search this data rises. Simultaneously, much of this data is unstructured, making it difficult to search using methods tailored to structured data. Search engine technology was designed specifically for large amounts of unstructured data, making it well suited to the health domain.

We developed a suite of solutions for searching health data. We harnessed the novel approach of exploiting clinical terminology (eg SNOMED CT) to improve search. Our search methods often involve strong natural language process components: extracting mentions of diseases or treatments from free text; or detecting negation. More recently, with the rise of deep learning, we are increasingly training neural network based ranking methods.

Our research is applied in several application areas:

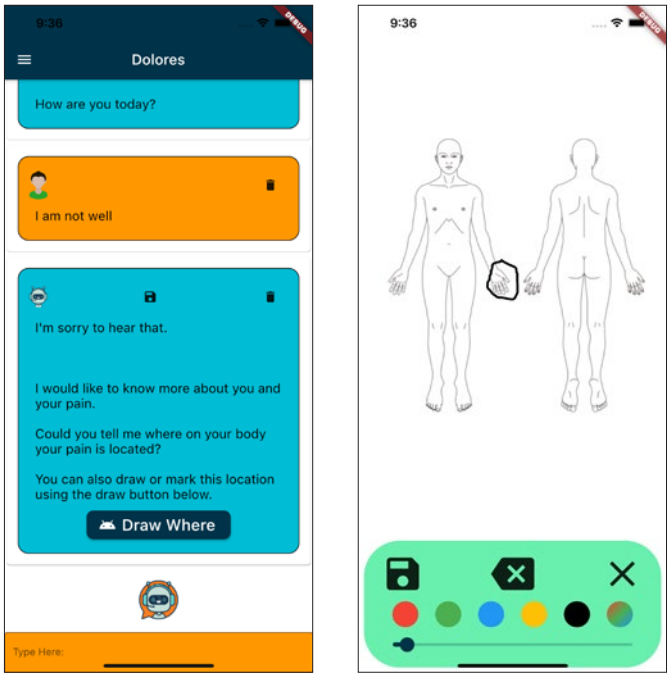
- searching medical literature for clinical decision support
- searching radiology reports to identify cohorts of patients
- matching patient to clinical trials
- finding targeted treatment from literature and trials for paediatric oncology patients
- helping the general public search for reliable and understandable health advice online.

This technology is also generally applicable as we have applied to search within an agricultural domain as part of a project with the Grains Research Development Corporation.

Chatbots for health

Chatbots bolster engagement in human-computer interaction. Fortunately, healthcare provides a plethora of opportunities for chatbots to support patients, carers and clinicians. A chatbot enables interactions between a knowledge base and a user in speech or text. Each chatbot is powered by a "brain" which needs to be developed and trained to support engaging dialogues. The AEHRC have developed a range of chatbots for clinical and social settings. Recent examples include:

- "Dolores" a chatbot to discuss all things related to chronic pain with language suitable for the age of the user. Dolores is expected to be piloted at pain clinics at the Royal Brisbane & Women's Hospital and Melbourne Children's Hospital in July 2021.
- "Quin" a smoking cessation chatbot built from 5000 hours of Quitline counselling sessions.
- Simulated Patient-Bots (or Sim-Bots) is a SMART On FHIR teaching tool developed with a collaboration between the AEHRC and the University of Queensland. A collection of simulated patients in the form of chatbot personalities are being developed to better train medical students in patient interaction.



Example dialogue of Dolores asking the user where the pain located. The user may respond verbally, text or by drawing.

Health Data Semantics and Interoperability: Project Reports

UK NHS-Digital – the UK National Clinical Terminology Service

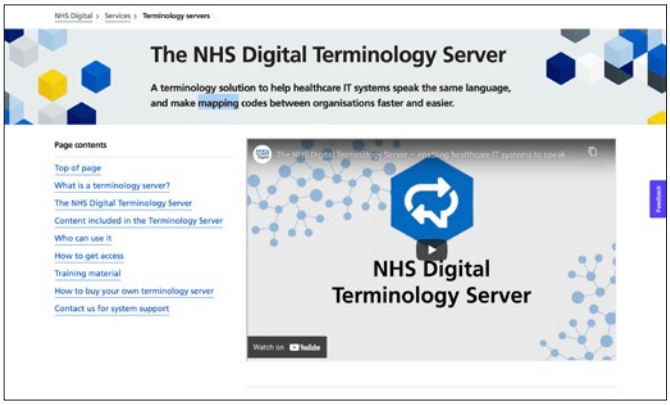
Collaborator: NHS Digital and Dedalus

In September 2020, our FHIR-native terminology server, Ontoserver, was selected as the software for the NHS Digital Terminology Server Framework through a globally competitive NHS Digital tender. For this framework, CSIRO partnered with the Dedalus Group, combining their experience in delivering business critical solutions for the NHS with the capability of Ontoserver to provide an end-to-end fully managed service to customers.

The framework was created to make the adoption of standards much simpler, easier and more cost effective, enabling healthcare organisations to use NHS Digital's service or procure and manage their own solution.

NHS Digital went live with their national terminology server on 16 June 2021 and now provides a nation-wide service with easy access to terminologies, vocabularies and value sets which can be synchronised – ensuring data collected across the UK uses a common language.

CSIRO has continued to work with NHS to formulate a product strategy for dm+d, the NHS's dictionary of medicines and devices (see below). To support this work, we have worked with HL7 to specify additional features and capabilties for version R5 of the FHIR Terminology Services standard. Also, we have extended Ontoserver's capabilities to pre-adopt these new features in advance of R5 being finalised and to deal with the special requirements specific to support of dm+d as a FHIR CodeSystem. These new capabilities went live in the NHS in early 2022.



NHS Digital Terminology Server Landing Page

UK Medicines Terminology Product Strategy

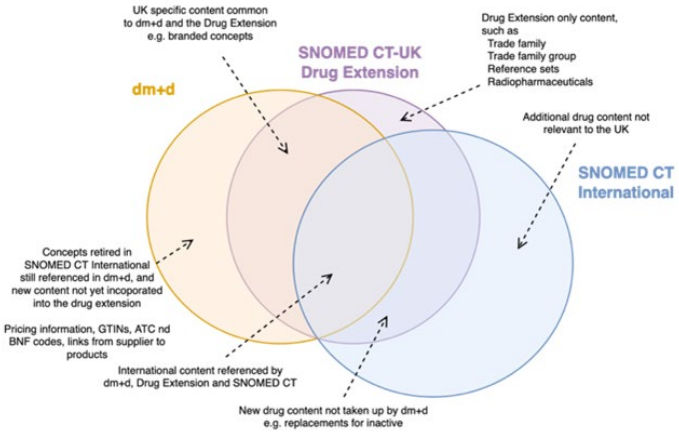
Collaborator: NHS Digital

NHS Digital commissioned the AEHRC to deliver a product strategy for UK Medicines Terminology (dm+d and SNOMED CT UK Drug Extension). The aim was to provide recommendations for future development based on:

- terminology products already in place and in development
- their current and potential future roles in UK healthcare
- feedback from users and implementers of these products

To deliver the product strategy, the AEHRC completed two rounds of interviews with key stakeholders. The first round focused on those directly using dm+d and/or the UK Drug Extension or coded data, and therefore those most impacted by the known interoperability issues. A specific session was held during the InterOpen Medications Interoperability Hack seeking broad feedback, and interviews focused on vendors (knowledge providers, EMR/EHR, pharmacy systems) and analytics users were conducted.

A second round of interviews were conducted consulting pharmaceutical and supply chain organisations, clinicians, patient safety, DHSC, and several NHS organisations. This second round highlighted current governance issues, and otherwise reinforced earlier findings. Additional tangential and peripheral findings and recommendations were also noted and added to the report.



dm+d, UK Drug Extension and SNOMED CT relationship

The report suggested 4 key recommendations and 13 supplementary recommendations. One of the key activities in the recommendations was to prototype the target dm+d and SNOMED CT UK Drug Extension, which we later completed.

Prototyping UK Medicines Terminology Product Enhancements

Collaborator: NHS Digital

Acting on a key recommendation from the UK Medicines Terminology Product Strategy developed by the AEHRC for NHS Digital, the AEHRC was asked to prototype future state dm+d and SNOMED CT UK Drug Extension releases to understand the key challenges and impacts on the existing tool chain and operations.

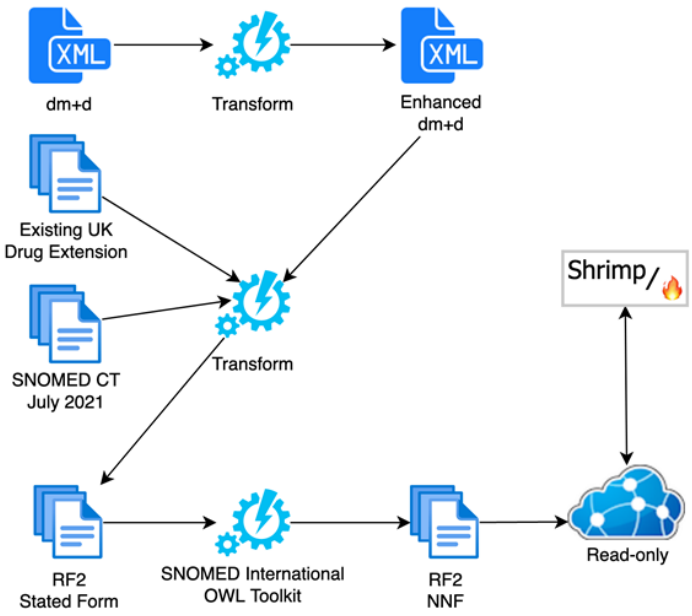
The objective of the project was to determine the feasibility of extending dm+d sufficiently to be the source of truth to automate generation of the UK Drug Extension. Additionally, it was important to ensure:

- the extensions to dm+d were backward compatible resulting in no impact to existing dm+d implementations
- the generated UK Drug Extension aligned to the SNOMED International drug model and SNOMED CT drug content

The prototype involved developing a transformation that made a sequence of enhancements to dm+d, generated the new UK Drug Extension stated form, then classified and generated the Necessary Normal Form (NNF) using SNOMED International's OWL Toolkit. The resultant SNOMED CT RF2 files were indexed and published in Ontoserver for browsing in Shrimp.

Alignment to SNOMED International's drug model and content was assessed to be quite straightforward up to and including their Medicinal Product Form concepts. However, beyond this point integration is problematic due to several modelling and content misalignments between dm+d and SNOMED International's drug model and content.

Ultimately the prototype demonstrated that the approach is feasible, with the required set of extensions to dm+d and draft new UK Drug Extension model determined and documented.



Prototype approach

SNOMED International Mapping Tool

Collaborator: SNOMED International

We developed a tool for SNOMED International's members and their stakeholders to collaboratively create and maintain simple maps to SNOMED CT. Maps produced by this tool are useful to support migration and adoption of SNOMED CT, identify any gaps in SNOMED CT and to support translation as part of EHR implementations.

The tool was developed with an agile methodology that uses our Ontoserver to provide the real time search functionality, as well as automated mapping suggestions.

The MVP was released in January 2022, with continuous improvements being deployed.

The current release of Snap2SNOMED supports a range of features including:

- ability to create simple maps to SNOMED CT
- online and easily accessible
- collaborative workflow features
  - allows teams of users to author and review a map
  - dual independent workflow is not yet available
- automated mapping suggestions are available as a bulk operation and for single source terms
- map review process available in workflow for map content
- intuitive UI to make browsing and mapping to SNOMED CT easy and efficient
- ability to perform map maintenance
- import your own code sets and maps
- export to CSV, TSV and XLSX

Snap2SNOMED is available as an open-source codebase and also hosted by SNOMED International for its members.

Snap 2 SNOMED CT mapping tool logo

Automating cancer data registries to enhance data quality

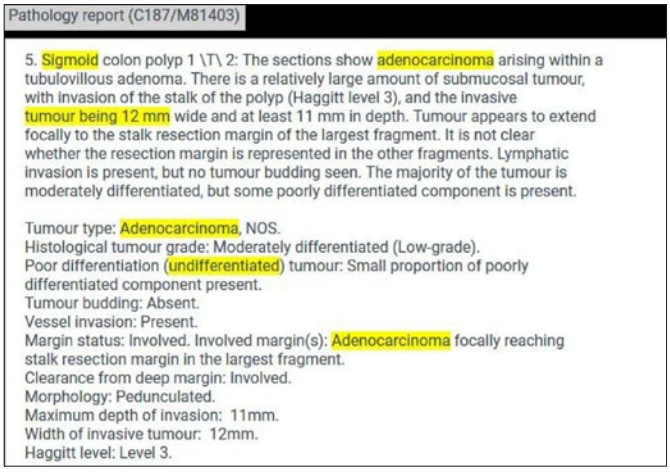
Collaborator: Cancer Alliance Queensland (CAQ), Queensland Health

Medtex is used by Cancer Alliance Queensland (CAQ) to assist in the automation of selected Cancer Register tasks. It extracts information from pathology and radiology reports and death certificates, using natural language processing (NLP) and machine learning technologies, for a variety of reporting purposes – including cancer notifications, cancer staging and synoptic reporting – and stores it in the Queensland Oncology repository. This supports the clinical coding workflow to improve data collection capture within the Queensland Cancer Register. It also improves the multi-year delay in the reporting of cancers by providing more up-to-date population-level statistics on Queensland cancer incidence and mortality.

Medtex is unique in that it targets the full range of cancers as opposed to tumour specific extractions used in other systems and studies. It aims to improve the current cancer notification workflow and abstraction processes for the Queensland Cancer Register. However, it extends to the abstraction of a much broader range of cancer information especially those important for deriving a cancer stage, identifying cancer recurrences and those contained in a variety of report types such as death certificates and radiology reports.

In collaboration with CAQ, improvements and extensions to Medtex included the extraction of relevant information from electronic data, such as pathology and radiology reports and other clinical tests, to derive cancer stage. Selected cancer types included lung, colorectal, pancreas and uterine cancers.

Read more about Medtex in Health Data Semantics and Interoperability: Platform Technologies.



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

Qld One Health AMR Hub – AMR Surveillance and decision support

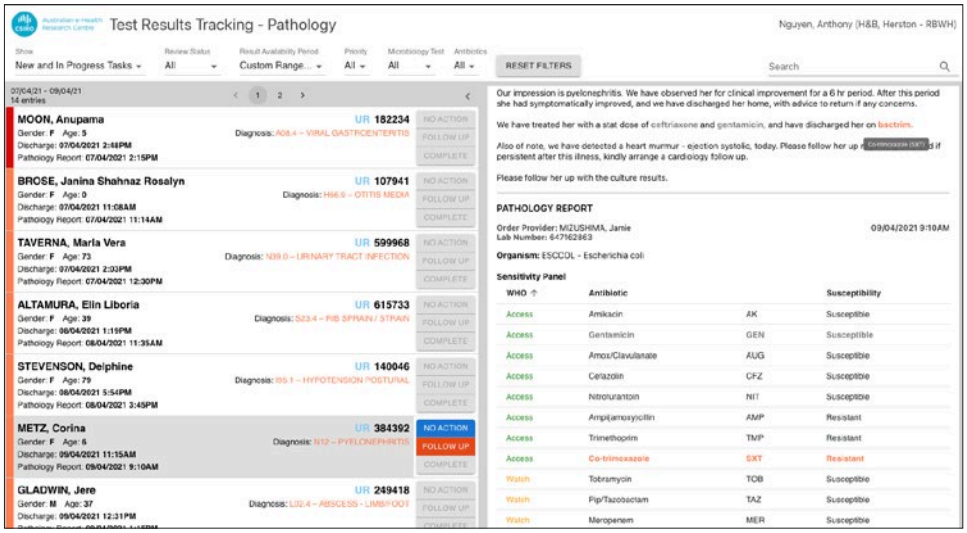
Collaborators: Herston Infectious Diseases Institute, Queensland Health and the CSIRO AMR Mission

The Qld One Health Antimicrobial Resistance (AMR) Hub is developing AI data-driven tools for a disease intelligence and decision support platform taking a One Health approach. It will provide a more comprehensive picture of AMR, enable time and location-specific trends of AMR to be better measured, analysed and managed, and facilitate AI-assisted decision support for antimicrobial stewardship.

To support AMR high quality digital health solutions interoperable with the wider health system, we have collated for the first time and published in a report, the Australian human health antimicrobial data landscape. The report reviews the velocity, ubiquity, complexity, and inclusivity of human health data collected by 13 programs that support antimicrobial surveillance in Australia and contribute to mitigating AMR. Establishing an understanding of how the data is collected, how it flows through the health system, and the efforts required to analyse, publish, and use this data is an important step in supporting AMR research and improvement of patient outcomes.

Digital health standards-based tools, based on the FHIR healthcare interoperability standard, were developed to support the tracking, tracing and tackling of antimicrobial resistances in the emergency department. The test result review app reconciles information from microbiology test results and patient discharge summaries to alert emergency physicians of drug-bug mismatches and hence when a change of antibiotic treatment might be needed. We'd be also able to use the data to provide hospital level summaries of prescriptions and test results to monitor the appropriate use of antimicrobials. Other digital health standards-based antimicrobial stewardship tools can be read in Vacation Student Projects: FHIRed up – SMART apps to counter superbugs.

Though the Qld One Health AMR Hub project 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 decision support app (with obscured patient information) streamlining and prioritising microbiology test results for clinical review in Emergency Departments.

Interactive dashboard summarising microbiology test result reviews and drug-bug mismatch outcomes.

Precision Medicine search engine for paediatric oncology

Collaborator: Queensland Children's Hospital and Queensland Children's Hospital Foundation

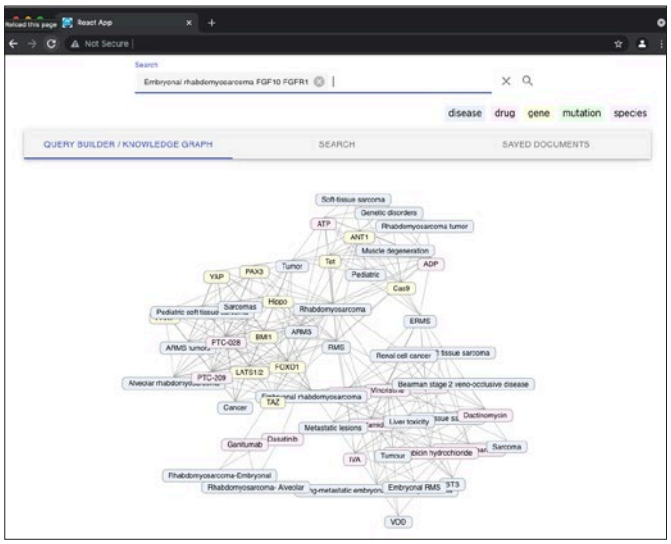
This project developed a search engine to help clinicians find targeted treatments for children with cancer.

Childhood cancer is a leading cause of death and clinicians increasingly seek treatments personalised to an individual patient's genetics. Finding paediatric treatments that match individual genetics is a real challenge amongst the vast body of medical literature and clinical trials.

We tailored a search system for clinicians to address this problem.

The system retrieves PubMed articles and clinical trials. Query suggestion helps clinicians formulate otherwise difficult queries and results are presented as a knowledge graph to help interpretability. The proposed system will significantly reduce the effort of searching for targeted treatments and potentially find life-saving treatments that may have otherwise been missed.

With a successful prototype we are now seeking to launch a bigger project to expand the initial prototype into a full-fledged system.



Screen shot of precision medicine search engine. Traditional search results can be viewed as a 'knowledge graph' indicating the relation between genes, drugs and cancers. This allows clinicians a quick overview of the treatment landscape and the ability to home in on targeted treatments.

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 apply our health research to the agricultural domain through a grant from the Grains Research Development Corporation in collaboration with UQ. The project will help growers search grain-related resources to answer their growing-related question.

We have developed AgAsk – a conversational search agent for growers to ask questions in natural language and get tailored responses. AgAsk indexes a collection of 90,000 agricultural reports. AgAsk uses a neural network language model to extract relevant answers from within a report and provide these in response to a grower's question.

The project offers strong commercialisation prospects. In addition, the new methods developed will be fed back to our health work, showing the general applicability and impact of our search engine research.

A sample chat session of how a grower may interact with the Agask chatbot to find contextualised answers to grower questions.

Health Data Semantics and Interoperability: Project Updates

Australia's 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 technology is a key component of this nationally hosted service. Ontoserver is also available from the Agency through a free of charge license for use by the health software industry and other technology providers, 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.

Throughout 2021/22 the team delivered eleven (11) new versions of Ontoserver including the first FHIR Terminology Server with significant support for translations via the SNOMED language reference set. We also closely engaged with the FHIR community to clarify, refine and improve details of the Terminology Services subsystem of the HL7 FHIR Specification with particular attention to ConceptMap, 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 more than 75 Ontoserver sub-licensees through the NCTS, including several health organisations, clinical colleges, research organisations and software vendors.

Queensland Clinical Terminology Service

Collaborator: eHealth Queensland

We are providing implementation support to Queensland Health who now launched the Queensland Clinical Terminology Service (QCTS) which adopts our Atomio and Ontoserver applications to support terminology content. Several systems across Queensland Health have been identified as first users of the service.

Northern Territory Clinical Terminology Service

Collaborator: Northern Territory and Core Clinical Systems Replacement Project

Northern Territory is in the process of standing up their own Northern Territory Clinical Terminology Service (NTCTS) which will be core to the deployment of their Core Clinical Systems Replacement Project, known as Acacia, to support the use of SNOMED CT and other national CodeSystems, ConceptMaps and ValueSets. We will continue to provide implementation support.

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 ie MR 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.

SMART Healthchecks

Collaborator: Federal Department of Health, Royal Australian College of General Practice (RACGP)

AEHRC was engaged by the Federal Department of Health to continue the Primary Care Data Quality Foundations Project to look at the use case of Aboriginal and Torres Strait Islander Health Checks. AEHRC developed a proof-of-concept SmartForm for health checks using the Aboriginal and Torres Strait Islander Peoples Health Assessment (Healthcheck) as a case study to demonstrate the capability of these forms, understand the requirements and principles of the use of Smart Forms for health check assessments and develop a strategy for deploying the health check SmartForm across primary care service settings nationally. This project also builds upon the NACCHO-RACGP Partnership Project which developed a series of new Aboriginal and Islander health checks templates, released in 2020 and endorsed by the Federal Department of Health.

Combined CSIRO, NACCHO and RACGP Collaboration Team.

Primary care roundtables with the community in March 2022.

AMR Landscape Report

To support the activities of many groups involved in antimicrobial resistance, including researchers, clinicians, data analysts, and government departments working towards delivering **Australia's National AMR strategy**, we developed a first draft report of the human health AU/AMR data landscape in Australia, we hope to assist others working in this space to understand how the data is collected, how it flows through the health system, and the efforts required to analyse, publish, and use this data to improve health outcomes.

This report reviews the velocity, ubiquity, complexity, and inclusivity of human health data collected by 13 programs that support antimicrobial surveillance in Australia and contribute to mitigating the impact of AMR.

RANZCR Project

Collaborator: Royal Australian and New Zealand College of Radiologists (RANZCR), Australian Diagnostic Imaging Association (ADIA)

The Royal Australian and New Zealand College of Radiologists (RANZCR) and the Australian Diagnostic Imaging Association (ADIA) contracted the AEHRC to assist in the development of a pilot Radiology Referral Set (RRS) using SNOMED CT content. The primary goal of the project is to develop a standards-based set of codes to support the electronic requesting of radiology investigations.

The key deliverables were:

- set of 20 radiology services coded using SNOMED CT
- Machine-readable artefacts to support the adoption of the terminology by software vendors
- Guidance for the use of these artefacts including:
  - Starter implementation guidance for requesting and receiving systems (RRS)
  - Guiding principles for the ongoing development of the RRS after this project.

OpenMRS

Collaborator: SNOMED International

SNOMED International engaged CSIRO to develop an open-source plugin module for OpenMRS to enable a standards-based (FHIR) and more advanced implementation of terminology.

OpenMRS is a flexible open source EMR system that has widespread adoption across low to middle income countries and is built around a relatively small core with many optional plugin modules to provide specific pieces of functionality. The core itself includes direct support for code systems / terminologies that are loaded into the system so properties of codes (synonyms, hierarchy, etc.) are available to other modules for activities such as data entry, reporting, cohort selection, and analytics.

We have developed a plugin module for OpenMRS with an additional tag that can be used in its HTML forms to provide dynamic support for SNOMED CT-coded fields bound to a FHIR ValueSet via the FHIR Terminology Services API. To support the OpenMRS internal concept representation model, the plugin loads details of a selected concept from Ontoserver in a just-in-time manner. The plugin also supports LOINC and is easily extended to support any code system from a given FHIR terminology server.

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 (ADHA). The aim of this project was to develop algorithms to automatically produce AMT from drug registration information in the Australian Register of Therapeutic Goods to support the ADHA 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.

Global Alliance for Genomics and Health

Collaborator: Global Alliance for Genomics and Health (GA4GH)

The AEHRC continues to be involved in the clinical and phenotypic data capture stream in GA4GH, actively collaborating in the development of standards to share clinical data relevant in the area of genomics. In the past 12 months the team has led the implementation of the FHIR implementation guide for the new pedigree standard, vital information for genomic medicine. The AEHRC was also involved in the development of the FHIR implementation guide for phenopackets, a standard developed to represent clinical phenotype information, and is now part of the Vulcan FHIR accelerator project.

Melbourne Genomics Health Alliance

Collaborator: Melbourne Genomics Health Alliance

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

Two AEHRC 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 SNOMED CT and Human Phenotype Ontology for clinical terminologies. The AEHRC has also undertaken bioinformatics projects with Melbourne Genomics and continues to work on patient-facing technologies such as a chatbot to facilitate informed decision making by patients in the provision of additional findings analysis.

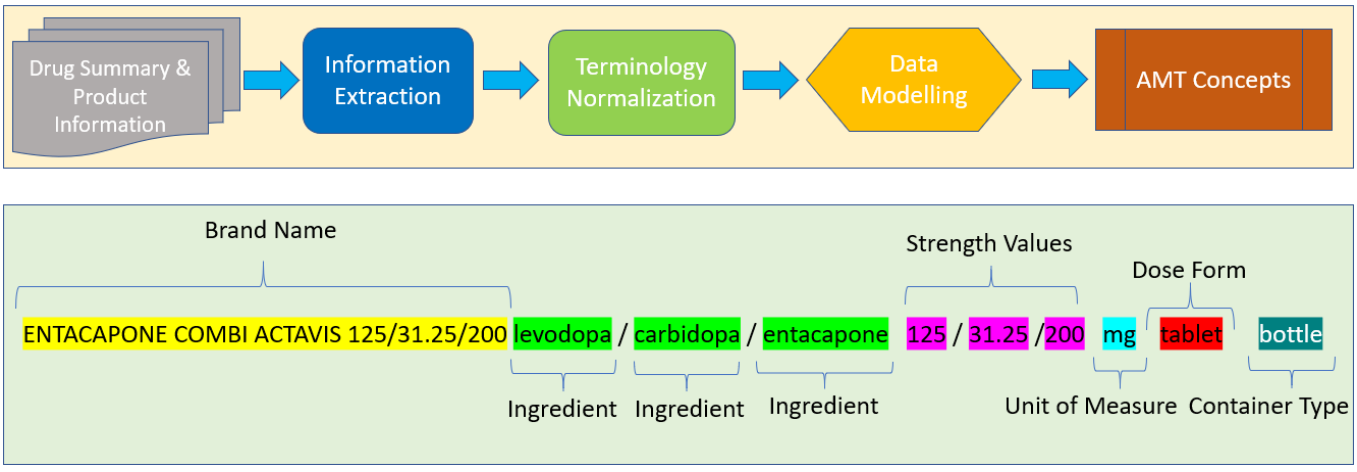
Quin: Smoking Cessation Chatbot and Virtual Companion

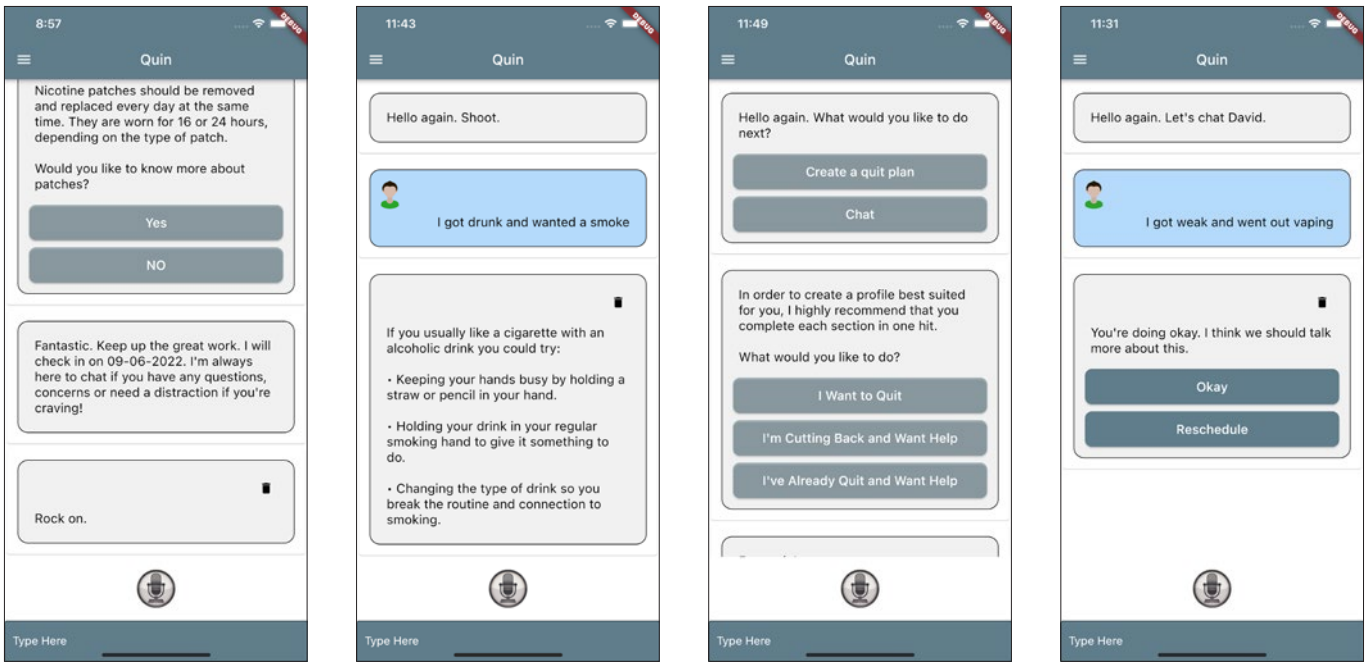
Collaborator: Prince Charles Hospital & University of Queensland

The tobacco epidemic persists as one of the greatest threats to global public health. More than eight million premature deaths are attributable to tobacco use alone every year across the globe, with smoking being the leading behavioural risk factor contributing to global burden of disease. Quitting smoking has significant positive short- and long-term health outcomes for all ages, therefore the importance of acceptable and effective smoking cessation support is vital.

We developed a chatbot called Quin that acts as a virtual companion to those wishing to quit smoking. Quin was developed from the thematic analyses of over 30 Quitline transcripts. Throughout 2022 and 2023 Quin will be tested in focus groups with clinicians and those intent on quitting smoking.

The AMT data extraction model





Quin constructs a personalised profile and plan for each user and provides advice and support through natural language. The user is able to convey to Quin on episodic events, triggers and stressors and effectiveness of nicotine replacement therapy.

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 2021. The course was led by Dr Chelsea Dobbins, lecturer at the UQ School of Information Technology and Electrical Engineering, and CSIRO Distinguished Visitor Professor Mark Braunstein, from Georgia Institute of Technology in Atlanta USA (again participating remotely).

The course cohort was slightly smaller in 2021, but with a broader group of clinical stakeholders, with student groups building SMART-on-FHIR apps covering new areas including clinical handover/referral and physiotherapy forms, in collaboration with clinical stakeholders from the UQ School of Medicine and CSIRO. Professor Braunstein's Health Informatics on FHIR online course was further expanded to include more videos and exercises covering the Australian digital health landscape. Again, we had an impressive series of guest lectures from local, national and international experts, including presenters from AEHRC talking about FHIR, SMART apps, and clinical terminology.

The course is now a permanent part of UQ's computer science, software engineering and information technology curricula, and we hope to see a further increase in enrolment in the second semester of 2022.

Case Based Learning on FHIR

Collaborator: University of Queensland

The case-based learning tool that CSIRO produced for the UQ School of Medicine increased in use and expanded its functionality throughout 2021–22. The tool, which already included a case authoring tool, a case player, and a tutor dashboard, now has a manager console that allows a course co-ordinator to see group enrolments and manage SMART-on-FHIR apps on the platform.

As the final part of a UQ Teaching Innovation Grant, this year the tool expanded to cases that involve participants from multiple disciplines, including support for clinical handover and reflection on role allocation, as well as improved support for the time coding of case data, which is particularly important for cases with compressed timelines such as neonatal cases, or extended timelines such as chronic disease cases. Participants in the grant from the UQ schools of nursing, physiotherapy, pharmacy and others are preparing to incorporate the tool into their case-based learning curricula in the coming academic year.

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 to support clinical decision making in a particular case. We have also recently finished integrating the use of chatbots into cases to allow for interactions between the medical student and simulated patient (more details below).

The tool has also been licensed and deployed by the University of Melbourne's School of Nursing for their curriculum, and we are involved in discussions with 3 other university clinical schools about further licensing opportunities.

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

Collaborator: Nutrition and Health, AMR Mission

Integrating health data from multiple sources, and new technologies such as AI, into the clinical workflow requires a new approach as the various domains currently tend to have data silos and different standards. Accordingly, we have developed a workflow platform, FORTE, based on the FHIR framework. FORTE maps and executes standard operating procedures and clinical workflows into the FHIR framework.

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.

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

Collaborator: Queensland Genomics, Pathology Queensland, University of Queensland, AMR Mission

Hospital-acquired infections (HAI) particularly those resistant to antibiotics, are a common and costly issue for modern health care globally and can be a significant risk to hospital patients. 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.

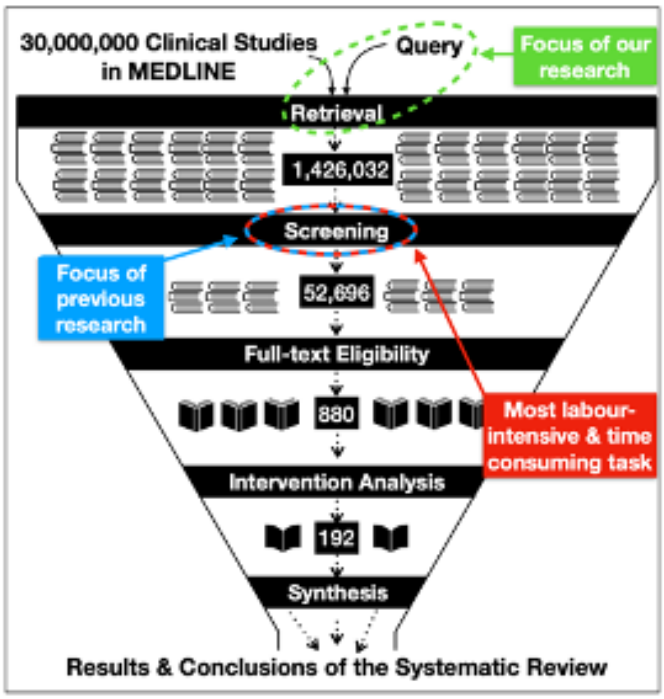
We have extended our collaboration with Pathology Queensland and the University of Queensland to also include Metro North Hospital and Health Services to implement a FHIR-based bioinformatics pipeline. This pipeline provides seamless integration of non-standardised data from the pathology laboratory and emergency department to a FHIR server, enabling a platform to build SMART-on-FHIR apps and a standardised 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.

This pipeline is currently integrated into the Qld One Health AMR Hub platform showcasing antibiotic sensitivity testing apps for the AMR mission.

Search Engines for Systematic Reviews

Collaborators: Bond University, UQ

This project will devise artificial intelligence (AI) based search engine technology that supports the formulation and refinement of effective search queries for systematic review literature searches. While previous work focused on method to help speed up screening, this research tackles the problem at its source – the query formulation phase.



Over the 12 months, PhD student Harry Scells completed his thesis titled “Query Automation for Systematic Reviews”. We also submitted a Research+ Postdoc application to continue work on this project.

Automating data extraction from electronic health records for a chest pain clinical data registry

Collaborator: Logan Hospital ED, Queensland Health

Improving the delivery of health outcomes is dependent on an up-to-date clinical data registry. The overall aim of the research is to develop a chest pain clinical data registry built from automatically extracted clinical information from both unstructured clinical notes 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.

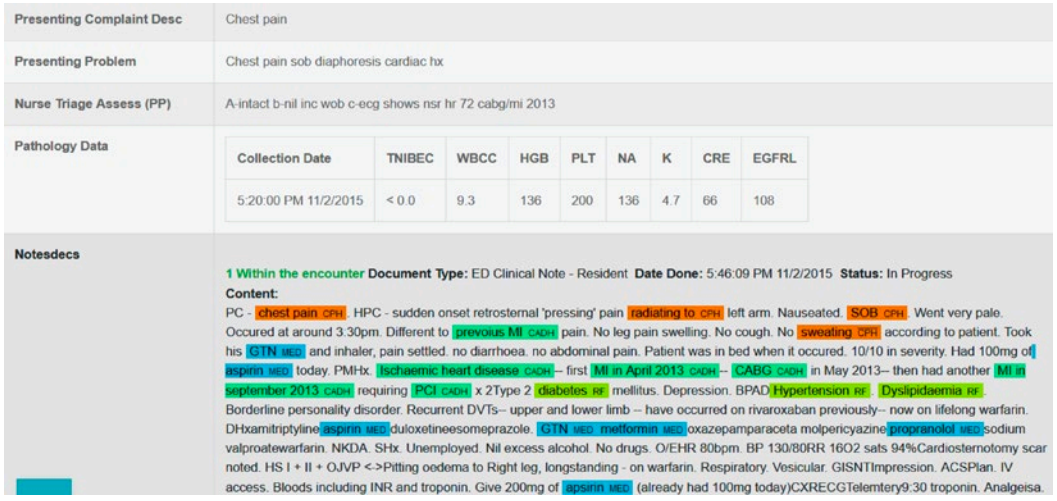
The information extracted into the clinical registry is envisioned to translate into actionable knowledge for clinicians, researchers and administrators for investigating and managing patients who present with possible cardiac chest pain. In particular, the chest pain clinical registry would be used 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.

Automatic Identification of Patients Presenting with Pain to the Emergency Department

Collaborator: Royal Brisbane and Women's Hospital, Emergency and Trauma Centre, Queensland Health

Pain is the most common symptom on presentation to emergency departments (ED), but recognition relies on self-report, which can result in delayed treatment and poor-quality pain care for some patients. Artificial intelligence may help to overcome limitations in the identification and documentation of pain at triage. This project will test several machine and deep learning algorithms to identify patients arriving at the emergency department with pain. This analysis is based upon the free-text triage assessments completed on presentation.

This study is the first-time machine or deep learning techniques will be used to identify the prevalence of pain on presentation to the ED. It will help characterise the treatment and outcomes provided. This methodology will be deployed on over 250 000 presentations to the RBWH ETC over the last three years.



Presenting Complaint Desc	Chest pain
Presenting Problem	Chest pain sob diaphoresis cardiac hx
Nurse Triage Assess (PP)	A-intact b-nil inc wob c-ecg shows nsr hr 72 cabg/mi 2013

Pathology Data

Collection Date	TNIBEC	WBCC	HGB	PLT	NA	K	CRE	EGFRL
5:20:00 PM 11/2/2015	< 0.0	9.3	136	200	136	4.7	66	108

Notesdecs

1 Within the encounter **Document Type:** ED Clinical Note - Resident **Date Done:** 5:46:09 PM 11/2/2015 **Status:** In Progress

Content:

PC - chest pain CPH. HPC - sudden onset retrosternal 'pressing' pain radiating to CPH left arm. Nauseated. SOB CPH. Went very pale. Occured at around 3:30pm. Different to prevoius MI CADH pain. No leg pain swelling. No cough. No sweating CPH according to patient. Took his GTN MED and inhaler, pain settled. no diarrhoea. no abdominal pain. Patient was in bed when it occured. 10/10 in severity. Had 100mg of aspirin MED today. PMHx. Ischaemic heart disease CADH-- first MI in April 2013 CADH-- CABG CADH in May 2013-- then had another MI in september 2013 CADH requiring PCI CADH x 2Type 2 diabetes RF mellitus. Depression. BPAD Hypertension RF. Dyslipidaemia RF. Borderline personality disorder. Recurrent DVTs-- upper and lower limb -- have occurred on rivaroxaban previously-- now on lifelong warfarin. DHxamitriptyline aspirin MED duloxetineesomeprazole. GTN MED metformin MED oxazepamparaceta molpericyazine propranolol MED sodium valproatewarfarin. NKDA. SHx. Unemployed. Nil excess alcohol. No drugs. O/EHR 80bpm. BP 130/80RR 16O2 sats 94%Cardiosternotomy scar noted. HS I + II + OJVP <->Pitting oedema to Right leg, longstanding - on warfarin. Respiratory. Vesicular. GISNTImpression. ACSPlan. IV access. Bloods including INR and troponin. Give 200mg of apsirin MED (already had 100mg today)CXRECGTelemtery9:30 troponin. Analgeisa.

Web-based search and annotation tool highlighting clinical data elements to be stored in a chest pain clinical data registry.

Output	Input Interpretation
Pain	2 24 frontal headache photophobia lower l back urinary incontinence
Pain	Aloc and seizure activity post 2 unit blood donation today pain behind l ear

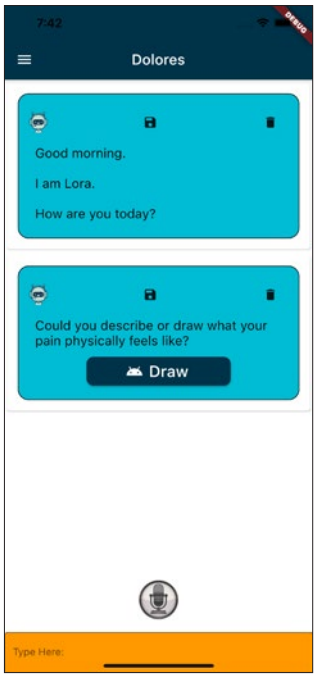
Explainable deep learning output from analysis of free-text triage assessment.

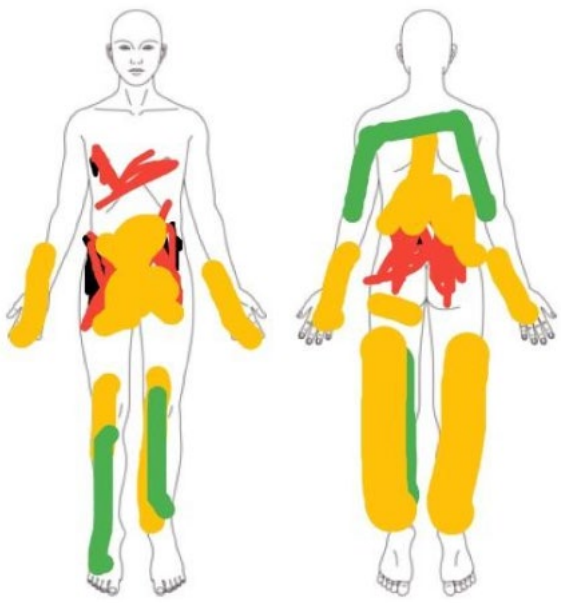
Dolores the pain chatbot

Collaborator: University of Queensland

Dolores is a chatbot developed to discuss all things related to chronic pain with language suitable for the age of the user. Topics include pain history, social interactions, medications etc. Dolores' 'brain' was developed by clinicians with backgrounds in occupational and speech therapy. Dolores also inquiries about the user's pain, where it is located (via text or a drawing canvas), and what the pain feels like.

Dolores has been piloted at the Royal Brisbane & Women's Hospital and Queensland's Children Hospital and has over 60 interactions with children, young adults and adults. Participants were able to interact either via voice, text and drawing. Feedback surveys have been overwhelmingly positive with one participant commenting what they liked most about Dolores was "How much I could learn about my pain". Example drawing interactions between a child user and Dolores are shown in the figures.





Drawn on 13/07/2021 from chat session BHUCT

Example dialogue of Dolores asking the user what their pain feels like. The user may respond verbally, text or by drawing. Some clients don't have the necessary expressive language to detail their pain experiences so interaction via drawing is research component of the Dolores project.

Health Data Semantics and Interoperability: Postdoc and Student Highlights

Postdoctoral fellow

Yutong Wu, CSIRO Research+ Postdoctoral Fellowship

Clinical information extraction and classification using interpretable deep learning

Most health data is recorded in free-text unstructured documents. This data contains valuable information for clinical decision making and secondary use. However, its clinical importance and large volume hinders manual analysis, undermining effective clinical decision support and population health monitoring and reporting.

In this research, revolutionary interpretable deep learning algorithms have been developed to automatically extract and classify clinical information from both unstructured clinical notes and structured data sources. These approaches scale to large amounts of data and are integrated within a highly distributed computational framework. Challenges include the meaningful interpretation of noisy free text from different report types across disparate sources and coping with rare diseases for which only few samples are available for computational learning.

Simon Thomas, CSIRO Research+ Postdoctoral Fellowship

Machine learning based tools for precision medicine

Medical free text such as clinical notes contain an enormous amount of latent value which could yield future diagnostic or clinic insights once analysed. However, even more value lies in medical texts that are yet to written (in the future!), and so going forward it is desirable to add structure as soon as they are created. This project looks at possible ways to enhance the efficiency of clinicians in their routine work e.g. clinical note writing, while at the same time generating high-quality structured datasets for future clinical research. As patient privacy is critical in such an environment, privacy preserving machine learning techniques such as Federated Learning can be used to learn personalised insights and adapt to the specific needs of the clinician. The system improves by sharing only the knowledge learned from each clinician, with patient data never leaving the original system.

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PhD students

Liebo Liu, UNSW – CSIRO Industry PhD

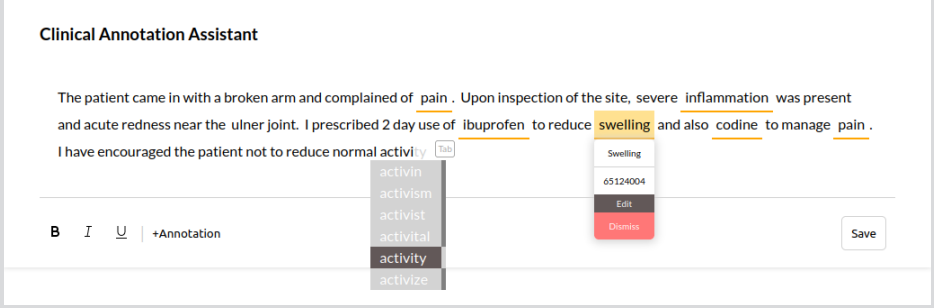
Extracting value from unstructured health data

This research applies natural language processing (NLP) technologies, including machine learning methods for named entity recognition (NER), to extract structured clinical information from narrative text. The emphasis is on developing tools to 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 able to process large corpora of clinical text to help clinicians use 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 enables scientists and industry partners to scale their research output using cloud-computing and machine learning. The group delivers impact in three disciplines: genome analysis, genome engineering and therapeutics as well as biosecurity.

Transformational Bioinformatics' science and impact highlights for 2021/22

- The group published the world's largest case-control study on COVID-19 disease-outcome to identify mutations that make the virus more infectious (*Computational and Structural Biotechnology Journal*, IF=7). The key finding was that mutations outside the spike protein region contribute to disease outcome, especially mutations in the NSP14 gene, which was independently demonstrated to down-regulate the host's immune system.
- We worked with two Australian SMES through the CSIRO Kickstarter program – Amaroq to bring cloud computing to their cancer therapeutics work and GenePath to undertake a study of newborn screening using targeted re-sequencing.
- The group was part of a successful $3M grant project for newborn screening with NSW Health, Westmead Children's Hospital, and Sydney University using whole genome sequencing.
- We also contributed to CSIRO's CRISPR initiative aimed at evaluating commercially available genome editing technologies and developing computational tools to support CSIRO's diverse editing applications.
- Denis was awarded Brilliant Women in Digital Health and AU/NZ Women in AI award.

Genome Insights

Team Leader:
Dr Natalie Twine

The Genome Insights team generates knowledge 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 leads to better diagnostics and new treatments. The developed software solutions also support incorporating 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 machinery, 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) and biosecurity (in areas such as the genetic control of invasive and dangerous species).

Transformational Bioinformatics: Platform Technologies

VariantSpark

Collaborators: Goldfinch, CAD Mission, Project MinE ALS genomics consortium, SAHMRI, UKBiobank

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, while uncovering specific biomarkers. VariantSpark is designed to 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. Compared to alternatives, VariantSpark is the fastest and the only software that scales linearly with data size and CPU. 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. VariantSpark is available for high-performance compute clusters, RONIN, AWS, Azure, and TerraBio.

Over the last 12 months, we have analysed the world's largest genomic data repository (UKBiobank) using Alzheimer's disease (AD) and cardiovascular disease (CVD) phenotypes. We subsequently performed validation analysis using the NIH TopMed datasets (CVD) and Alzheimer's Disease Neuroimaging Initiative (ADNI) cohorts. Crucially we have developed and published a novel significance testing methodology for VariantSpark, which enables prioritisation of disease associated variants and controls the false positive rate. This has enabled us to submit a publication identifying both novel AD disease genes and novel genetic interactions associated with the disease. Our work made the ground-breaking observation that VariantSpark captures more genetic variance in the UKBiobank and ADNI cohorts than is possible with traditional PLINK methodology.

We further developed an ecosystem of open-source software around VariantSpark—publishing novel tool (BitEpi, 2021) which visualises interacting genes from VariantSpark output and PEPS to create realistic synthetic datasets. Speaking to the application agnostic capability of VariantSpark we applied it to find COVID-19 viral mutations associated with worse disease outcomes (published in *Computational and Structural Biotechnology Journal,* 2022).

Outcomes include our application paper using VariantSpark in Alzheimer's disease (submitted to Nature Aging 2022), novel significance testing methodology publication, VariantSpark methodology paper in Oxford journal GigaScience (2020) and sister tool, BitEpi in *Nature Scientific Reports* (2021).

Read more in Transformational Bioinformatics: Project Reports.

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

Serverless Beacon

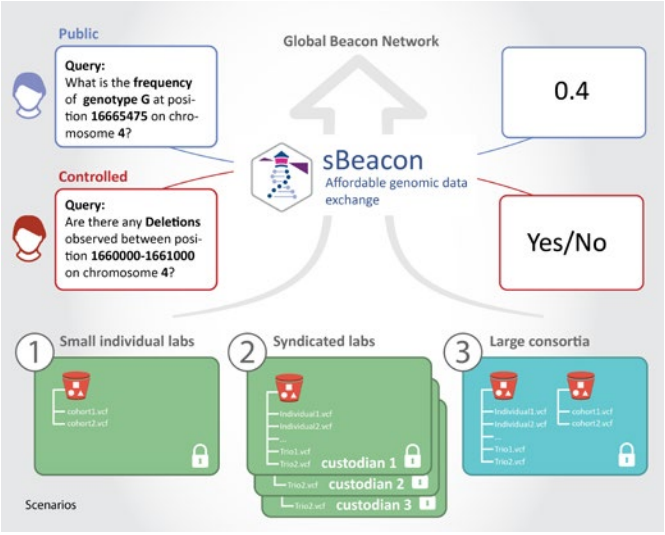
Collaborators: NSW Pathology, MGHA, DFAT, CSIR Institute of Genomics and Integrative Biology (CSIR-IGIB, India).

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 efficiently in the haystack. 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. Serverless Beacon 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 a 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.

Beyond the human genomics space, the Beacon protocol is also effective for efficiently sharing genomic information for other application domains. As part of our COVID-19 response, we developed PathsBeacon, which enables the rapid detection of specific strains, i.e. SARS-CoV-2 genome variants that define a subtype of the virus, in the large volumes of international data (1.4M samples from around the world).



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

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. Finding a suitable genome editing spot is like finding a specific grain of sand on the beach; it needs to have the right shape and colour (properties for CRISPR to bind) and 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 Function-as-a-Service or serverless. We also improved accuracy by 30 percent 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 past years, 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 GOANA (evaluation framework for gene-editing experiments), TUSCAN (CRISPR-Cas9 on-target efficiency predictor), CUNE (efficiency and effect predictor for HDR-based editing) and VARSCOT (SNP-aware off-target finder). Our work led to a review on CRISPR-Cas9 predictive tools (cited over 90 times) and has been presented at many international conferences.

Read more in Transformational Bioinformatics: Project Updates

Transformational Bioinformatics: Project Reports

Contribution to Australian Genomics (NAGIM, Dynamic consent and HPO-terms)

Collaborators: Data61, Melbourne Genomics Health Alliance, Australian Genomics Health Alliance

National Approach to Genomics Information Management

The AEHRC contributed several prototypes to the Australian Genomics "National Approach to Genomics Information Management" process. These included:

- federated genomic data sharing through Serverless Beacon (sBeacon) (https://bioinformatics.csiro.au/serverless-beacon/)
- support for the GA4GH Passport specification within Pathling (https://pathling.csiro.au/docs/server/authorization#ga4gh-passports)
- modular analysis capability by bringing the compute to the data through Marketplace deployment of VariantSpark (https://bioinformatics.csiro.au/variantspark/)
- dynamic Consent using decentralised identity and permission management

The prototypes were assessed by an international panel and received positive reviews. Australian Genomics is now moving to the next stage where we expect we will be working these technologies further into the NAGIM process.

Serverless Beacon (sBeacon)

sBeacon is an implementation of the GA4GH Beacon protocol, aiming to scalably and cost-effectively support queries and responses across future mega-biobanks. sBeacon supports several other NAGIM Prototype Projects by enabling cloud-based federated data handling. Specifically, 1) UMCCR Gen3AWS, where it demonstrates the real-time, fine-grain permission/access control capability, 2) Garvan TerraGoogle, where it supports the serving of federated variant data and 3) Trustless-DAC where it demonstrates rea-time dynamic patient consent on federated data.

Pathling

The GA4GH Passport specification provides a way for permission to access patient data to be encoded within tokens that are used for accessing data within servers. The implementation we created within Pathling contacts a "visa issuer" that can provide the list of participants who have consented to their data being used within a particular context. Pathling can then calculate the set of FHIR resources relating to those patients and dynamically filter the results of queries based upon the visas provided by the requesting party. We worked with the University of Melbourne Centre for Cancer Research (CCR) and CILogon to demonstrate a proof-of-concept ecosystem of passport brokers, visa issuers and resource servers that could serve as the foundation for a data sharing ecosystem in support of genomic research.

VariantSpark

VariantSpark is a machine learning approach for phenotype-genotype association detection. It can identify polygenic interactions on whole-genome data without requiring an initial filtering step to the individually associated genomic variance. It is also better suited to identify complex epistatic interactions than traditional logistic regression due to the underlying random forest algorithm. VariantSpark is hence envisioned to supplement traditional GWAS/Polygenic Risk Models (e.g. HAIL).

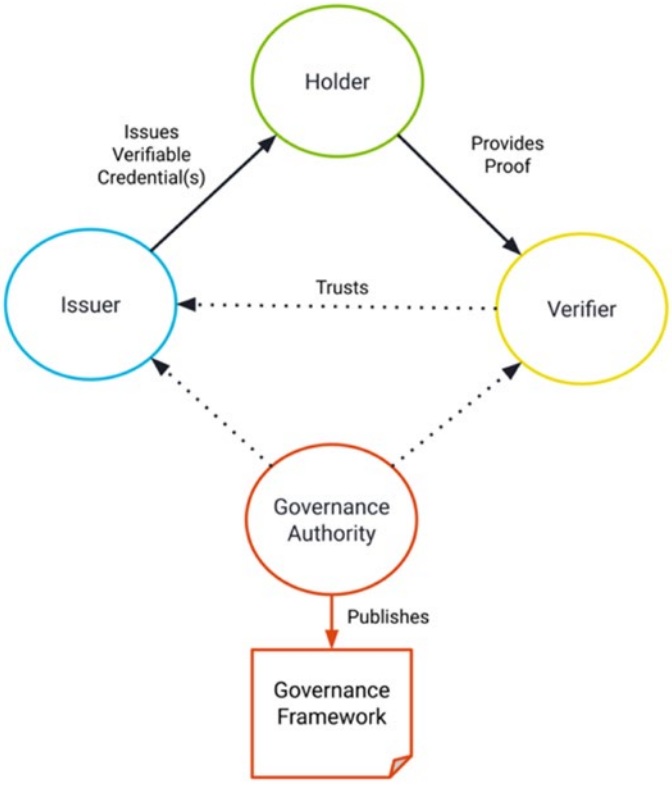
By enabling VariantSpark to easily slot into existing workflows, this prototype project demonstrated the concept of "bringing the compute to the data" and tests the idea of "a national approach to genomic information management" being federated. Using VariantSpark as the example for setting an analysis module up on two other NAGIM Projects 1) NCI-Garvan HPC Analytics and 2) Garvan TerraGoogle.

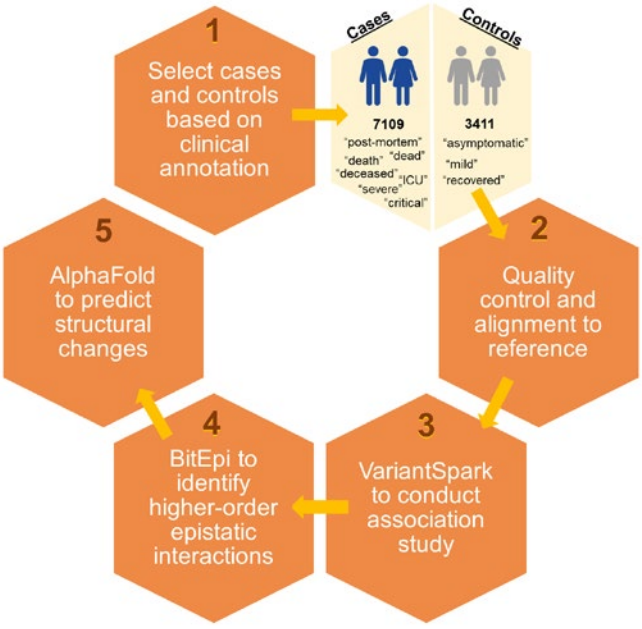
Consent

Individuals are increasingly aware and concerned about the data captured about them. This hampers the implementation of digital health, as well as medical research, and limits large biobank initiatives, as current models of consent generally do not support the type of dynamic consent sought by many patients. As a result of our work in the NAGIM process the need for support for dynamic consent in digital health solutions became even more obvious.

The group is now working with key groups across CSIRO Data61 and AEHRC to identify how this might be implemented in standards such as HL7s FHIR. This project will create a dynamic consent system validating the data owner's tiered consent before accessing the corresponding genomic data for analysis. CSIRO is already involved with consent management, decision and enforcement services. This includes technology such asData61's activities in the self-sovereign identity management space through D61 Macrokey. The aim is to together CSIRO's data61 and AEHRC digital health research to add an additional security layer between the data owners and researchers conducting downstream data analysis specifically for genomic data.

The transformational bioinformatics team has also been involved in the health data semantics and interoperability group's efforts for improving interoperability of SNOMED CT and human phenotype ontology. Specifically, the team has contributed to the transformation task and has utilised 'Pathling' (advanced FHIR analytics tool) to access/deliver patient HPO terms.





VariantSpark COVID GWAS publication

Collaborators: Intel, RONIN, Data61

Currently, the Global Initiative on Sharing All Influenza Data (GISAID) contains the largest SARS-CoV-2 viral sequence database to date, with more than 11 million samples as of June 2022. Despite the large number of sequences deposited, the utility of most samples for data analysis is limited due to poorly annotated clinical information. Nonetheless, we have identified samples from patients annotated with favourable outcomes (such as mild, asymptomatic disease) as our controls, and samples annotated with patients with unfavourable outcomes (dead, critical) as our cases.

We utilised the RONIN platform using Intel processors to run our machine learning tool, VariantSpark2, to perform an association study on 3412 cases and 7109 controls to detect mutations in SARS-CoV-2 that correlate with patient outcome. Our approach identified mutations previously known to impact viral transmission rates and disease severity, such as D614G and V1176F, associated with the Brazil and South Africa variants of concern. We also found mutations in the nsp14 protein, and novel mutations in the spike regions associated with worse patient outcome. Using our epistasis tool BitEpi, we also identified putative higher order epistatic interactions that could represent novel interacting loci which impact disease severity. In collaboration with Dr Michael Kuiper (Data61), we used AlphaFold to predict the consequences of our candidate mutations on protein structure. This work has now been published in *Computational and Structural Biotechnology Journal* (https://doi.org/10.1016/j.csbj.2022.06.005).

Future work will involve hyperparameter tuning to fine-tune our models and perform clustering to identify patterns of pathogenic mutations using the full cohort of samples in GISAID. This will require continued collaboration with Intel and RONIN, as we work together to optimise the analysis of >300 billion datapoints.

Medical Research Future Fund (MRFF) project with Australian Centre for Disease Preparedness (ACDP) on COVID drug development

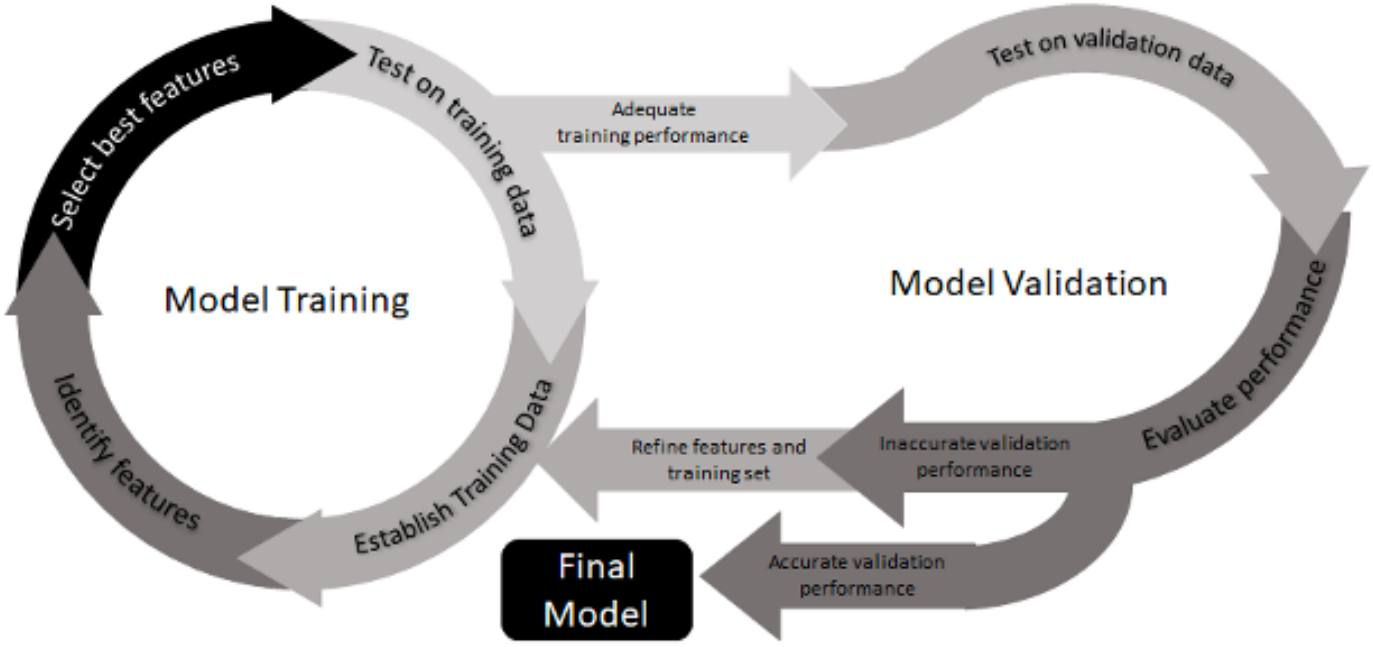
Collaborators: CSIRO's Australian Centre for Disease Preparedness; Manufacturing; Land and Water, Deakin University/Barwon Health, UNSW School of Mathematics and Statistics

Since 2020, the COVID-19 pandemic a global health concern with worldwide cases recording over 500 million cases and 6 million deaths. Vaccines cannot prevent all infections and the emergence of new COVID-19 variants of concern (VOC) has complicated vaccine development. Safe, effective, and affordable COVID-19 treatment is vital in the pandemic response, especially for 'long-COVID'.

This project is led by CSIRO's Centre for Disease Preparedness (ACDP), in collaboration with multiple CSIRO Business Units, Deakin University/Barwon Health, and UNSW School of Mathematics and Statistics. The project is a multi-disciplinary initiative to develop a screening panel of clinically relevant and human stem cell-derived tissue models to test and identify three currently US Food and Drug Administration/Therapeutic Goods Administration (FDA/TGA)-approved drugs which will allow fast-track to phase 2-3 clinical trials. Subsequently, machine learning methods will be used to identify useful signatures of ex vivo disease progression and drug efficacy based on a multi-omics approach (transcriptomics, proteomics, lipidomics, and metabolomics).

Over the last 12 months, the drug selection committee has identified three promising drug-candidates and developed a multi-tissue screening platform enabling progression of compounds to phase 1-2 clinical trials. From this, three journal papers are currently under review for publication. Moving forward, machine learning will be used on the generated multi-omics data to identify useful biomarkers of disease progression and predict the treatment efficacy of the respective drugs. The outcomes of this project identified additional drugs to use for COVID-19 treatment and a tissue and drug screening platform that can be utilised for other diseases.

This project is funded by the Australian Government's Medical Research Future Fund and internal CSIRO funding.



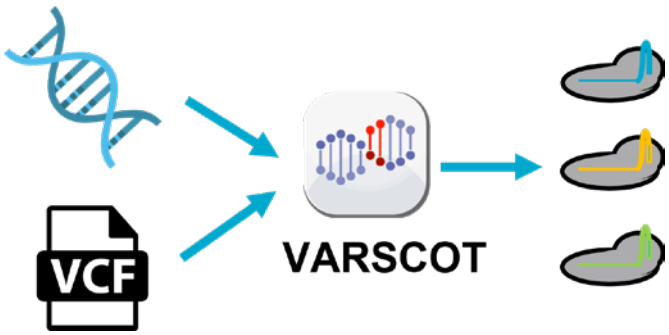
Machine learning method to identify treatment progression and efficacy.

Gene Drive Platform

Collaborators: Australian Pest Genome Alliance

Gene drives are an emerging technology that may lead to genetic biocontrol of pest species, manipulating their genome to prevent their spread. However, the technology is still in its beginning stages with numerous challenges to overcome. Chiefly, the challenge of ensuring genomic diversity. To successfully target a wild population, the gene drive must be fashioned in a way that makes it robust against the natural diversity within the population. This means accounting for the natural variations among genomes, a computationally intensive process.

The aim of our project is to expand our previous work to construct a high-throughput platform which could be used to analyse wild populations and design gene drives to account for the natural diversity. This platform builds upon our VARSCOT pipeline, the first tool for designing gene editing approaches that accounts for an individual's unique genomic profile. We have now expanded the pipeline to handle population level information in a high-throughput manner using AWS cloud computing. In addition to identifying drives common within a target population, the platform can also analyse the genome of bystander populations reducing the risk of the drive spreading beyond its intended targets. The platform will integrate with the GUARD pipeline being developed by the Australian Pest Genome Alliance, which is used to model the effectiveness of potential guides, providing researchers and policy makers with an end-to-end platform for the design and evaluation of targeted drives.

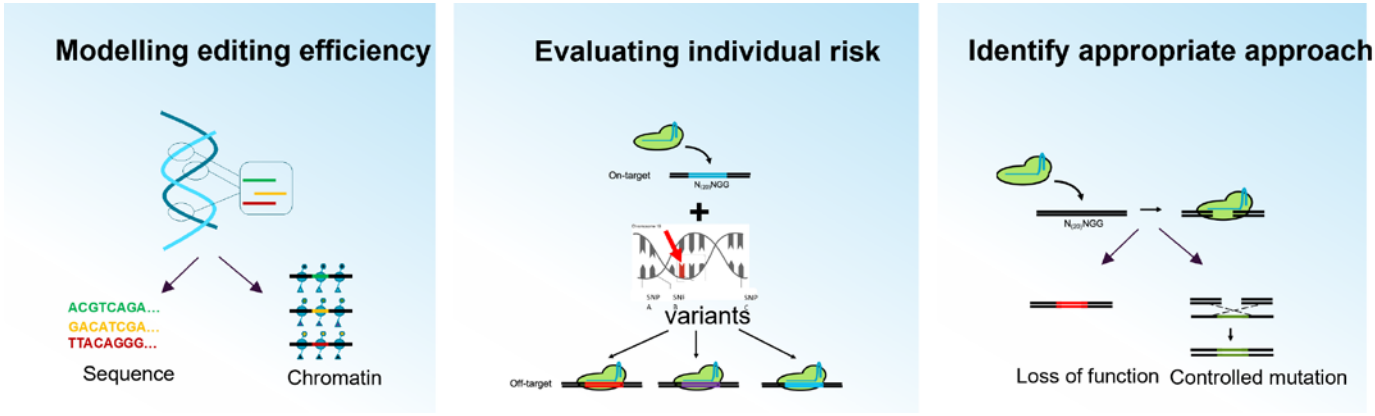


Our new gene drive platform builds upon our VARSCOT platform to analyse the genetic variance within a population (stored in a VCF file) to identify strategies to target the entire population.

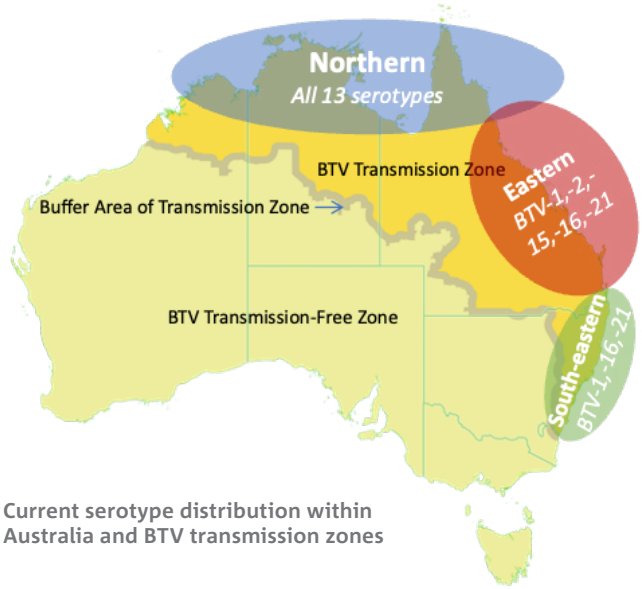
CSIRO's benchmarking of gene editing platforms

Collaborators: CSIRO's Australian Centre for Disease Preparedness; Land and Water; Agriculture and Food

The gene editing CRISPR-Cas technology was ground breaking, allowing researchers to directly modify the DNA of living cells. It has enabled breakthroughs in the fields of precision health, biosecurity and agriculture and led to an explosion of new technologies building upon the original CRISPR-Cas9 system. The aim of the CRISPR-APAIR project is to evaluate these different methods across different plants and animals to identify the most optimal editing strategy for CSIRO. Our contribution to the project has been the development of high-throughput pipelines for the design, evaluation and analysis of these experiments. Building on our GT-Scan suite (Figure), we have created algorithms for evaluating the effectiveness of these strategies, which have reduced research time and resources.



The GT-Scan suite contains a collection of tools which simplifies the design and analysis of genome editing experiments.



Current serotype distribution within Australia and BTV transmission zones

CSIRO's Bluetongue virus research

Collaborators: CSIRO's Australian Centre for Disease Preparedness

Australian bluetongue virus (BTV) outbreaks can have a significant economic impact on Australia's livestock trade industry and the BTV-free status in Victoria is vital for some export markets. The availability of whole genome data has shown that a combination of genomic segments is invaluable to assess patterns of movement and relatedness between individual isolates over space and time.

We collaborated with CSIRO's Australian Centre for Disease Preparedness to develop an enhanced surveillance tool for BTV using machine learning (ML) and visualised using the Nextstrain platform. We used a k-mer approach to develop ML models based on three concatemers of commonly co-segregating segments (capsid, core, and non-structural proteins). These k-mers represent regions of the genome as genomic fingerprints or signatures to differentiate between highly related strains, like those of BTV. Using these signatures provided by INSIDER, we were able to determine various sub-regions and clade differentiation amongst the three concatemers. Within Australia, we identified cluster of sequences consistent with sub-regions of isolate origin including three and one sub-regions for the core and non-structural proteins respectively. We also identified several non-Australian sub-regions distinguishing the Indo-Malayan and European isolates. For the capsid proteins, we identified over twenty clusters separating both geographic and serological groups. The resultant ML models will predict the various defined clusters using genomic sequences of BTV and in combination with Nextstrain analyses, provide enhanced characterisation of the BTV genome.

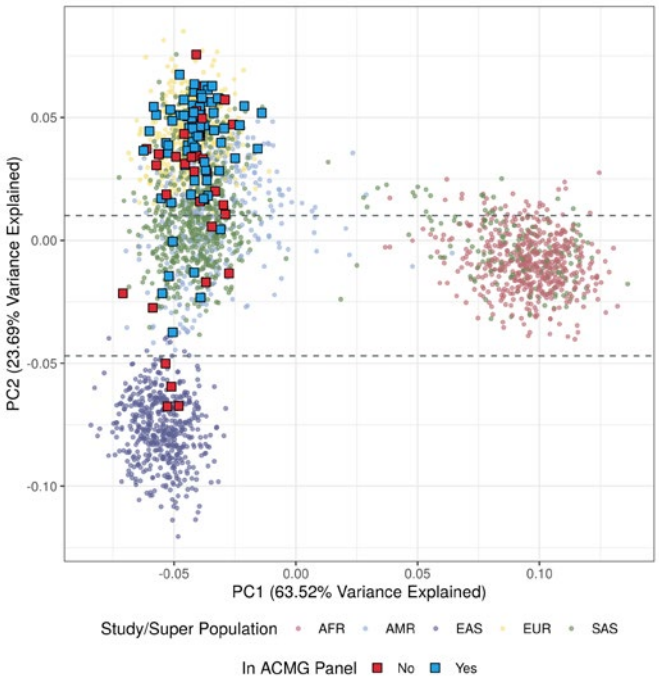
This work is packaged into an automated BTV database with a devised nomenclature system for individual virus isolate descriptors of the genetic composition. This will be used to interrogate specific clades and isolate features for disease-causing potential and real-time surveillance of BTV incursion in Australia.

GenePath newborn screening

Collaborators: GenePath, Pathology QLD, Monash University

The current newborn screening protocol also known as the heel prick test screens for up to 25 rare medical conditions including cystic fibrosis and congenital hypothyroidism mainly using blood biomarkers. However, there are 633 genetic conditions with available treatments. In a pilot study, GenePath, an Australian start-up, has used targeted next-generation DNA sequencing (NGS) to screen for 154 genes and 200 diseases in a whole of population sample of 2,552 newborns in Queensland. We have completed data analysis of their NGS results including a population stratification analysis to estimate ethnicity of samples. Of note, we showed high analytical sensitivity and specificity of the NGS approach and its suitability to be implemented into the current newborn screening approach.

Following this, we focussed on cystic fibrosis (CF), looking into the spectrum of CF causing variants and the ethnic inequity of current CF screening protocols in Australia. We showed that the spectrum of clinically significant CF-causing variants in Australia is broader than previously thought, leading to high rates of false negative results when current recommended screening strategies are used. Furthermore, we showed that newborns of non-Caucasian ancestry are more likely to be affected by false negatives. Using longitudinal data from the Australian Cystic Fibrosis Data Registry, we highlighted the decline in performance of variant based screening recommendations and available diagnostic tests over the last 10 years, coinciding with the increase of second-generation Australians of non-European descent. Taken together, results from our studies suggest that current CF testing guidelines in Australia should be reviewed, especially as Australia becomes more ethnically diverse.



Genetic distribution of study cohort compared to the 1000 genome projects ethnicities.

Transformational Bioinformatics: Project Updates

Machine learning variant prioritisation platform

Collaborators: Centre for Population Genomics, Garvan Institute of Medical Research and Murdoch Children's Research Institute, Australian Genomics Health Alliance, Melbourne Genomics Health Alliance, QIMR Berghofer Medical Research Institute, University of Melbourne

Whole genome sequencing has become a standard tool for the diagnosis of rare inherited diseases, but without regular reanalysis, the diagnostic rate remains low. The aim of the automated reanalysis project is to develop a sustainable program for the systematic reanalysis of genomic data that utilises highly scalable and cloud-based systems, together with a machine learning (ML) algorithm for the prioritisation of disease-causing variants.

In the last 12 months investigators have developed a minimum viable product (MVP) for the automated reanalysis of rare disease patients. The MVP focuses on the identification of high confidence pathogenic variants in singleton and trio genomic datasets. In the absence of a molecular diagnosis samples will be assigned to the ML, variant prioritisation algorithm. The ML algorithm is in the early stages of development and is expected to integrate variant pathogenicity and patient phenotypes as features.

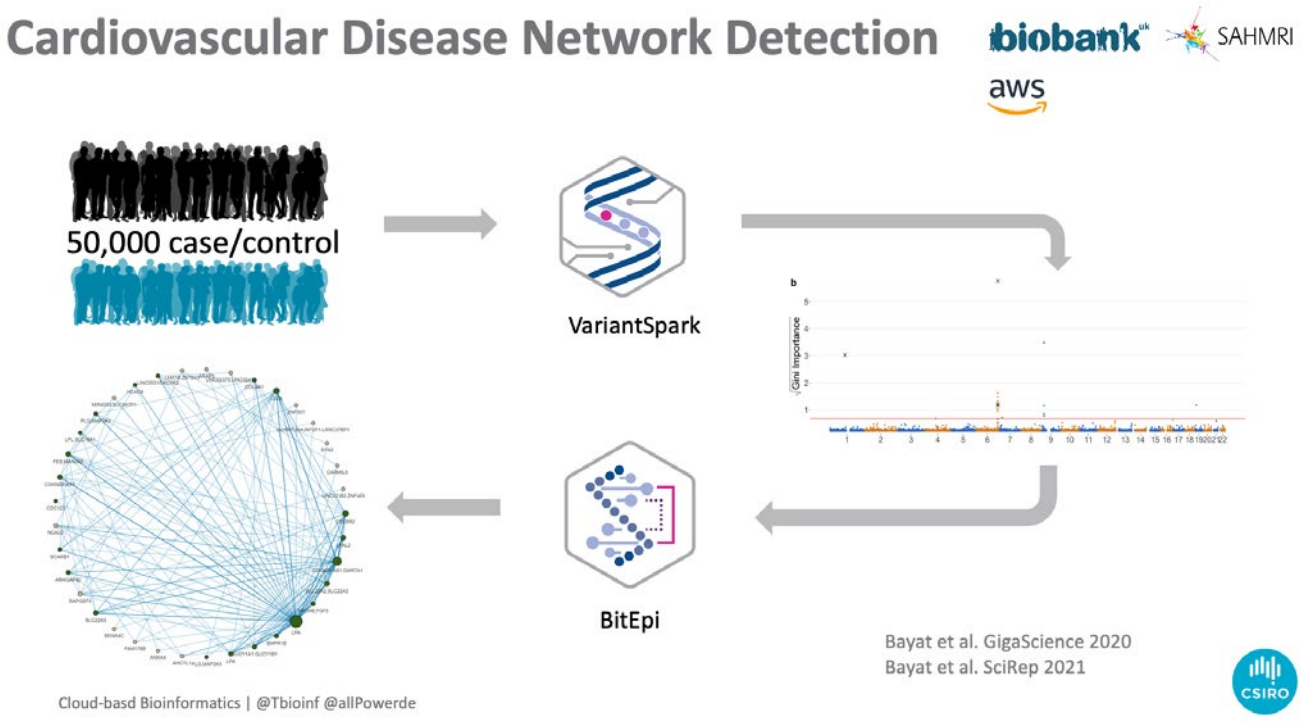
VariantSpark analysis of Alzheimer's and cardiovascular disease, with UKBiobank

Collaborators: Johan Verjans (SAHMRI), Sydney University, UKBiobank, NIH TopMed

Gene by gene interactions, or epistasis, is proposed to be partly the answer to the missing heritability problem in genomics.

VariantSpark is a cloud-based machine learning platform that accounts for both marginal and epistatic effects of genotype associations to complex phenotypes. An exciting new development to our VariantSpark platform is the RFlocalFDR, which enables the identification of significant associations, overcoming the challenge of attributing statistical significance to variable importance scores. Significant associations are then fed into BitEpi, our tool that identifies higher-order epistatic interactions, creating a complete genome-wide association study and epistasis analysis pipeline. We have applied this pipeline to identify novel genes and genetic mutation markers associated to two complex diseases, Alzheimer's disease (AD) and coronary artery disease using the UKBiobank, which contains genotype and phenotype information from up to 500,000 samples as a discovery dataset.

Validating our results with the Alzheimer's disease neuroimaging initiative cohort, we have found a novel gene associated with AD through an epistatic interaction involving the well-known AD-causing gene, *APOE*. Along with this novel discovery, we have also replicated known AD genes and mutations. The calculated variance explained for the UKBiobank cohort was shown to increase with the inclusion of BitEpi interactions indicating that epistasis is involved in AD. Similarly, work to validate our results for CAD using the Trans-omic for Precision Medicine (TopMed) is currently underway.



Metabolic associated fatty liver disease novel therapeutic target discovery

Collaborators: Associate Professor Mohammed Eslam, The Westmead Institute for Medical Research, University of Sydney

Metabolic associated fatty liver disease (MAFLD) is a major comorbidity for COVID-19 severity; however, the underlying mechanisms remain uncertain. It is known that cytokine storms are responsible for multiple organ failure in severe COVID-19 and that they are triggered by the breakdown of toll-like receptor (TLR) tolerance.

We worked with Westmead and Sydney University to conduct a phenome-wide (PheWas) study, which identified MBOAT7 (membrane bound O-acyltransferase domain containing 7) as a crucial negative regulator of TLR signalling. MBOAT7 deficiency in macrophages, as observed in patients with MAFLD and COVID-19, alters cellular phospholipid composition. This is associated with a redistribution of arachidonic acid toward proinflammatory eicosanoids, the induction of endoplasmic reticulum stress, mitochondrial dysfunction, and remodelling of the accessible inflammation-related chromatin landscape. This in turn enhances macrophage inflammatory responses to TLR and SARS-CoV-2 spike protein challenge. Reactivation of MBOAT7 reverses these effects. These outcomes are modulated by the MBOAT7 rs8736 variant. Our results identify MBOAT7 as a critical link between MAFLD and severe COVID-19 that can be exploited as a therapeutic target.

Viral capsid modelling

Collaborators: The Translational Vectorology Group, Children's Medical Research Institute (CRMI), Westmead

Gene therapies are transformative technologies that enable treatment of previously untreatable diseases. Most approaches use viral capsids, protein shells derived from viruses such as AAV2, as delivery methods for the therapeutic DNA cargo. The size and volume of these capsids provide strict limits on what can be packaged inside them.

To improve packaging, we are exploring two complementary approaches: increasing the volume of the capsid through targeted mutations and reducing the effective volume of the DNA cargo through more efficient folding. By using new developments in protein and molecular modelling, such as AlphaFold, we can model how the viral capsid and DNA interact in 3-dimensions and test how specific changes influence packaging effectiveness. We are collaborating with Associate Professor Leszek Lisowski, leader of the Translational Vectorology Group at the CMRI, Westmead, a world leader in the design and manufacturing of gene therapy capsids.

Pathogen genomics pipeline for viral evolution

Collaborators: CSIRO's Australian Centre for Disease Preparedness, CSIRO's Data61

SARS-CoV-2 undergo evolution via mutations as part of host-pathogen interactions impacting disease progression, treatment resistance and vaccine development.

To efficiently track the growth and spread of key mutations advantageous for viral replication and transmission, we improved upon an existing pipeline using data from the largest public repository of COVID-19 sequences (GISAID).

The pipeline allows users to search for mutations of interest within the SARS-CoV-2 genome and its associated metadata for downstream analyses. As a case study for the pipeline, we identified 5,767 samples as of 28 April 2022 with a combination of SARS-CoV-2 key mutations that has not outcompeted other variants warranting further *in silico, in vitro* and *in vivo* investigations. With the large number of mutations in COVID-19, such as the Omicron variant, this work is useful to understanding whether specific combinations are more transmissible.

Chicken gene editing

Collaborators: CSIRO's Australian Centre for Disease Preparedness (ACDP)

Poultry are a key agricultural staple in Australia. They're also an important research tool, with chicken eggs being critical for the development and manufacturing of viral vaccines. As such, CSIRO has launched multiple projects around editing the chicken genome. This includes developing ways to better screen male and female chicks to influence how well influenza virus can grow within the eggs to better understand its biology.

We are analysing and developing the optimal gene editing strategy using our GT-Scan suite. In collaboration with researchers at CSIRO's ACDP we have designed approaches to target and knock-out every single gene in the chicken genome and are exploring ways to develop knock-in new sequences.

Transformational Bioinformatics: Postdoc and Student Highlights

Postdoctoral

Priya Ramarao-Milne

Library design is a key aspect of successful CRISPR experiments. However, most commercial libraries are not suitable for every use case and may require fine-tuning. The New Zealand based MedTech startup, Amaroq Therapeutics, utilises a commercial library, CRiNCL, and a custom-designed library to detect candidate long non-coding RNAS (lncRNAs) involved in cancer cell line growth.

Priya Ramarao-Milne, a postdoc in the Genomics Insights team, performed differential expression analysis on CRISPR screen data to identify the candidate lncRNAs. In addition, she enhanced Amaroq's prioritisation framework by including an analysis on potential off-target effects of their candidate targets. We will continue to collaborate with Amaroq in future to develop a pipeline for target prioritisation. Read more about this project here: https://aehrc.csiro.au/research/data-and-interoperability/boosting-product-confidence-of-a-world-leading-rna-therapeutics-start-up/

Engineering highlight

Yatish Jain

Digital marketplaces are going to play a big role in commercialising and disseminating knowledge. With VariantSpark already on the AWS Marketplace, Yatish Jain, an engineer in the Genomics Insights team, has engaged with multiple teams both within Azure (DevOps, marketplace) and CSIRO (IM&T, Cloud Right) to streamline the deployment of the first CSIRO product on the Azure marketplace. We plan to address technical challenges (identifying dependencies and resource requirements), finance-based challenges (linking CSIRO revenue stream, identifying scaling up of resources within Azure and charge the same to end-users), cloud-specific challenges (getting the right set of permission to make the deployment generic enough for any user to deploy within a secured environment) and pioneering challenges (engaging with Azure partner portal within CSIRO). We are also documenting mitigation steps for the challenges to easily allow any team within CSIRO to deploy their software on the Azure Marketplace.

Masters' student highlight

Kilian Salomon

Microbial-based food production (precision fermentation, PF) offers a scalable complement to traditional animal-and plant-based systems, which is needed to feed a global population of 10b by 2050. However, current production systems rely on pure sugars, especially glucose, which is not sustainable due to high production cost. For PF to take on the expected 11% ($290bn) of the global protein market by 2025, non-conventional yeast strains need to be designed that can utilise cheap carbon-based by-products as feedstocks. Using machine learning Kilian Salomon, a masters' student from Freie Universität Berlin, Germany, uses bioinformatics approaches to identify and transfer the genetic control of the metabolism of "humble-eating" organisms to PF production species.

The Biomedical Informatics Group

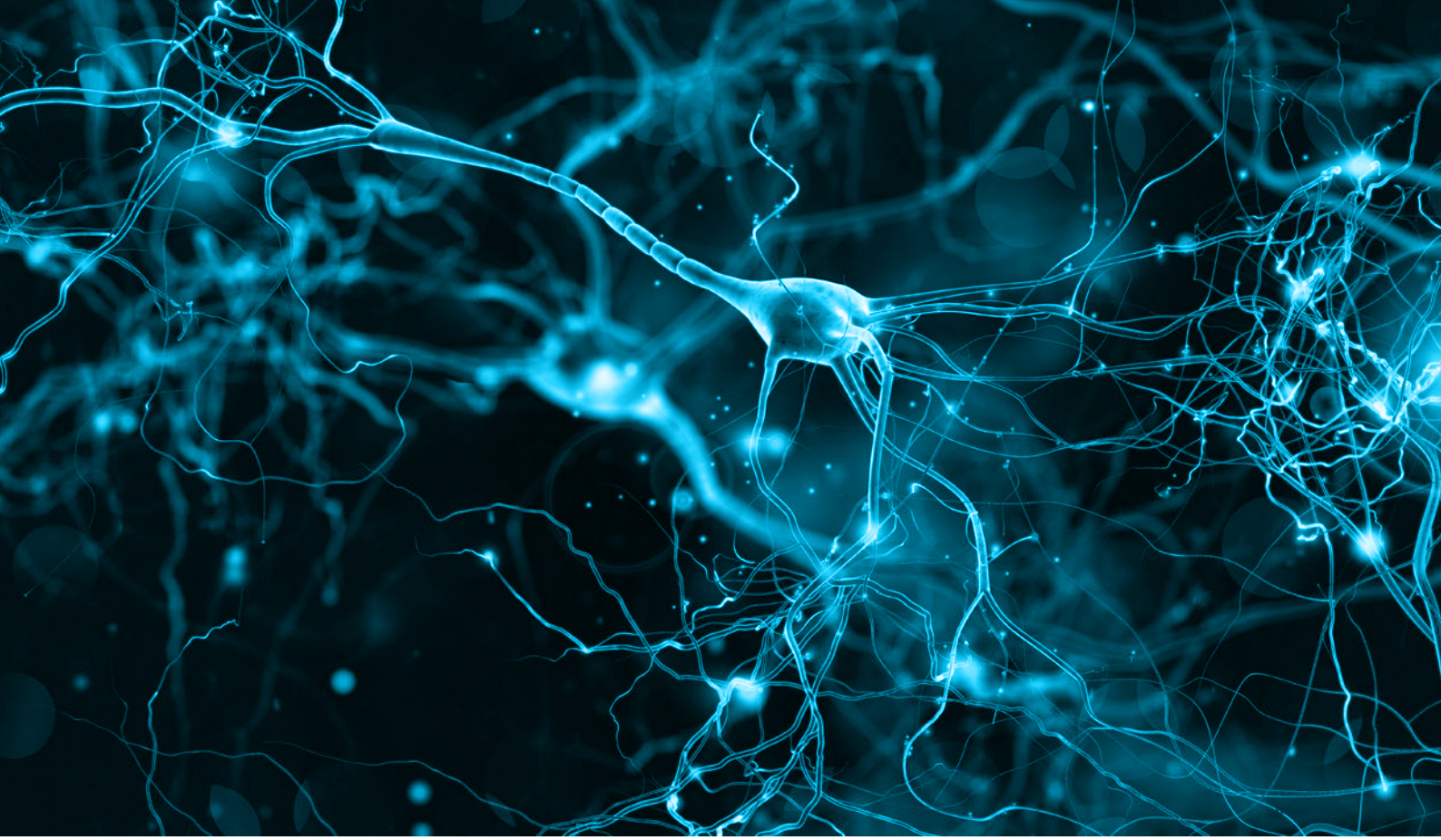
Group Leader: Jurgen Fripp

The Biomedical Informatics group develops and validates novel and advanced machine learning (ML) and artificial intelligence (AI) methods for medical research and clinical translation. We use medical imaging biomarkers with 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 clinics, hospitals and on our cloud informatics platform where they're 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).

The group is a key partner in many clinical trials and studies in Australia and internationally where we contribute to the collection and analysis of data and interventions with our clinical and research partners.

- Dementia is the second leading cause of death of Australians and is likely in future to become the leading cause as our society ages. The hallmarks of dementia are characterised by a range of fluid and imaging biomarkers, including amyloid and tau PET. Our group is a key partner in the Australia Dementia Network (15 institutions nationwide) and the Australian Imaging Biomarker Study of Aging (AIBL); providing advanced image analysis and biostatistical expertise. This is highlighted by our role in over 20 journal papers in the last 12 months.
- Each year in Australia, more than 20,000 infants are born premature and/or with low birthweight. This puts them at risk of neurodevelopmental conditions, such as cerebral palsy, where they potentially face a range of adverse cognitive, behavioural, educational and motor outcomes. In a large collaborative effort, including with the University of Queensland, Monash Health and the Cerebral Palsy Alliance, we are currently contributing to 11 projects which allow us to track brain development and investigate functional brain networks. These studies, conducted across the childhood period from preterm infancy to adolescence, provide insight into neuroplasticity following insult or intervention, and can be used to improve clinical reporting and to tailor the most effective therapy to enhance quality of life for the children and their families.



Biomedical Informatics' science and impact highlights for 2021/22

- We demonstrated the value of early MRI scans in providing measures that could accurately predict two-year outcomes for motor, cognitive, and to a lesser extent, language scores, in babies born very premature
- In children with severe neuropathology, current techniques to segment and measure brain structures are inaccurate. We developed a new automated approach to segmenting areas of the brain, including the deep grey matter and the corpus callosum, which outperformed three state-of-the-art methods and could be used in future trials to improve predictions of patient outcomes.
- A team of postdocs participated in ImageCLEF – an international challenge to build the best AI system for medical imaging tasks. The team won the tuberculosis detection from CT task and came 3rd in the image captioning task.
- Our cloud platforms and image analysis technology support the collection of data for a range of cohorts and trials. The Australian Dementia Network is using this platform nationwide (six sites in five different states) and has collected detailed data from over 1100 participants, with MRI and PET imaging biomarkers calculated by our technology.
- Cartilage assessment from MRI accurate evaluation of the morphology and degeneration of cartilage. In partnership with the University of Queensland and Siemens Healthineers, our ChondralHealth software is undergoing clinical validation and regulatory approvals.

Biostatistics team

Team Leader:
James Doecke

The Biostatistics team works on various projects across a wide array of biomedical data. Our specialists in bioinformatics and statistics apply their knowledge to medical data to identify disease-specific relationships. Our bioinformaticians develop software to process raw genomics data into usable summary information, while our biostatisticians provide reproducible reports for each project to customers.

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.

Medical Image Analysis team

Team Leader:
Jason Dowling

The Medical Image Analysis team works seamlessly with clinicians, industry, and patients to understand needs, develop, validate, and translate precision imaging AI and machine learning tools for improved disease diagnosis, treatment planning and treatment delivery. This involves the development of AI and ML methods for the extraction, quantification, and modelling of information from 2D and 3D medical images and sensors; mapping data across imaging modalities and individuals/populations; and performing image reconstruction and synthesis.

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 use advances in neuroimaging to measure localisation and extent of neuroplasticity in response to both injury and 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 develop disruptive technologies that extract clinically meaningful metrics (diagnostic tools, disease staging) from medical images for use in precision medicine application. Statistical modelling is then used to characterise at-risk for developing dementia groups and allowing early interventions (such as improving lifestyle choice).

The team contributes to image-based biomarker analysis for several 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 and is comprised of 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 ML methods to increase the throughput of reporting.

Biomedical Informatics: Platform Technologies

Milx: Medical image processing platform

The medical image analysis platform supports the analysis of a suite of medical imaging modalities (MRI, PET, CT and US) that are utilised within our clinical research projects or trials. This platform leverages open-source image analysis libraries such as ITK and VTK, and includes algorithms such as image enhancement, feature detection, tissue segmentation, registration, shape modelling and classification.

This platform provides the core of a range of applications that extract imaging biomarkers for use in neuroimaging, musculoskeletal image analysis and MR-alone radiation therapy. These applications are generally fully automatic and incorporate a range of supervised and unsupervised artificial intelligence and machine learning techniques that extract clinically relevant information or knowledge from the medical images; read more in Biomedical Informatics: Project Reports and Project Updates.

MilxCloud: Cloud based image analytics

The MilxCloud web application is used to access our workflows that perform automated quantification and extract imaging biomarkers from medical imaging data. This has been implemented in the Galaxy framework (galaxyproject.org) to provide scalable access to the cloud. Typically, this involves uploading of the medical images (MRI, PET, CT) to a cloud-based platform for analysis. The user is then provided with a PDF analysis report containing quantitative measurements. A version of MilxCloud with our most popular workflows can be evaluated at milxcloud.csiro.au.

MilxCloud applications: CapAIBL

Recent developments in medical imaging facilitate 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 is a sensitive technique for the detection of the key pathological hallmarks of Alzheimer's disease which occur many decades before the onset of clinical symptoms. PET provides invaluable insight into the future development of this disease, while MRI provides useful clinical information on neurodegeneration. Thus, in-vivo brain imaging has an increasingly important role in therapeutic trials.

The computational analysis of PET by AIBL (CapAIBL) is a web-based implementation of our automated PET reporting tool. These reports include a Z-score display which allows a universal visualisation and comparison of tau and Aβ imaging PET scans. It allows the report to be sent to, and reviewed by, a specialist not specifically trained for the tracer used for scanning. It will reduce the cost of analysing PET scans and will provide wider access to tau and Aβ imaging scans, including in Australia's remote areas.

We have been working on the new harmonisation of PET quantification, which will be available in a forthcoming version. A trial version of CapAIBL is available on MilxCloud, our web platform (milxcloud.csiro.au); read more in Biomedical Informatics: Project Reports and Project Updates.

MilxCloud applications: AssessCP

AssessCP is a web-based tool to support the assessment of paediatric brain MRI by providing quantitative information of brain structure (including anatomical volumes and cortical shape) relative to a typically developing cohort. The platform uses AI and ML techniques designed to be robust to potentially severe brain injury, making it able to quantitatively assess children with cerebral palsy (CP) and acquired brain injury (ABI). To support clinical translation, 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.

This software has been used in multiple projects to find cross-section associations between brain structure and childhood function in collaboration with Queensland Cerebral Palsy and Rehabilitation Research Centre (QCPRRC), as well as to elucidate subtle differences in brain structure associated with genetic markers associated with CP (with collaborators in Monash University, Phoenix Children's Hospital). Currently it is being validated on a large paediatric cohort (combined n=366) of children born preterm or with CP, after which a trial version will be available on MilxCloud.

Health research data: CSIRO AWS REDCap

The collection of data (personal and medical) is one of the most important steps in any clinical study or trial concerning human health. Key components to effective data collection include:

- confidential information is stored in compliance with legislation, policy and regulatory frameworks
- data is centrally stored and managed, thus creating transparency and oversight
- with the requisite approvals data can easily be accessed, shared, re-used and linked

The AEHRC has developed a secure CSIRO managed Amazon Web Services (AWS) cloud platform using a collection of open source and in-house software systems that follow CSIRO governance controls and standards. Electronic data capture is handled using 1) REDCap, which is a web application used to manage and capture basic clinical research data; 2) XNAT, which is an imaging informatics platform used to capture imaging data, and 3) Dashboard, an in-house web application that allows for a seamless experience in dealing with data entry, collecting summary data and completing study specific tasks.

The XNAT platform is used in several large multi-site neuroimaging studies (ADNeT and PISA); read more in Biomedical Informatics: Project Reports and Project Updates.

FORTE – Workflows in FHIR

Workflows are the basic building blocks of clinical tasks. While there may be several platforms in the clinic such as the hospital information system (HIS), the radiological information system (RIS), the patient management system etc, these are utilised to collect information rather than track and guide a clinical workflow. It is therefore up to clinicians and hospital staff to make sure that their interactions with these systems are as per their best practices, guidelines and standard operating procedures.

Fast Healthcare Interoperability Resources (FHIR) is a new standard for storing and querying health care data which is being rapidly adopted into the clinic. The concept of workflows is modelled in FHIR which can allow us to track and guide the completion of tasks as part of workflows independent of clinician input.

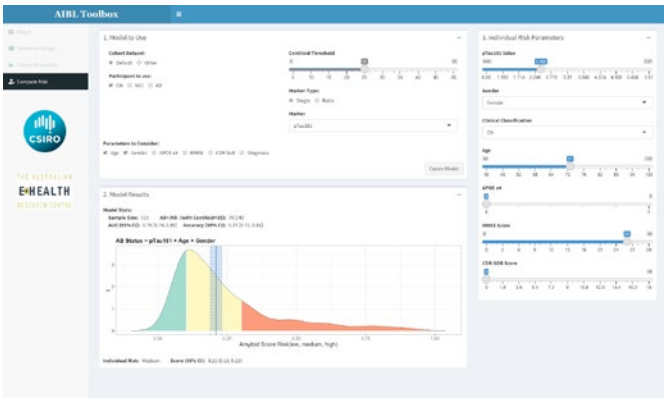
Our FORTE platform allows for the definition and execution of clinical workflows using FHIR. These workflows can be used to embed automated tools (including artificial intelligence systems) and decision support systems directly into the clinical workflow. We are developing and applications in radiology (RIS) and ophthalmology based on these concepts that encompass the entire clinical workflow.

Biostatistics and bioinformatics with ML and AI

Our team develops biostatistical workflows (reproducible workflows with R Markdown) and applications (R Shiny Apps) for clinical, pharmaceutical and industry partners. Applications are created for both internal and external use given project requirements. 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 ML and AI methods to examine 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.

Shown below is an example of a R Shiny app to visualise data from the Australian Imaging Biomarkers and Lifestyle (AIBL) study of ageing. The app is being developed with multiple functions to both guide clinical decisions and direct research designs.



Data visualisation through R Shiny.

Biomedical Informatics: Project Reports

Australian Dementia Network (ADNeT)

Australian Dementia Network
REGISTRY. CLINICS. TRIALS.

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

ADNeT (australiandementianetwork.org.au, PI Prof Rowe, University of Melbourne) is a large five-year NHMRC funded collaboration with 15 partners across Australia. Its foremost aim is to improve quality of care, quality of diagnosis, and accelerate development of new therapies. One major outcome has been the establishment of an integrated network of dementia researchers, clinicians and health service providers which are enabling 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.

CSIRO is joint technology lead providing the following:

- **Technology support:** Providing secure data collection platform and harmonisation for the ADNeT consortium.
- **Image analysis:** Provide the imaging biomarker quantification and clinical translation for the thousands of medical images associated with this novel and far-reaching project. This currently includes amyloid and tau PET analysis and MRI analysis.
- **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 the destructive pathological processes that lead to Alzheimer's disease.
- **Status update:** Over 3300 subjects have volunteered for recruitment into trials, with 1100 subjects enrolled into the well characterised trial ready cohort.

OUR PARTNERS

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

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

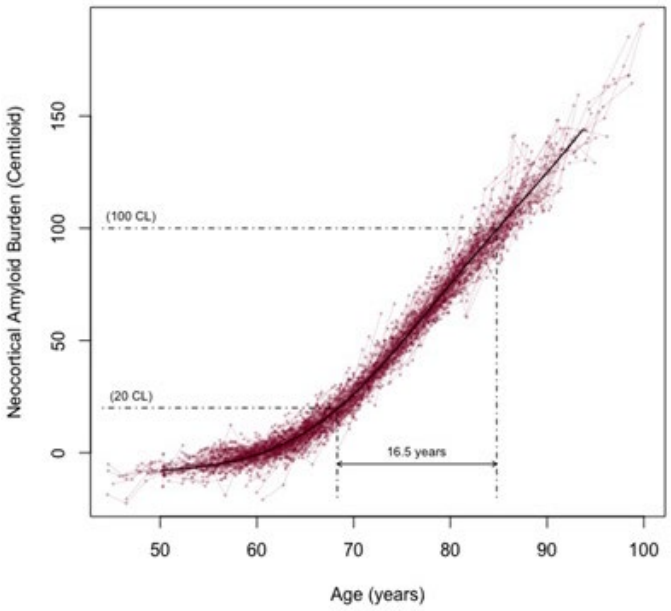
ADOPIC is a NIH-funded (PI Prof Masters, University of Melbourne) study looking at establishing and validating the impact of demographics, genotype and comorbidities on the onset and progression rates of Alzheimer's dementia. This international consortium will leverage the power of five leading well characterised longitudinal cohorts to clarify risk and protective factors for Alzheimer's disease and related dementia.

The dataset (clinical phenotypes, imaging, cognitive, CSF-biomarkers, genomics) consists of over 1500 subjects (each assessed three times over a minimum of 4 1/2 years) and spans the entire disease lifespan; from its preclinical stages through to post-mortem analyses. One key strength of this project is a strong focus on harmonisation, which ensures findings are more easily interpreted and transferable to clinical settings.

A key development this year was a novel PET quantification method based on the non-negative matrix factorisation (NMF). It defines a new common space where the images of different amyloid tracers can be projected and harmonised. Using this approach, we've been able to show a significant reduction in the number of longitudinal discrepancies in the PET quantifications from AIBL, leading to more robust estimates of the expected rate of amyloid accumulation.

Post-doctoral highlights

- Dr Li has developed a model to correct systemic differences between PET cameras (from hardware and software). This model corrects amyloid-β quantification from the image of one PET camera to the other one, without re-processing the raw PET data.
- Dr Shishegar has developed and validated a machine learning method for harmonised imputation (non-parametric multivariate imputation using random forests (missForest). The method was used to create composite scores for the Pre-clinical Alzheimer's Cognitive Composite (PACC) score and the Episodic Memory Composite score for AIBL, ADNI and OASIS data sets as part of ADOPIC.
- Dr Cox analysed the longitudinal CSF data with respect to the longitudinal PET amyloid data. Estimates of age of onset for CSF AD biomarkers Aβ42 and pTau181 have been calculated in preparation for a manuscript to describe how CSF markers change with Alzheimer's disease over time.
- Dr Cox has used harmonised NMF centiloid data to confirm the natural history curve for amyloid accumulation. The figure below shows the real data with centiloid values on the y-axis and years of amyloid accumulation on the x-axis. The cluster of dots on the far left represents those participants who have little to no amyloid pathology in the brain, whilst on the right participants with growing amyloid burden. Zero on the x-axis represents when the pathology begins to accumulate with increasing age.



Natural history curves of amyloid deposition using the harmonised PET quantification.

HABIT-ILE – a camp-style intervention for children with cerebral palsy

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

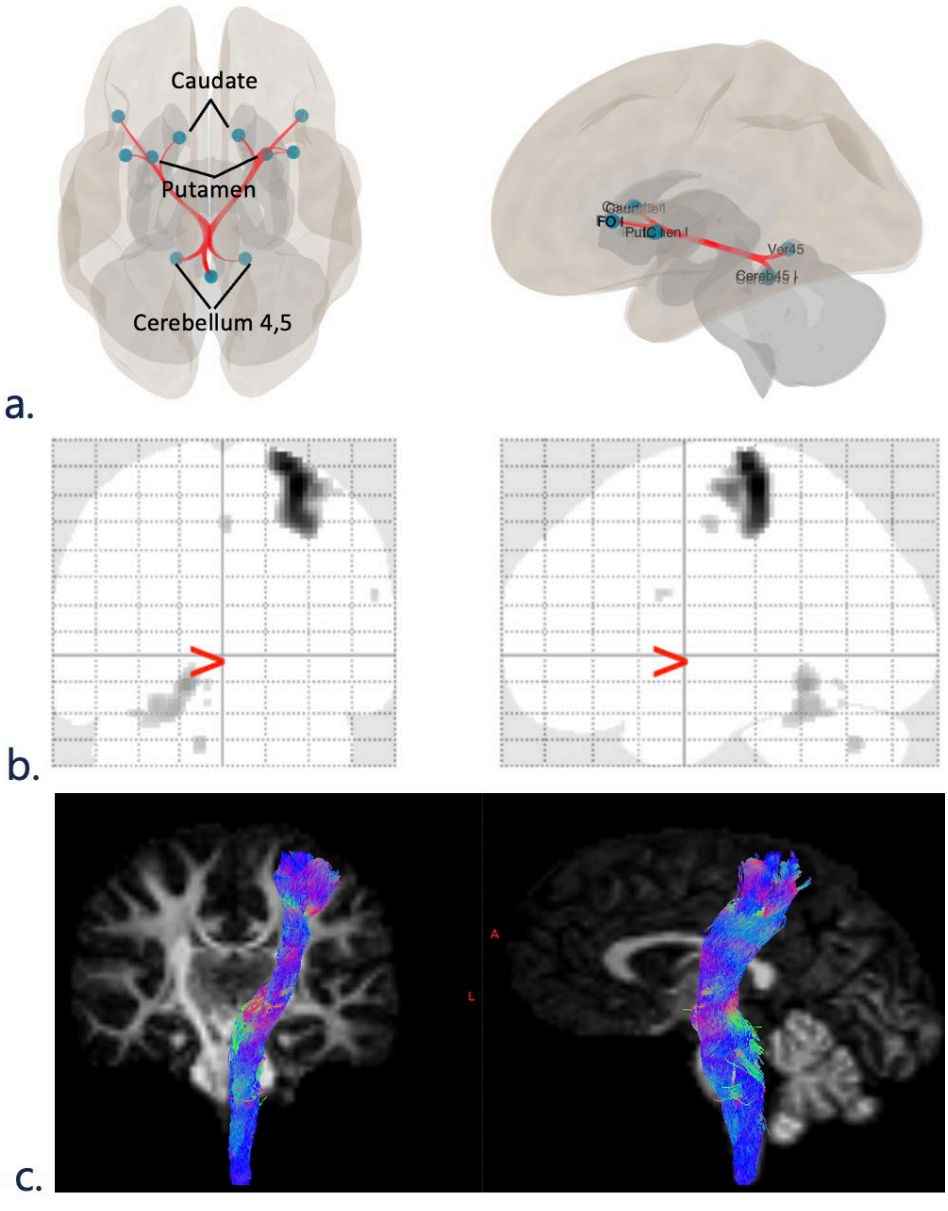
In Australia, there are 35,000 people living with cerebral palsy (CP), a life-long condition characterised by increasing physical disability over time. There is no cure and nearly 70% of people with CP have significant motor difficulties on both sides of their body, thus limiting their ability to use their hands, walk and perform daily life tasks.

A novel and promising intensive intervention called HABIT-ILE (Hand Arm Bimanual Intensive Training Including Lower Extremity) aims to significantly improve the hand and gross motor function of children aged 6–16 years. HABIT-ILE camps were recently conducted by our collaborators at the University of Queensland Cerebral Palsy and Rehabilitation Research Centre.

Our research focuses on exploring if this new clinical intervention induces changes in the brain, known as neuroplasticity. To achieve this, we are using two advanced brain imaging techniques, functional MRI (fMRI) and diffusion-weighted imaging (DWI), which look at connections in the brain to assess differences in the brain before and after HABIT-ILE intervention. Over the last year, we have found functional differences in motor networks (the basal ganglia and cerebellum) when comparing groups of children with and without HABIT-ILE intervention.

Using fMRI while performing hand and motor movements allowed us to pinpoint the precise brain regions involved in motor control. We are currently using these regions to assess whether the strength of the connection changes before and after HABIT-ILE intervention.

Studying and quantifying functional and structural neuroplastic differences after the clinical intervention will provide additional evidence to support a novel intensive bilateral training protocol as a clinical therapy to improve daily life tasks for children with bilateral CP.



a. Functional differences were found between the basal ganglia and cerebellum when comparing groups of children with and without HABIT-ILE intervention.

b. Dark regions showing brain regions that were active during motor task, which are used as starting points to evaluate their structural connections.

c. bottom image throughout the brain.

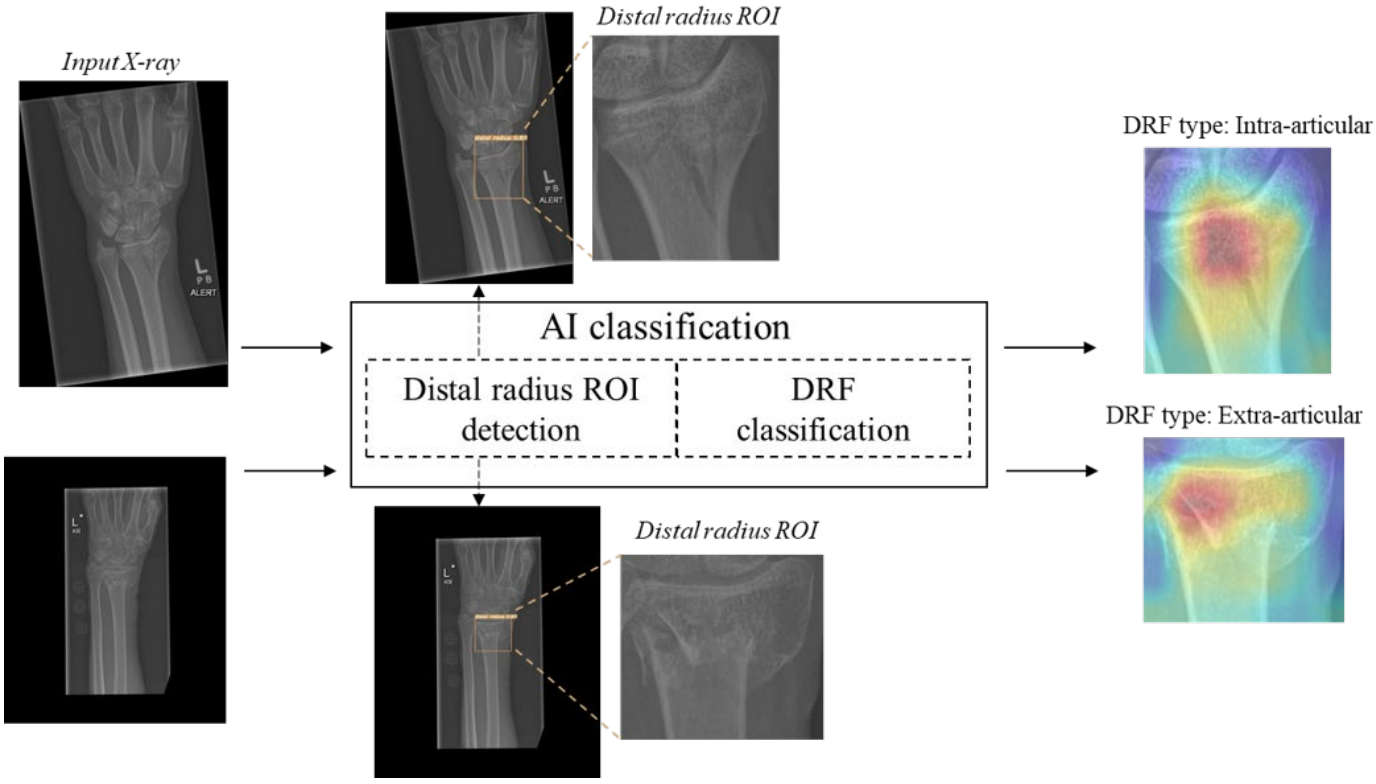
AI screening system to identify patients requiring a CT scan following distal radius fractures

Collaborators: Jamieson Trauma Institute and Royal Brisbane and Women's Hospital

This project is developing an AI system to identify patients with complex distal radius fractures (DRFs) which may require further CT scan and examination. We have established a two-stage deep learning DRF classification pipeline which imitates clinicians' search patterns.

The framework firstly zooms in on the distal radius region of interest using an ensemble model based on YOLOv5 object detection network and classifies the DRF in the region as intra- or extra-articular fracture using an ensemble model based on EfficientNet. The identification of intra-articular fracture can alert clinicians of fractures extending to the joint surface which could have long term functional impacts on the joints and may require CT scans.

This year we completed the collection of the clinical data and developed and evaluated the initial AI DRF classification framework. The AI framework achieved promising results in DRF classification on single-view radiographs (posteroanterior view) and can be further extended into a multi-view system. A publication in *Medical Physics* (a prominent journal in the field), is under review.



Automatic AI classification of distal radius fractures on radiography.

Biomedical Informatics: Project Updates

Improving radiotherapy treatment clinical trial quality assurance

Collaborators: Ingham Institute, Liverpool Hospital

We are developing new artificial intelligence methods for real-time quality assurance for clinicians and for mining large clinical oncology datasets. The aim is 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

We developed an automatic delineation QA system on prostate MRI for both the clinical target volume (CTV) and organs-at-risk (OARs). This QA system uses a deep learning segmentation network to provide benchmark delineations and suggests 'pass', 'minor correction' or 'major correction' for manual delineations. A pdf QA report is generated for the clinicians, which shows the QA outcome (pass, minor or major correction required) and visualises the differences between the manual and computer-generated delineations. This QA system has been validated on the CT-MRI fusion radiation therapy dataset PROMETHEUS and yielded promising results. The next step is to apply and further improve this system on MRI-only radiation therapy clinical trial data.

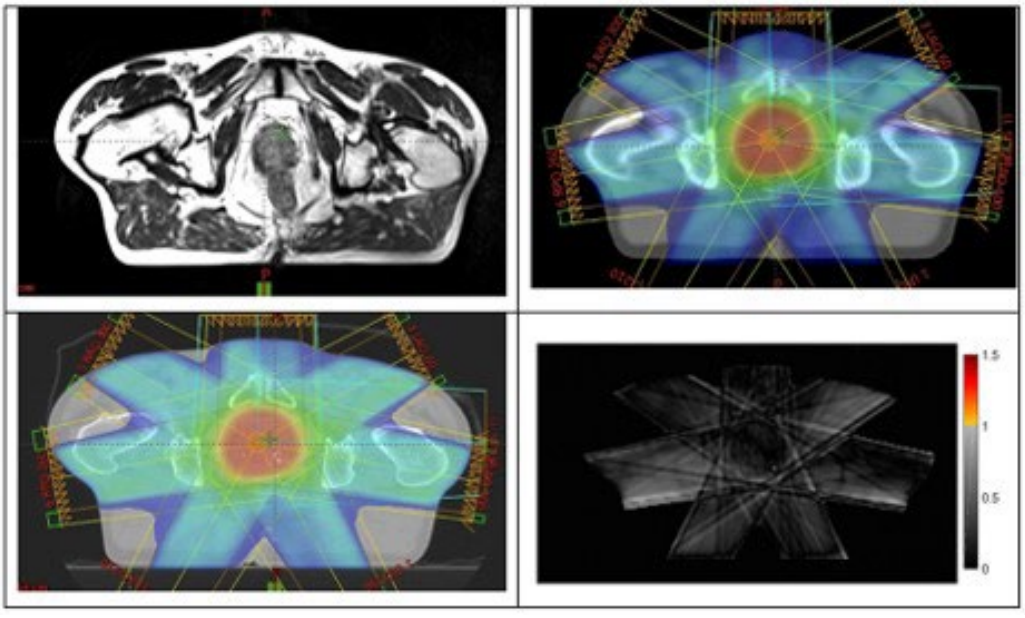
NINJA multi-centre clinical trial

Collaborators: Trans-Tasman Radiation Oncology Group, Ingham Institute, Liverpool Hospital, Calvary Newcastle Mater Hospital

The novel integration of new prostate radiation therapy schedules with adjuvant androgen deprivation (NINJA) clinical trial aims to compare two emerging schedules of radiotherapy in the treatment of intermediate or high-risk prostate cancer. The trial is supported by funding from Cancer Australia (APP1158455).

Participants will be randomly assigned to one of two radiotherapy schedules as part of this study. In schedule 1 (called Stereotactic Body Radiotherapy) participants will receive five radiotherapy treatments over two weeks, and in schedule 2, (called Virtual High Dose Rate Boost), participants will receive stereotactic body radiotherapy delivered in two treatments over one week followed by 12 treatments of conventional external beam radiotherapy over two and a half weeks.

This research potentially improves the accuracy and quality of radiotherapy treatment in prostate cancer. An important component of the study includes validation of MRI-only radiation therapy treatment at eligible sites. This involves the generation of synthetic CT from patient MRI scans to enable dose delivery planning using CSIRO's sCTGen software. To date 62 men in this trial have been treated with sCTGen (TGA: CT-2020-CTN-03318-1; ACTRN126180018062 57; Protocol: https://bmjopen.bmj.com/content/9/8/e030731).



Axial slice from a patient's MRI scan (top left) and matching MRI generated synthetic CT with dose plan (top right). A comparison CT is shown bottom left and dosimetry quality assurance (bottom right).

Musculoskeletal image analysis: ChondralHealth

Collaborators: University of Queensland, Siemens Healthineers

The ChondralHealth project developed a range of image processing techniques for MRI of human joints (knee, hip and shoulder) for non-invasive assessment of common chronic conditions including osteoarthritis.

Our algorithms for automated segmentation of joint cartilages from MRI scans were used to identify morphological and biochemical quantitative descriptors of cartilage health. Our methods for bone and cartilage segmentation are harnessed in the NHMRC Development grant (NHMRC Development and NHMRC Ideas) "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 are supported by Siemens Healthineers, Germany, who are the commercialisation partner for the technology. This software is evaluated and additional data collected by several international collaborative imaging sites to support regulatory approvals.

MRI-based paediatric lung structure and function assessment

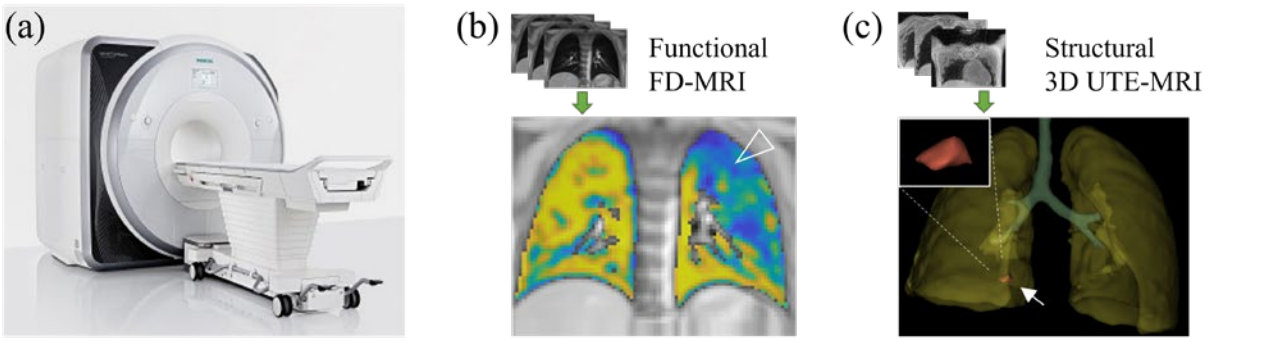
Collaborators: Queensland Children's Hospital, Siemens Healthineers, Herston Imaging Research Facility

This project will 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 several x-ray images, and repeated CT scanning increases a child's cancer risk due to the radiation dose delivered. For this reason, children with CF currently have CT scans only 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 is supported by a three-year CSIRO postdoc grant and external funding from the AT Children's Project, the US CF Foundation, and a 2020 NHMRC MRFF grant.

Progress over the past 12 months

- paper submitted to *Magnetic Resonance Imaging*.
- developed a TBdet-3D network for tuberculosis cavern detection using chest imaging, winning 1st place in the international ImageCLEFmed challenge 2022.
- corresponding paper submitted to the ImageCLEF conference 2022
- delivered presentation, "MRI analysis for paediatric lung disease", at AEHRC Colloquium 2022, and a poster at AEHRC EMCR workshop 2021.
- Completed the AT trial phase 1, acquiring baseline pulmonary MRI imaging from 15 AT patients. We also implemented a new protocol to acquire multiple-slice functional MRI.



(a) Siemens Skyra 3T MRI (HIRF, RBWH). (b-c) Free-breathing non-contrast-enhanced MRI for detecting abnormalities in children with ataxia telangiectasia. Figure b shows ventilation defects (in blue) using functional Fourier decomposition (FD) MRI. Figure c shows consolidation (in red) using 3D structural ultrashort echo time (UTE) MRI.

AI for cardiac substructure quantification

Collaborators: UNSW, St Vincent's Private Hospital, Liverpool Hospital, and Royal North Shore Hospital

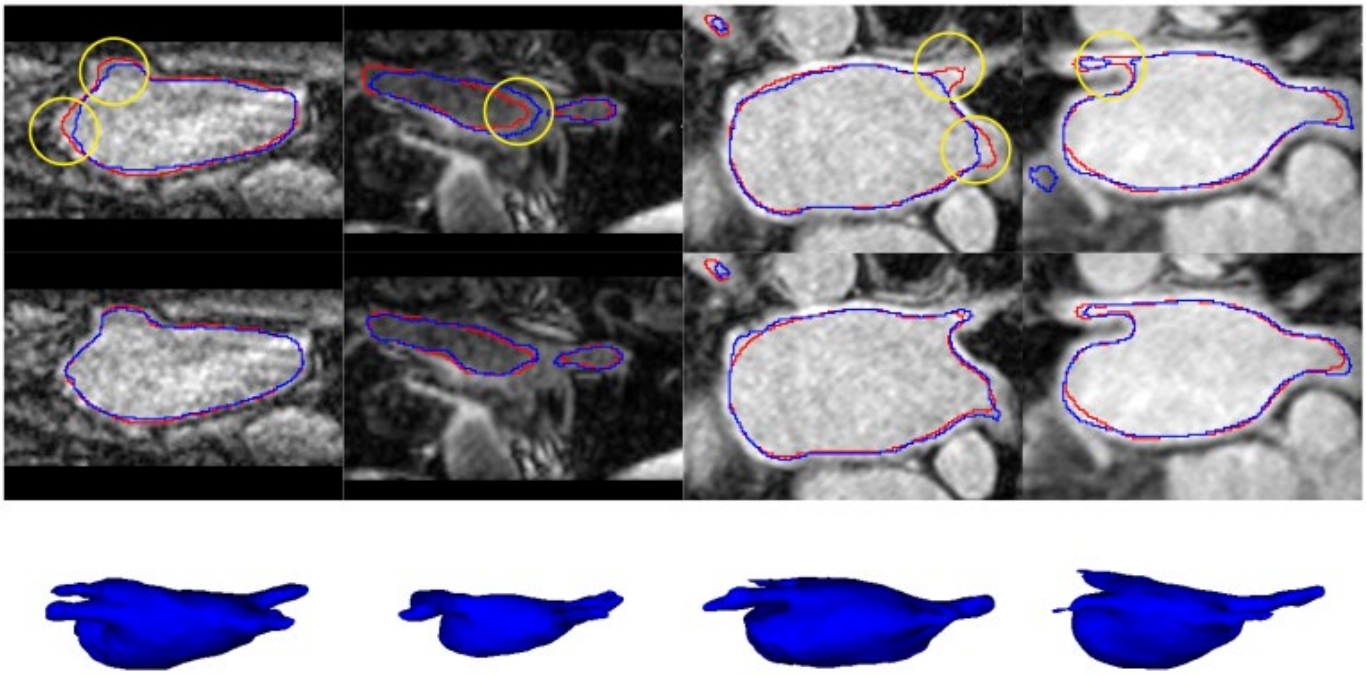
The aim of this project is to develop novel 3D medical image analysis methods to assist clinical screening and quantification of cardiac substructures from CT scans.

Progress over the past 12 months

We developed a novel anatomically constrained vision transformer (ACVT) network for cardiac substructure segmentation in CT. The proposed ACVT network has obtained improved segmentation accuracies over current benchmark methods, and will be presented at the Society of Cardiovascular CT Annual Scientific Conference, Las Vegas (July 2022).

Our novel semi-supervised learning algorithm, Cross-task Graph Representation Learning (CTGRL), detects the left atrium using limited training data (8-16 training samples only). The proposed CTGRL method has achieved improved segmentation accuracy over existing state-of-the-art approaches and will be presented at the Australian and New Zealand Cardiac Society Annual Scientific Conference, Gold Coast (August 2022). Some qualitative results are shown below.

Journal submissions of the proceeding techniques are currently being prepared.

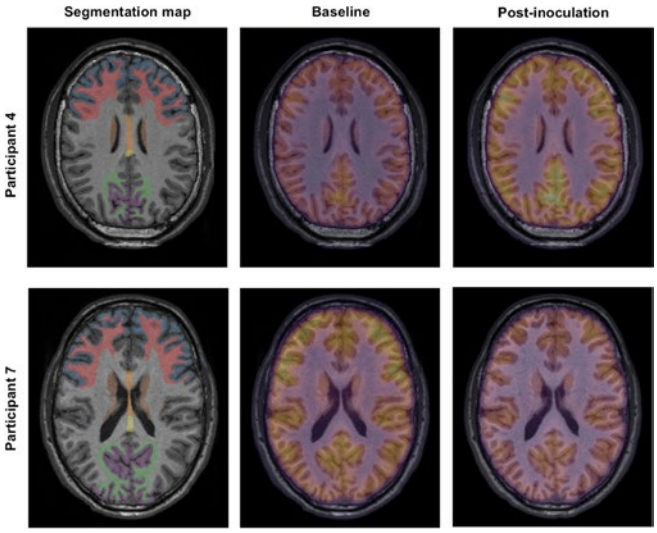


Segmentations of the left atrium from four test images (columns 1–4), taken from the Atrial Segmentation Challenge Dataset, where CTGRL predictions (blue) are compared against the ground-truth (red) when training from 8 (10%) labelled training samples (row 1) and 16 (20%) labelled training samples (rows 2–3).

Functional and structural imaging in malaria: a preliminary trial

Collaborators: QIMR Berghofer Medical Research Institute, Herston Imaging Research Facility

The distribution of malaria parasite on autopsy has been well-described, but the *in vivo* distribution, especially the development during early disease stages, is not well understood. This year we disseminated our findings on the distribution of malaria parasite in the brain as measured with FDG-PET, a biomarker for metabolism. This compliments our previous work on the distribution in the liver. Together, these publications have demonstrated FDG-PET as a biomarker for malaria and have demonstrated important differences in parasite distribution between different malaria parasites can occur much earlier than previously expected.



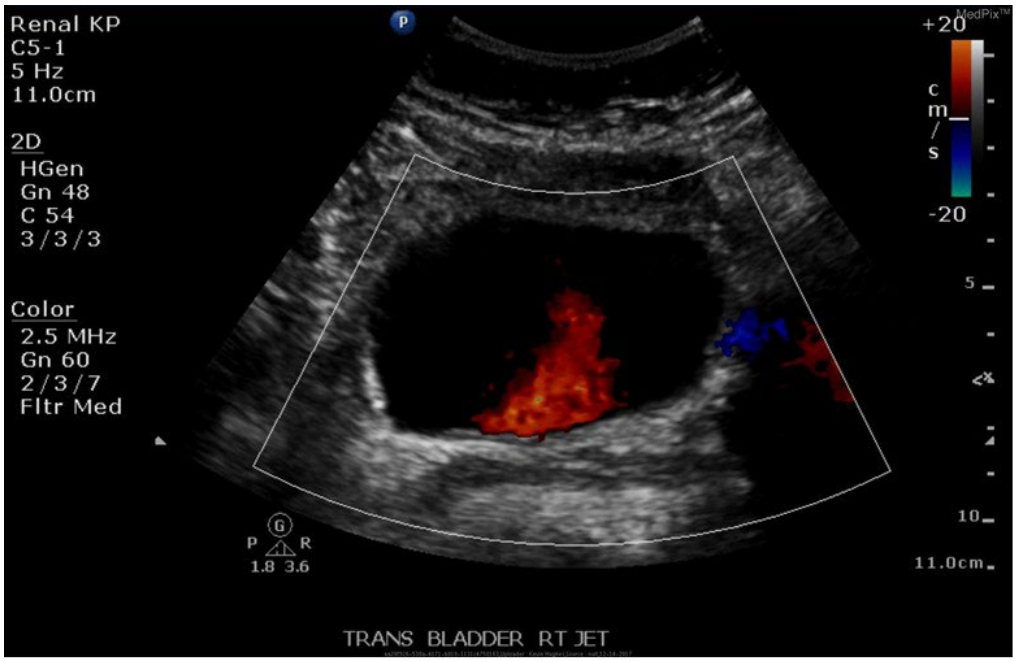
As FDG is a non-specific indicator of intracellular glucose accumulation, changes in uptake following inoculation may be related to parasite or host activity.

Multimodal learning for medical image analysis

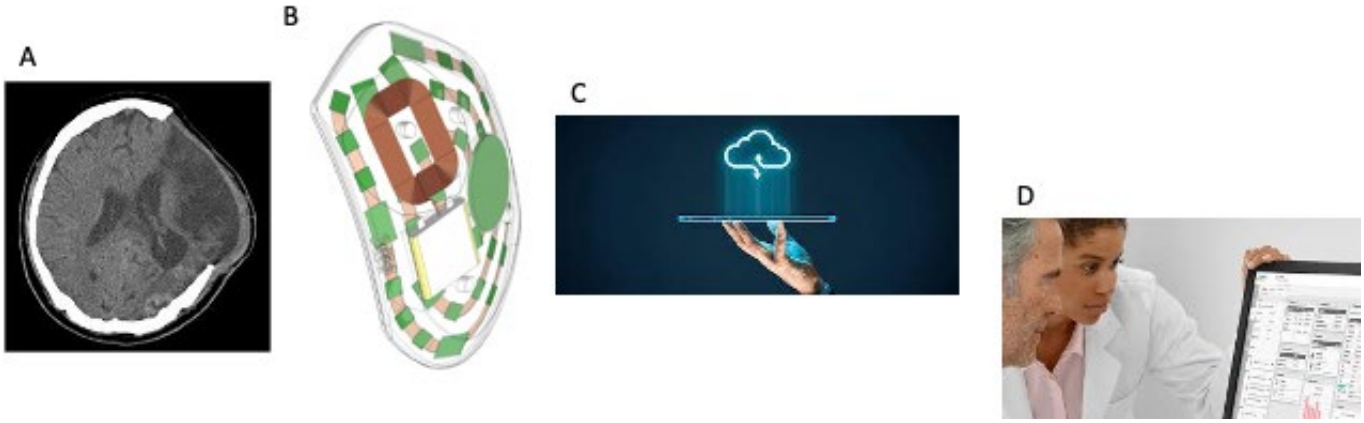
Collaborators: MLAI FSP, Data 61, & A&F

The aim of this project is to develop machine learning and artificial intelligence methods for medical image analysis that consider multiple modalities, e.g, medical images and their associated medical reports. This will lead to medical image analysis tools that can perform more complex tasks such as generating medical reports from images, generating medical images from reports, medical image-to-image translation (such as medical image manipulation conditioned on text), and information retrieval that can consider either medical images or text or both.

Over the past 12 months, we have investigated recent machine learning and artificial intelligence techniques to improve chest X-ray report generation. We also participated in an international challenge where we placed 3rd for medical image captioning (the medical image captioning task is shown in the figure below). We are now investigating methods to expand the number of medical image analysis tasks we can consider.



This image is a transverse evaluation of the bladder and right ureteral jet. Renal ultrasound studies also include evaluation of the ureterovesical junction through color flow doppler study of fluid movement of the ureteral jet.



Craniectomy patient (a) wears skull cap containing sensor (b) which sends data to a mobile device for cloud storage (c) accessed via a web-based clinician portal (d) to determine optimal timing for cranioplasty.

Images (a) doi.org/10.1186/s41983-019-0077-8 (b) CAD (c) Getty Images/iStockphoto (d) Siemens Healthineers.

SkullPro2: wearable sensor and clinician portal for remote monitoring of craniectomy patients

Collaborators: Anatomics, Data61

Decompressive craniectomy involves removing a portion of the skull to relieve potentially fatal brain swelling. As the swelling can take months to subside, the patient is discharged from an acute care facility to recover elsewhere prior to cranial reconstruction surgery (cranioplasty). Cranioplasty is associated with a high complication rate due to infection, seizure and brain bleeds.

Our objective is to allow clinicians to remotely monitor patients to facilitate optimal pre-operative review, which may lead to improved health outcomes. Working with our collaborators we developed a 'smart' device fitted into a skullcap to measure physiological parameters and relay this information to the clinician via a cloud-based data processing framework. Our preliminary studies found clinicians were most interested in monitoring physiological variables (brain swelling, skin temperature) as well as behavioural factors (headgear compliance, patient inactivity), with a preference for customised alert frequency. We are currently co-designing the functionality of the clinician portal with neurosurgeons and rehabilitation specialists.

Predicting long term outcomes for babies born pre-term: a six-year follow-up study (PREBO-6)

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

Pre-term infants face a range of adverse neurodevelopmental outcomes, including cognitive, behavioural, educational and motor deficits. With collaborators, we followed up our landmark preterm cohort (PREBO) at six years to determine if MRI scans of preterm infants acquired at 29-35 weeks postmenstrual age are predictive of academic achievement and health outcomes at school-age.

Currently we have followed up 68 children at six years, with a high rate of MRI success due to the advanced facilities at the Herston Imaging Research Facility and the measures taken to prepare the children for the scan. Our expertise in management of the imaging, demographic and clinical data for this cohort on Redcap and XNAT ensure the value of this dataset for future research.

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.

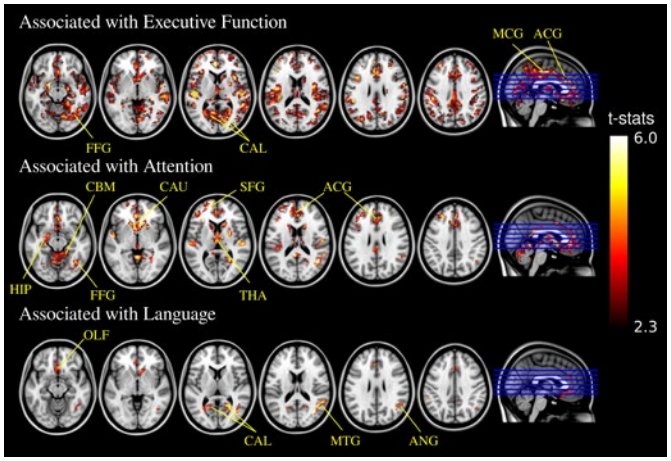
We are applying cutting edge imaging technologies to examine the neurobiological features associated with high risk for dementia and identify the changes that lead to a patient's transition from high risk to cognitive impairment. The combined use of genetic risk scores and neurobiological markers creates a potential prognostic marker for dementia development. Currently the baseline cohort of 304 subjects has been recruited for the PISA imaging study. Funding for the study is complete in 2022, with future research integrated into ADNeT to support future intervention programs that target preventing and treating dementia.

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 that target the symptomatic treatment of Alzheimer's disease. Identification of patients likely to respond to ChEI using biomarkers would significantly impact treatment and policy guidelines for the use of these cognitive enhancing drugs.

In this collaboration we are investigating a novel PET tracer for direct imaging of cholinergic neurotransmitter function. The current cohort of 26 participants underwent the baseline MR and PET imaging using florbetaben (FBB; for amyloid) and FEOBV radiotracers. Current baseline image analysis in association with cognitive assessment have demonstrated promising proof of concept that FEOBV PET imaging could be a direct and quantitative tool to assess region-specific cholinergic function in the cortex, which in turn could be used for early detection of future risk of Alzheimer's disease or to assist in the diagnosis of other neurological conditions with underlying cholinergic dysfunction.



Voxel-wise analyses of the correlation between the cholinergic integrity measured using FEOBV PET and domain-specific cognitive scores.

ChemoBrain

Collaborators: Royal Brisbane and Women's Hospital, Herston Imaging Research Facility

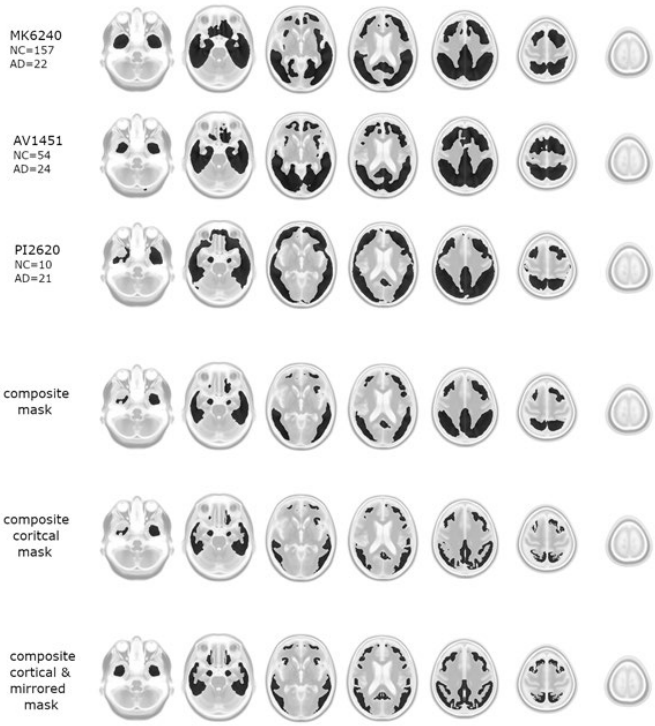
ChemoBrain trial is an MRI-based study, which aims to identify if chemotherapy associated neurocognitive impairment in acute myeloid leukaemia (AML) patients is linked to brain iron overload. It is a prospective observational longitudinal cohort study and patients undergoing standard chemotherapy treatment will be eligible for participation in this study. Recruitment is ongoing, with 20 patients recruited and 15 who have completed at least two assessments. MRI analysis provided advanced imaging reports that capture the anatomical and biochemical tissue properties. The trial outcome will help determine if iron chelation therapy may be a suitable intervention to prevent cognitive decline while patients undergo chemotherapy.

Universal tau sampling mask

Collaborator: Austin Hospital

Amyloid-β (Aβ) plaques and tau neurofibrillary tangles (NFT) are the two hallmarks of Alzheimer's disease (AD). Over the past two decades, the introduction of Aβ and tau PET ligands have allowed the assessment of both neuropathological markers *in-vivo*. As well as measuring therapeutic efficacy, Aβ and tau PET are crucial for the detection of AD pathologies even before the manifestation of the first clinical symptoms and the recruitment of participants to clinical trial at pre-symptomatic stage. Used routinely in clinic they provide critical diagnostic and prognosis information.

As for any biomarkers, the standardisation of PET quantifications is a crucial step to move the use of a new PET tracer from small research settings into the clinical arena. In this project, we constructed a "universal" tau mask for the Alzheimer's disease continuum from all the major tau ligands aimed at standardising tau sampling (and quantification) across tracers and across centres.



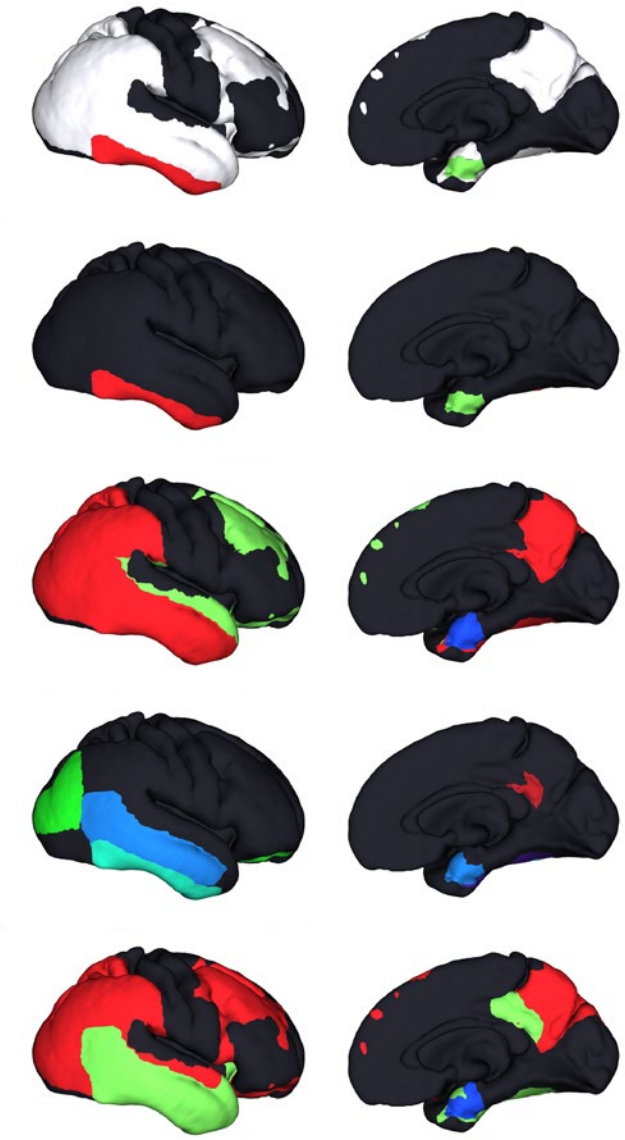
Top three rows are the tracer specific tau masks, followed by the composite, composite cortical and the composite cortical and mirrored mask.

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.

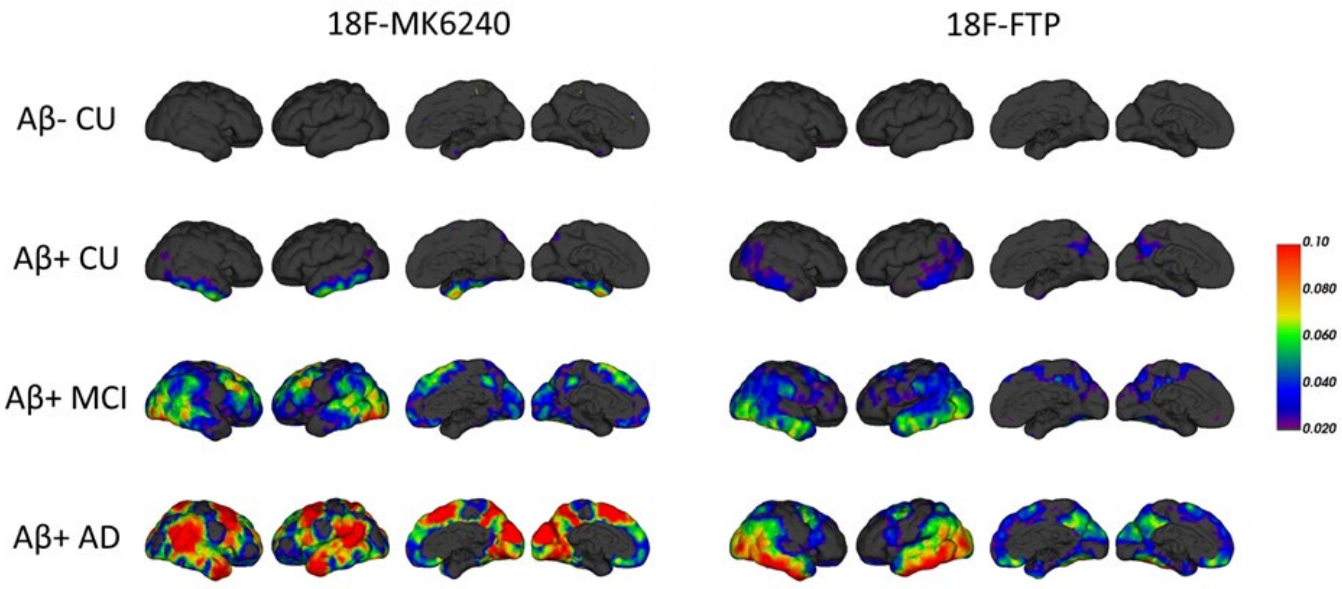
Cross-sectional and longitudinal comparison of 2 tau PET tracers in case-matched populations

Collaborators: AIBL, University of Pittsburgh

Longitudinal tau quantification provides a useful biomarker of drug efficacy in clinical trials. Each tau PET tracer has a different sensitivity to longitudinal changes, but without head-to-head datasets, the results obtained in different cohorts can be biased. In this study we developed a method to minimise this bias by case-matching subjects in two cohorts imaged using either 18F-MK6240 or 18F-flortaucipir (FTP). In our case-matched population we found that at baseline both tracers can detect significant differences between clinical groups. However, 18F-MK6240 was able to detect higher rates of accumulation in preclinical cognitively unimpaired individuals. These results indicate that 18F-MK6240 might be a more sensitive tracer of early accumulation.



Sub-segmentation of the universal mask. From top to bottom, universal mask, Johnston/Spearling, Rabinovici/Jagust, Jack/Lowe, Villemagne/Dore



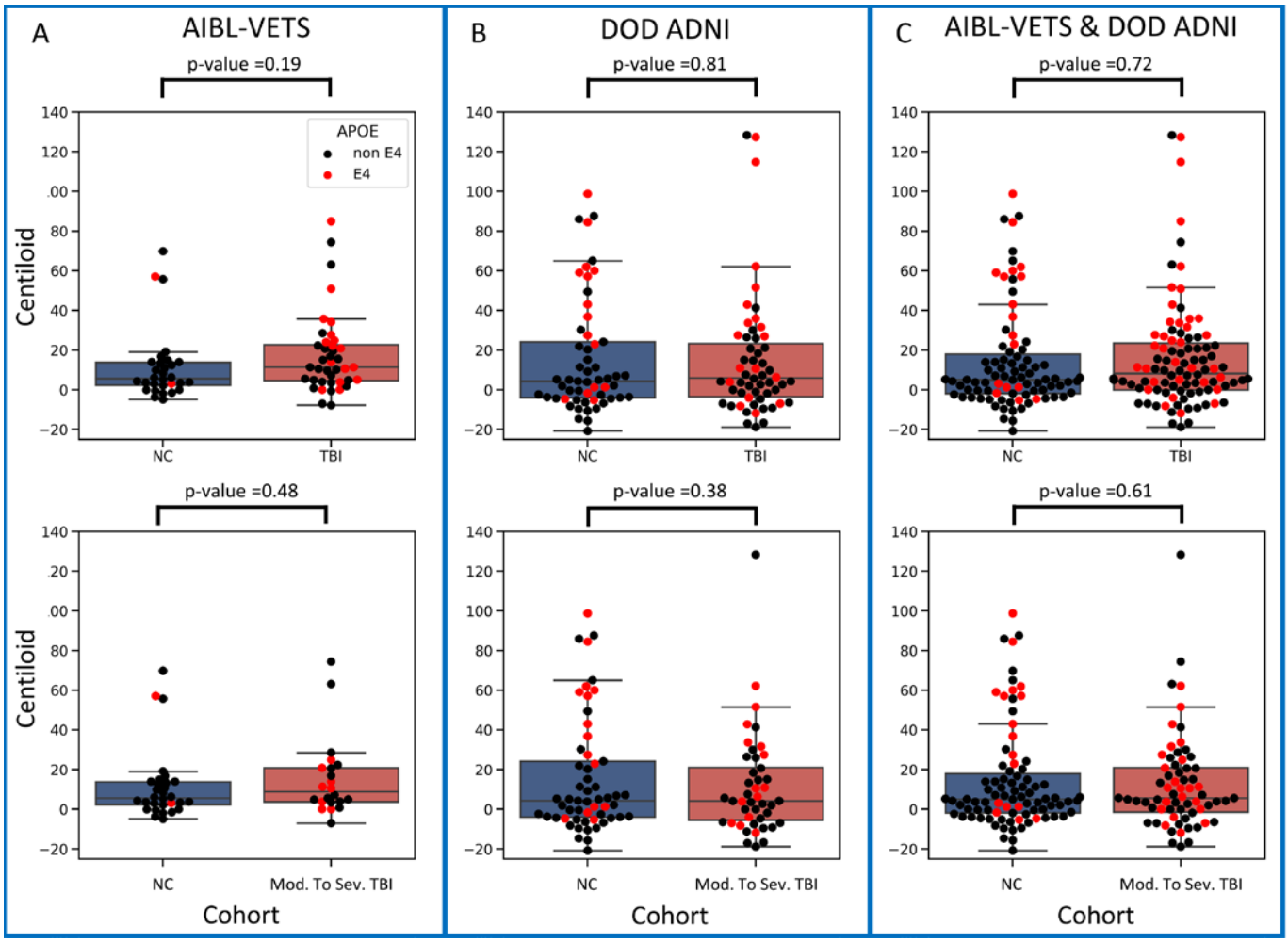
Mean increase in SUVR/Year in each subgroup for 18F-MK6240 (Left) and 18F-FTP (Right). CU cognitively unimpaired, MCI, milc cognitive impairment, AD Alzheimer’s disease.

Tau, β-amyloid, and glucose metabolism following service-related traumatic brain injury in Vietnam war veterans: The AIBL-VETS study

Collaborator: Austin Health, DOD-ADNI

In the 2020 Lancet report on dementia prevention, traumatic brain injury (TBI) was listed as a factor that can contribute to increased dementia risk. However, no differentiation between AD and non-AD dementia was performed and the mechanism underlying this increased dementia risk remains unclear. In this study, we used data from the Australian Imaging Biomarkers and Lifestyle – Veterans study (AIBL-VETS) cohort to compare β-amyloid and tau biomarkers for AD pathology, and FDG as a marker of neurodegeneration in Vietnam veterans with a history of TBI compared with case-control individuals. The analysis was validated on an independent DOD-ADNI (US Department of defence Alzheimer dementia *Alzheimer's Disease Neuroimaging Initiative*) cohort.

We did not find evidence of increased amyloid deposition amongst veterans with TBI nor in tau tracer uptake, even in those with more severe injuries. Our findings were replicated in the DOD-ADNI validation cohort. Our findings suggest that TBI is not associated with the later life accumulation of the neuropathological markers of AD and that the observed increase in dementia risk may be due to other causes of dementia as has been suggested, such as dementia with Lewy bodies or frontotemporal dementia.

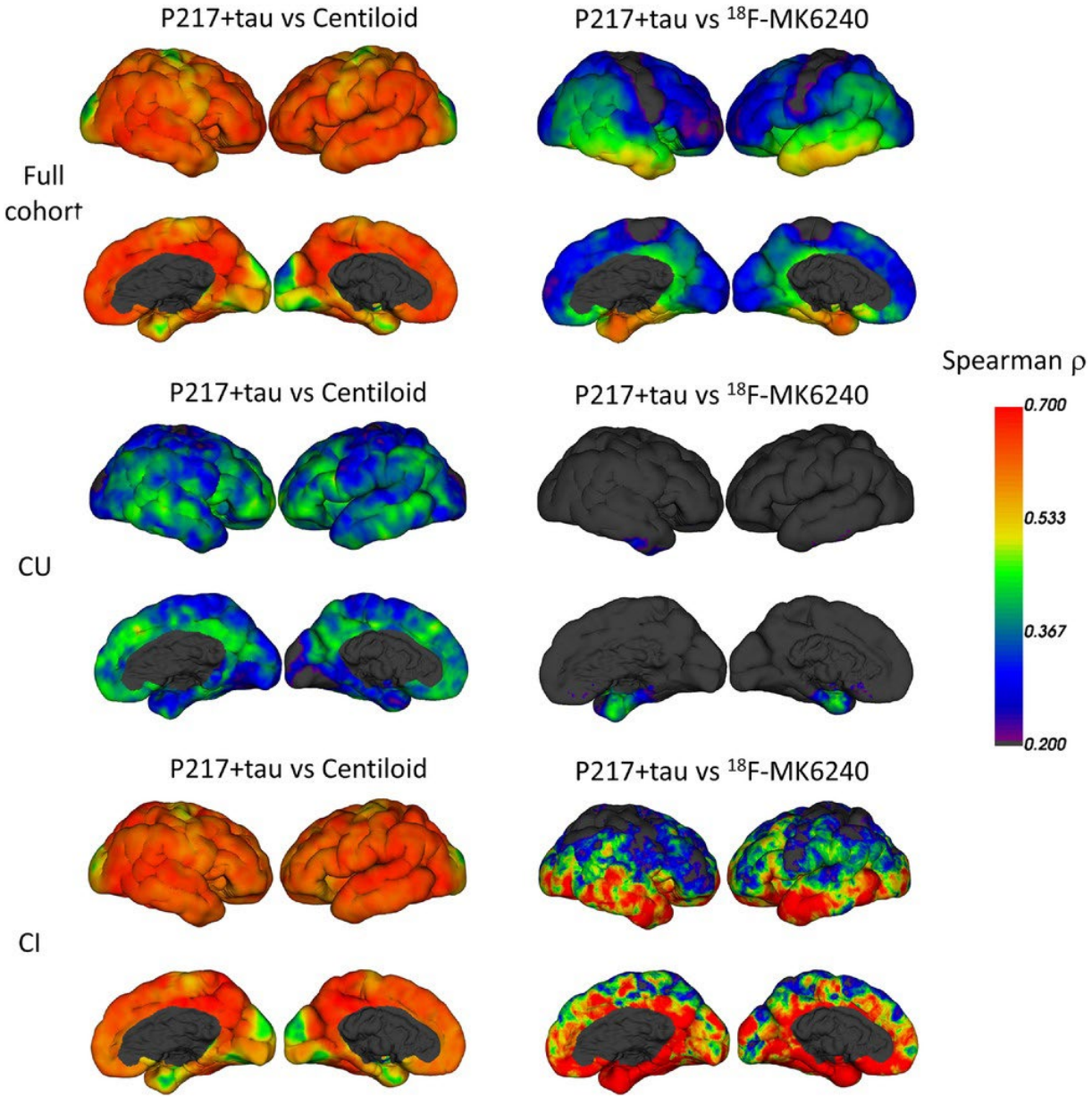


Amyloid quantification for Vietnam veteran without (NC) and with TBI history from AIBL-VETS and DOD ADNI cohorts and both cohorts together. Top row – normal controls (NC) vs all TBI; Bottom row – NC vs moderate or severe TBI

Assessing a novel blood measure of phosphorus tau against Alzheimer's disease pathologies amyloid beta and tau

Collaborator: AIBL, Janssen

Over the last 15 years, the AIBL study have been collecting PET imaging data from tracers designed to identify amyloid beta and tau. By retrospectively analysing blood samples collected at the same time, using an assay developed by Janssen, we measured the abundance of phospho-tau 217+ (pTau217+). This analysis demonstrated that plasma p217+tau obtained a high accuracy in detecting Aβ+ individuals across the clinical spectrum. Our data suggest plasma p217+tau (1) begins to rise soon after brain Aβ levels begin to trend up as assessed by PET; (2) concordant with the rise in tau in the amygdala region on PET; and (3) prior to the rise in meta temporal tau PET. In conclusion, an elevated level of plasma p217+tau is associated with both elevated Aβ and tau across the clinical spectrum of AD. Elevated p217+tau strongly supports a diagnosis of AD in persons with MCI or dementia, whereas a low level in CU persons is strong evidence against preclinical AD.



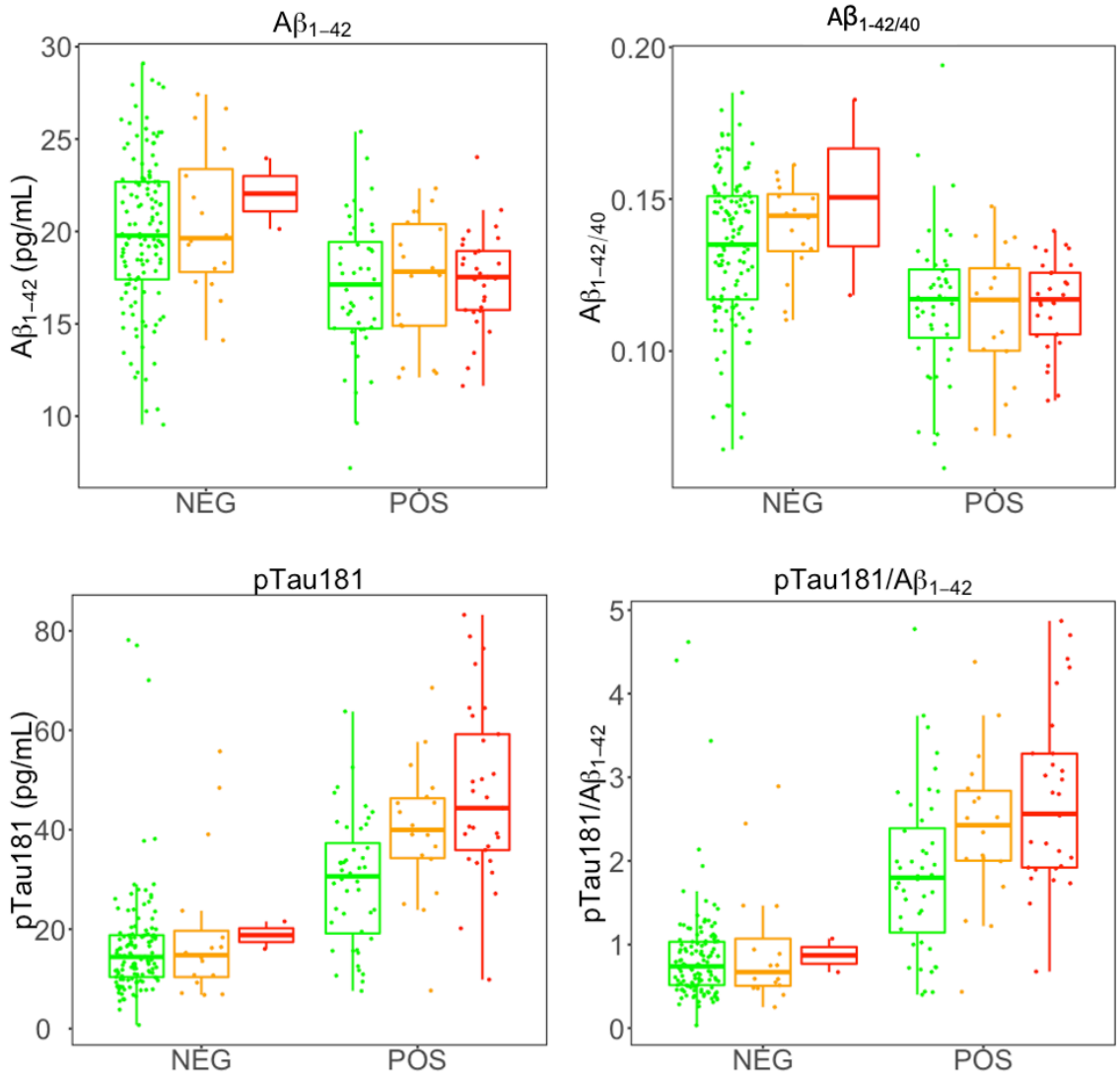
Vertex-based analysis of regional Spearman correlation between plasma p217+tau and Centiloid (left column) and 18F-MK6240 SUVR (right column). CU is cognitively unimpaired, CI is cognitively impaired.

Fluid based biomarkers to predict Alzheimer's disease (AD)

Collaborator: AIBL, Biogen, Roche, Eisai, Biogen, AbbVie, Janssen

Identifying biomarkers for the early prediction of AD pathology and the cognitive trajectory of the disease are important for the increasing number of pharmaceutical treatments for prevention. In collaboration with several pharmaceutical companies, we have been assessing a range of potential biomarkers for predicting AD pathology and progression.

Our research is focused on 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. We are working with the world's largest pharma and industry partners to define an optimal blood test for AD. Shown below is an example of a blood-based biomarker to predict the AD pathology amyloid beta as measured via PET imaging. Shown below is an example of some blood-based biomarkers that differ between those with/without AD pathology.



Example blood-based biomarker data to separate PET Amyloid positive participants from PET amyloid negative participants. Top Left: blood based AB42 (y-axis) vs PET amyloid groups (NEG = amyloid negative, POS = amyloid positive) (x-axis). Bottom Left: blood based pTau181 (y-axis) vs PET amyloid groups (x-axis). Top Right: blood based AB42/40 ratio (y-axis) vs PET amyloid groups. Bottom Right: blood based pTau181/ AB42 ratio (y-axis) vs PET amyloid groups. Green represents those who are Cognitively normal (CN), orange represents those who have Mild Cognitive Impairment (MCI), and red dots represent those who have Alzheimer's disease (AD).

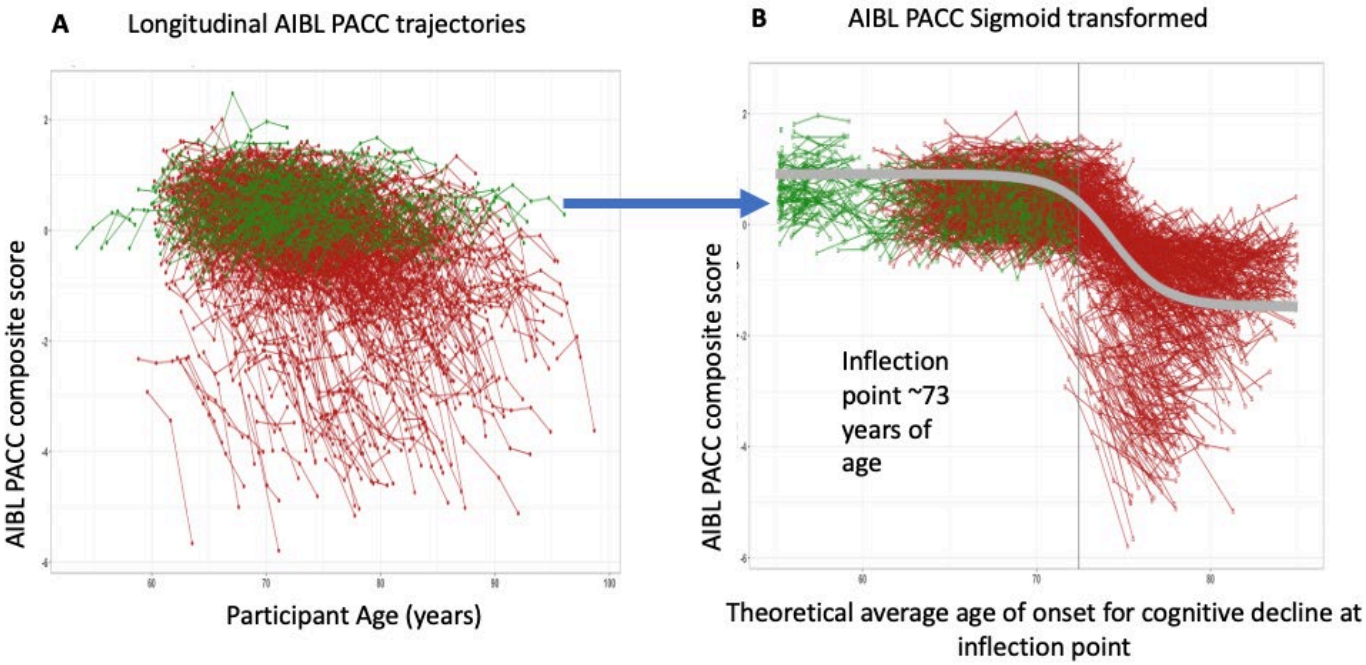
Biostatistics for Alzheimer's disease biomarker identification

Collaborators: Australian Imaging, Biomarkers and Lifestyle Study, Biogen

Alzheimer's disease has a long lag period between the onset of pathological changes and clinical symptoms. The AIBL study of ageing has been focussed on identifying biomarkers to detect disease pathology prior to the onset of clinical symptoms.

The Biostatistics team contributed to a five-cohort wide international collaboration to understand the underlying disease aetiology for the FDA application for the Biogen drug Aducanumab. Within this work, we selected participants from the AIBL study that met the strict admission guidelines for Biogen's two clinical trials and assessed imaging and cognitive biomarkers related to change in the Mini Mental Score Examination (MMSE) and Clinical Dementia Rating (CDR) score. Using results from AIBL and the other four cohorts, Biogen was able to formulate a better understanding of Alzheimer's disease and using this knowledge Biogen have now been successful in their FDA application.

This is the first drug conditionally approved for AD in 20 years and marks a huge milestone for possible disease treatment. The figure below demonstrates some of the work that was sent to Biogen as part of the collaboration with AIBL, with the graphic demonstrating the data before (left) and after (right) the sigmoid transformation to identify those participants who have declining cognition (those in red). Shown as the grey vertical line is the average age at which participants in this population begin to decline cognitively.



A. Longitudinal trajectories for the AIBL PACC cognitive composite score. Red lines indicate participants classified as having accelerated cognitive decline, green line represent participants classified as stable cognition. B. AIBL PACC sigmoid transformation to yield mean age of onset of cognitive decline. Vertical grey line indicates point of inflection where cognition begins to decline.

Biomedical Informatics: Postdoc and Student Highlights

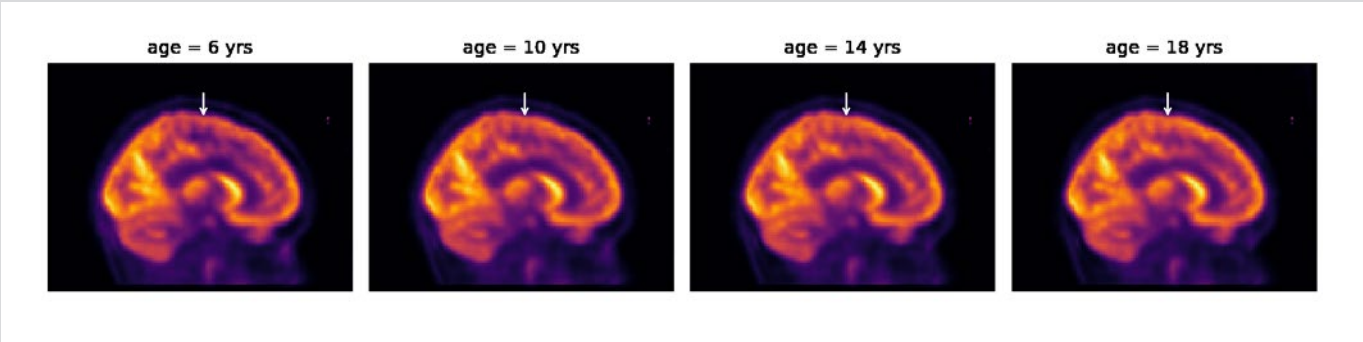
Modelling healthy neurological metabolic development in children

CSIRO Early Research Career Fellow: Ashley Gillman

Collaborators: Sydney Children's Hospitals Network (SCHN, Westmead Research Hub)

Changes in brain metabolism in children as they develop are poorly understood. Positron emission tomography (PET) allows for this to be measured, but this is rarely performed due to radiation exposure.

As part of his postdoctoral research, Ashley Gillman is creating a map of paediatric metabolism that shows the development of healthy brain activity to 18 years. This project leverages a retrospective cohort collected over the last decade, consisting of healthy paediatric brain PET images acquired at Sydney Children's Hospital. This metabolism map will provide insight into healthy brain development and provide a reference for future diagnostic tools that identify atypical brain metabolism. Current research is focused on optimising a deep learning algorithm to produce a spatiotemporal 3D map of brain metabolism.



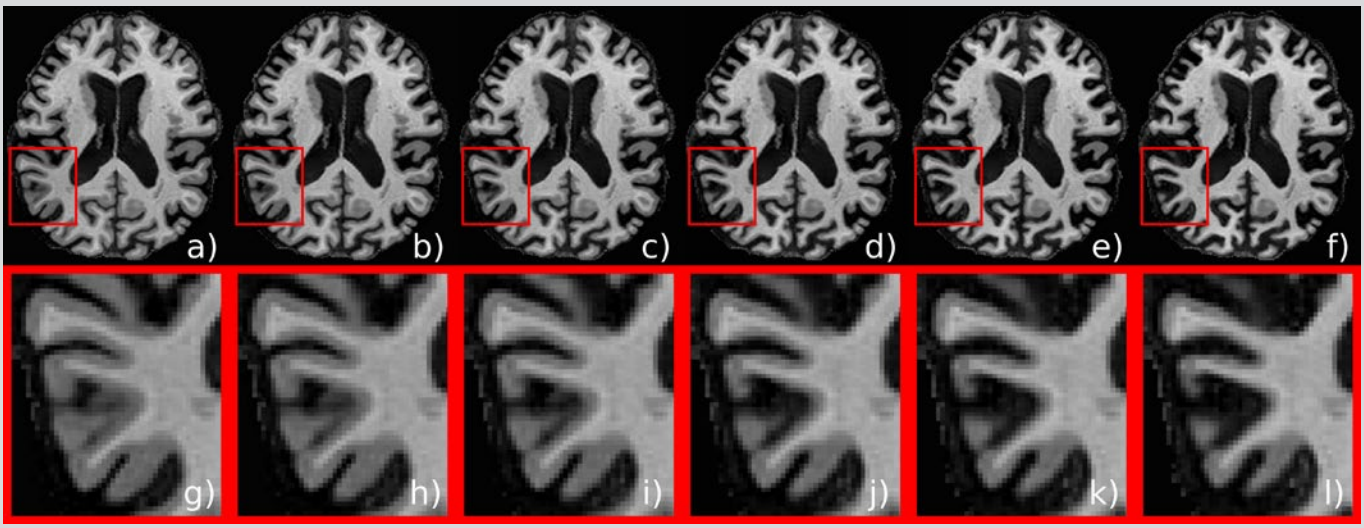
Population average maps show changes in metabolism over time. The pictured map is produced from a reduced dataset used for validation of the technique. Increasing metabolism in the superior frontal lobe (arrow) is consistent with previous studies.

Quantifiable brain atrophy synthesis for benchmarking of cortical thickness estimation methods

PhD Students: Filip Rusak

Collaborators: Queensland University of Technology (QUT), Maxwell Plus

Adequate evaluation of cortical thickness estimation methods requires a longitudinal dataset with quantifiable atrophy (ground truth) between subjects' time points—rarely available in medical imaging. This study investigates a method to address this lack of ground truth labelling for cortical thickness estimation evaluation and methods benchmarking. Specifically, we developed a method that performs brain atrophy synthesis based on existing cortical surface meshes. This was used to create a synthetic longitudinal brain MRI dataset with each subject having 19 follow-up scans (19 levels of atrophy). The synthetic dataset is suitable for cortical thickness estimation methods benchmarking and is publicly available at the CSIRO Data Portal.



Synthetic brain MRIs with uniformly introduced atrophy at different levels: a) 0 mm, b) 0.2 mm, c) 0.4 mm, d) 0.6 mm, e) 0.8 mm and f) 1 mm. The corresponding zoomed areas are shown in g), h), i), j), k) and l), respectively.

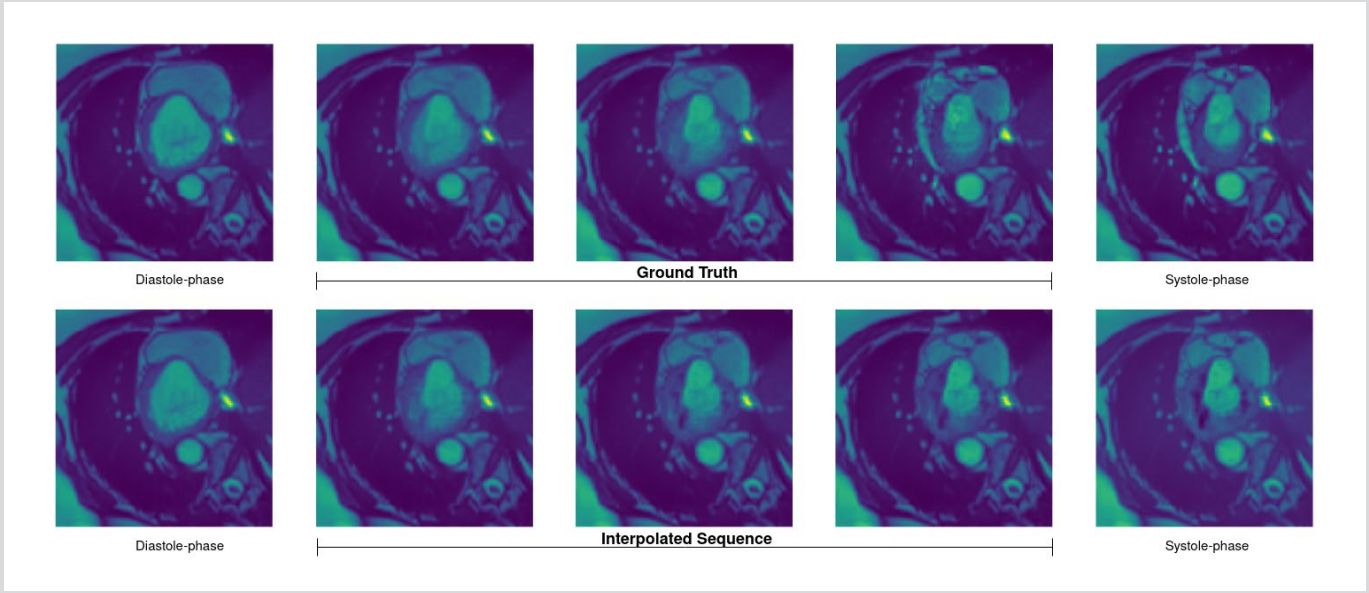
Motion prediction to improve patient management in MR-guided radiotherapy

PhD Project: Febrio Lunardo, supervised by Ashley Gillman

Collaborators: Townsville University Hospital, James Cook University

Recently developed prostate radiotherapy systems provide precise image guidance when delivering radiation to treat cancer. Unfortunately, patient movement during the treatment limits their accuracy.

As part of this PhD, a model has been developed to predict (1) the types of movement likely within a session based on patient features such as bladder volume, and (2) the likelihood of future motion to impact the treatment accuracy. This technology should allow radiotherapy sessions to be planned more effectively and more precise bounds to be defined for the treatment volume of the prostate. A computational spatiotemporal model has been developed and validated on data from the heart. This was shown to produce anatomically accurate interpolation of motion over time.



A deep learning model can interpolate between cardiac cycles (diastole and systole phases) on MRI in a proof-of-concept model to be applied in prostate radiotherapy.

The Health Services Group

Group Leader: Mohan Karunanithi (until October 2021) and Marlien Varnfield (From October 2021)

Our Health Services scientists yoke emerging sensor systems, digital technologies, data access, and analytics to accelerate the healthcare revolution, catalysed by the COVID-19 pandemic. The positive impact technology in health services is becoming increasingly visible. We have seen truly remarkable examples of higher calibre of care delivery demonstrated by our partners and collaborators embracing digital solutions to improve their service delivery to the elderly, people living with disability and the chronically ill. Our expertise in developing cutting-edge digital platforms, and the validation of new models of care are well illustrated in our science and impact highlights.

Health Services' science and impact highlights for 2020/21

- The implementation trial of the M♡THer platform (developed to support women with gestational diabetes) has seen over 4000 women and their treating physicians benefiting from the solution. The imminent roll-out of pregnancy hypertension support will further benefit women in 3 major NSW hospitals.
- We completed a 12-month Smart Home random control trial among 200 older people – one of the largest trials undertaken in Australia. The aim was to evaluate whether smart home technology-enabled self-management and care delivery can maintain or improve the impact of care provided by aged care service providers to older persons living independently in their own homes. Results indicate that smart home intervention significantly improved the health-related quality of life and quality of care of the participants.

- The “Smart foot monitoring for diabetic foot care and amputation prevention” feasibility project concluded that the diabetic foot sensing system developed by our Mobile Health Systems Team was fit-for-purpose and viewed favourably by participants. Further work in this field is now being supported by CSIRO appropriation funding
- A retinal imaging study at Royal Perth Hospital has advanced understanding of how eye imaging may provide precision, dynamic assessment of cardiovascular risk, leading to better outcomes for patients.
- We developed a framework and implementation roadmap to support participants from the National Disability Insurance Scheme (NDIS) to objectively and reliably evaluate existing and new AI-enabled Assistive Technologies.
- We completed the first phase of the Care Assistant and support Program for people after Stroke or transient ischaemic attack (CAPS). This stage included the co-design (with over 200 consumers and clinicians) and development of a new platform (mobile app and clinical portal) to support secondary prevention of stroke.
- Completed a pilot study of M♡THer-HF platform at The Prince Charles Hospital Heart Failure Service to evaluate the functionality of the prototype and to understand potential user acceptance and challenges of implementation.

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 combines 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
(to January 2022)

David Silvera
(from January 2022)

With wireless sensors, mobile technology and health technology pervasive in everyday use, new and rich sources of data are now available to determine the influence of lifestyle on health and wellbeing. The Health Internet of Things team has developed an innovative home-care platform that can access and aggregate data from a wireless 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, as well as support their carers and service providers.

Mobile Health Systems team

Team Leaders:

Marlien Varnfield

Christian Redd

Jane Li

Increasingly, the focus of chronic disease management is shifting to in-home and community settings. The use of mobile technologies in healthcare as mHealth solutions has become an integrated part of care, transforming the future of medical services and routine clinical care. With the increasing use of wearable and other smart devices, patients and providers are increasingly relying on health apps to facilitate diagnosis, treatment, and care. The Mobile Health Systems team works closely with clinical partners to develop new innovative care models using smartphone, Internet, and home monitoring and lifestyle devices with the aim to make prevention and management of chronic disease services accessible to all people from their homes or communities.

Tele-Health Solutions team

Team Leader:
Janardhan Vignarajan

The Tele-Health Solutions team develops and deploys software tools and solutions, enabling efficient delivery of remote healthcare and supporting telemedicine research. Our team plays a key role in bridging the gap between healthcare requirements and cutting-edge research. Our team works with clinicians to deliver software applications usable in the health service industry. The Tele-Health Solutions team has expertise in developing software tools for AI, interactive clinical visual systems, big data labelling and automation on cloud technologies and traditional infrastructure.

Health Services: Platform Technologies

Smarter Safer Homes platform

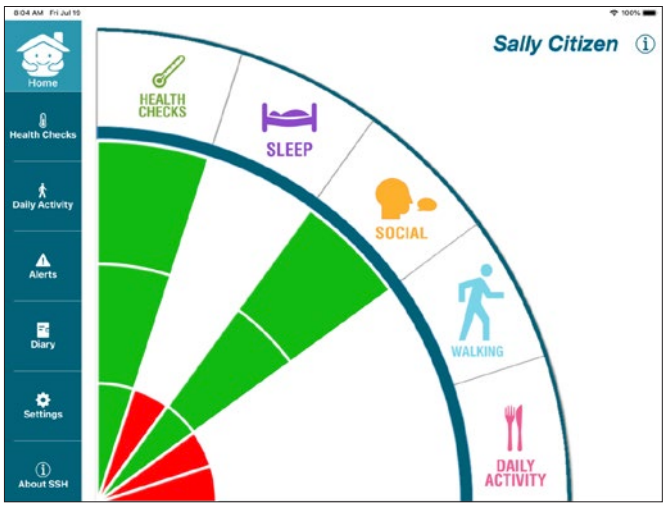
Our Smarter Safer Homes (SSH) platform was developed to support people to be functionally independent and live longer in their own homes as they age. The platform uses cutting edge pervasive communication and wireless sensor and monitoring technology and features a novel metric that determines personalised functional independence, indexed through the objective activities 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 for self-management, and opportunities to engage support from formal and informal care providers.

Evolved via several pilot studies since 2013, the platform recently underwent a randomised control trial among 200 older people receiving support from three aged care providers. The outcomes of the trial will determine if the SSH technology intervention improved the quality of life of older residents and care by the service providers, as well as its cost benefits to the service.

The SSH platform technology readiness is at TRL 8, having been licensed to an Australian ASX listed company, and currently being integrated within a commercialised aged care platform and service offering.

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

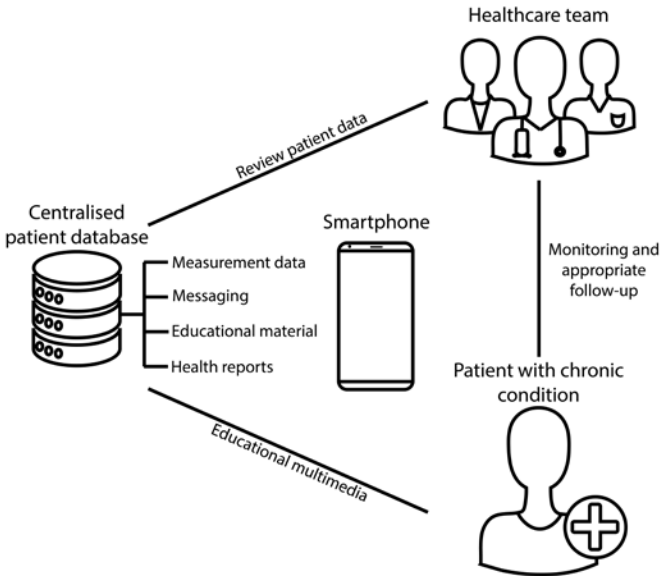


The SSH mobile application enables residents to view data derived from the sensors and medical devices.

Mobile health platform

Our mHealth platform, developed to support the management of chronic conditions such as cardiovascular disease, diabetes, kidney disease and mental illness, has recently been extended to the management of hypertension, heart failure and stroke. The digital solution, which utilises smartphone apps and the internet for ambulatory monitoring of health and wellness measures, was re-engineered and improved to integrate new wearable technologies such as a variety of activity and sleep-tracking devices.

Applications of the mHealth platform for various medical conditions are being evaluated in collaboration with our health service and industry partners. In addition to using the platform for self-management of existing health conditions, we have also developed a preventive smartphone application risk profiling matrix for chronic diseases.

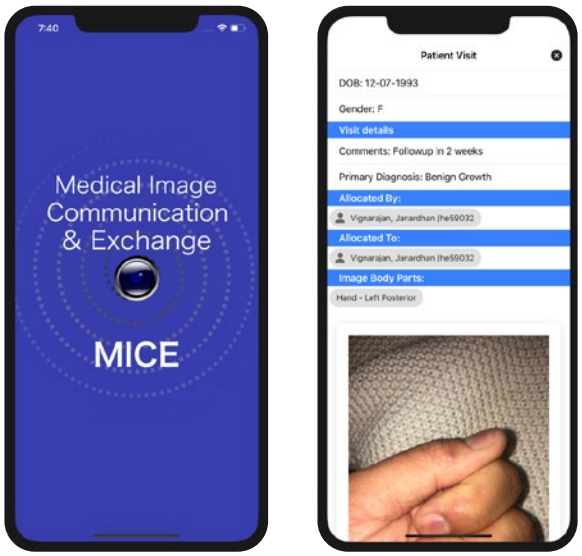


Components of the mHealth platform and data communication.

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 the MICE platform, a secure and safe mobile health platform which assists clinicians to manage patient-related images and consent forms securely. The MICE platform does not store any information on the clinician's smartphone, and automatically sends the records to the hospital's electronic medical record system, helping to protect patient confidentiality and privacy through a controlled process. The platform consists of a centralised server which accommodates the communication, along with two mobile applications (MICE and eCo). The platform also has web access that provides various features including integration with hospital infrastructure.

The platform has now transitioned to "business as usual" technology within the WA Health infrastructure and has been deployed in different clinical settings, such as burns ward rounds, plastics, emergency cases, radiology consent forms and home-based patient visits by nurses. We are also further exploring collaborations to expand the technology in rural and remote regions in the general practitioner setting and Aboriginal health workforce.

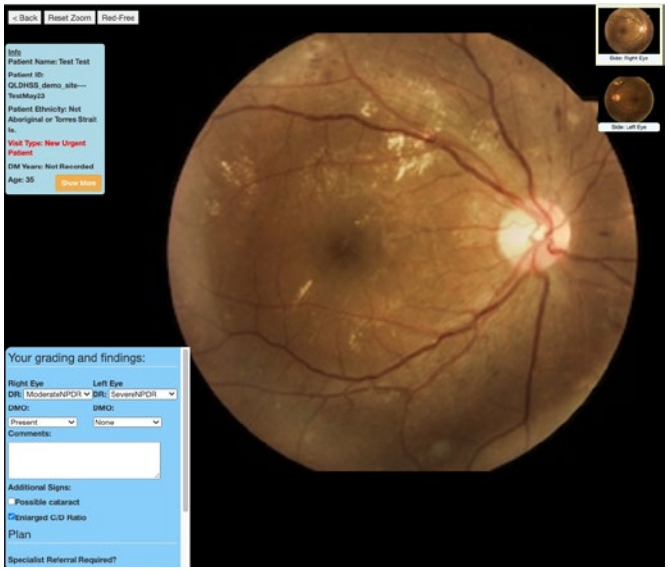


The MICE app image review

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 enables 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.

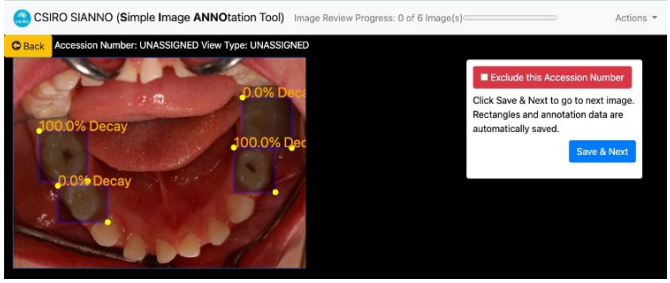
The technology has been deployed into CSIRO-managed cloud infrastructure with implemented cybersecurity best practices such as two-factor authentication, encrypted end-to-end communication and well-monitored cloud infrastructure. It is scalable and can be translated into different clinical settings. Medical device integrations were also achieved through a client-side application (the Remote-I Sync app) which reduces the double entry of data. The technology accommodates various file formats including JPEG, PNG and DICOM. The platform has further been used with the QLD tele-health unit and we are working collaboratively with external partners on future deployment.



Remote-I – Eye Specialist Review Screen

SIANNO: simple image ANNOtation platform

CSIRO has developed an easy-to-use image labelling and annotation platform (SIANNO) which manages the workflow of labelling, annotating and inferring medical images. The platform handles common 2D medical image formats and allows the user to use a handful of imaging tools (including rectangles, labels, custom labelling forms and polygons) in generating large amount of image dataset with a unified workflow. The platform has been made open-sourced in GitHub and is being used for various projects including dental AI, foot x-ray AI and diabetic foot wound detection. Once the AI model is trained, the output of the AI detection can be integrated into the platform for managing patient imaging workflow in a clinical environment.



AI detection integrated into SIANNO tool to detect dental caries.

AI-enabled AT framework for the National Disability Insurance Scheme (NDIS)

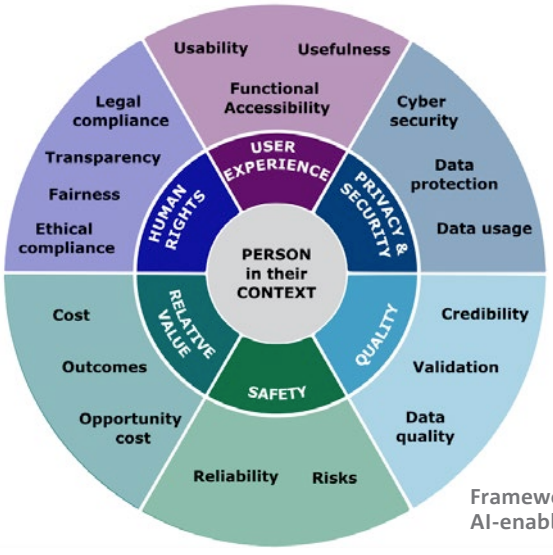
Collaborators: The National Disability Insurance Agency (NDIA)

Artificial Intelligence (AI) offers enormous opportunities for people with a disability. These innovations have the potential to promote better functioning as well as greater independence and dignity. This is particularly evident where AI is embedded with assistive technology (AI-enabled AT). However, there is currently little guidance for users, funders, and developers of AI-enabled AT on how to objectively evaluate existing and new AI-enabled AT.

To support use and innovation in this space, the NDIA commissioned CSIRO to design a framework and roadmap for AI-enabled AT. This framework will improve the capacity of the National Disability Insurance Scheme (NDIS) stakeholders to make decisions about AI-enabled AT and grow consumer trust in this technology.

This project was undertaken in three stages: (1) AI and AT frameworks review, (2) consultation with a variety of stakeholders (e.g., people with a disability, carers, and representatives from industry, peak bodies, and government departments), and (3) framework and roadmap development. This process resulted in a new framework (below) which focuses on six core domains: user experience, value, quality, safety, privacy and security and human rights. This framework also highlights the importance of a user-centric approach which places the person with a disability and their context (e.g., environment, social and cultural factors, community etc) at the centre of the framework.

The report delivered to the NDIA is a first step towards the development and implementation of an AI-enabled AT framework in Australia. A fully operationalised framework will require further collaboration with end-users, families, carers, disability workforce, and industry stakeholders.



Framework for AI-enabled AT

M♡THer Studies

Collaborators: Metro South Hospital and Health Service (MSHHS), Mater Mothers' Hospital and South Western Sydney Local Health District

Antenatal clinics are under growing pressure to deliver gestational diabetes mellitus (GDM) care to an increasing proportion of their maternity patients. To support patients and clinicians, we co-designed, developed and successfully tested a mobile platform, M♡THer, with 40 women at the Redland Hospital (Metro South Hospital and Health Service) in 2018.

In mid-2020, we began an implementation trial of the M♡THer platform at the Mater Mothers' Hospital and Redland Hospital, offering the M♡THer app as part of their usual care for all women diagnosed with GDM. Logan Hospital followed suit in 2021, offering the M♡THer app to all their patients with GDM on insulin medication. To date >3500 women with GDM have used the app, with clinicians and women reporting satisfaction with the usability of the mHealth platform. Early results also show that augmenting GDM patient care by introducing the M♡THer model of care has positive cost implications for the health service and for patients, without compromising clinical outcomes.

Royal Brisbane and Women's Hospital is soon to commence their participation in the implementation trial, expected to conclude at the end of June 2023.

Future studies will see M♡THer trialled for the management of hypertension during pregnancy in a randomised control trial at three South Western Sydney Local Health District hospitals in New South Wales. In Melbourne, Victoria, two major urban health services have indicated interest in trialling M♡THer to quantitatively compare maternal and fetal outcomes against usual care. As well as exploring the platforms' appropriateness for use with a high-risk population of women, those with type 2 diabetes in pregnancy and in the post-partum period; the project would have a special focus on understanding if the platform is an acceptable engagement tool to support the needs of culturally and linguistically diverse women experiencing GDM.

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

Smarter Safer Homes: DACS trial

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

This trial was a community based, aged care trial, that looked at a technology solution to support older people living independently in their homes. The research question examined whether smart home technology could maintain or improve the impact of care provided by the aged care service providers (ACSPs) to older persons living independently in their own homes. The technology solution was a home sensor system with an associated platform which was called the Smarter Safer Homes Platform (SSH Platform).

The DACS trial was conducted with 195 older people living in metropolitan and regional areas across South East Queensland. The setting was home-based, with participants living in their home, although they were receiving aged care home support from Anglicare Southern Queensland, integratedliving Australia, or All About Living ACSPs. Collaborators from Macquarie and Griffith Universities provided analysis of the ACCOM tool and health economics report.

The trial demonstrated significant improved health and social related quality of care of participants with SSH platform installed in their homes. It showed impacts on older persons' feelings of safety and confidence when having the technology installed in their homes. Service providers identified that the technology had potential to improve early intervention strategies and to provide increased "light-touch" monitoring of their clients. Carer burden measurements did not appear to see a reduction in carer burden overall, although informal carers appreciated the technology as an extra support for their loved ones. This research highlighted many future applications of the technology while also providing invaluable lessons in designing and implementing technology like this into the current aged care system within Australia.

The DACS trial was completed in October 2021 and the final report will be released shortly.

Paving the way for Australian health innovations in Vietnam

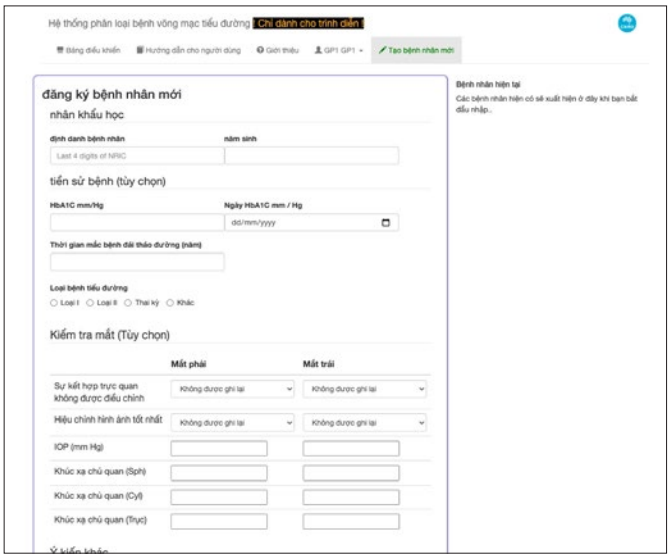
Collaborator: Fred Hollows Foundation

The complexity of diabetes and the prevalence of the condition globally is growing rapidly. One sight-threatening condition of diabetes is diabetic retinopathy (DR). CSIRO is collaborating with the Fred Hollows Foundation to explore DR prevalence in Vietnam. With our knowledge of service delivery in telehealth eye care in remote and rural Australia and artificial intelligence-based DR detection algorithms, this project works with various Vietnamese agencies in exploring a suitable telehealth model for a successful deployment of services which includes AI. The project is funded by the Department of Foreign Affairs and Trade through its Australia-Vietnam Enhanced Economic Engagement Grant (AVEG) Pilot Program.

Through our partnership with the Fred Hollows Foundation, the project team has coordinated a deep dive scan of the Vietnamese existing eye health service delivery model and the complications of diabetic retinopathy in the community, as well as the treatment pathways at communal, provincial and country levels. A final project dissemination and recommendation report will be submitted to DFAT along with plans for further engagement with existing stakeholders on new initiatives.

As a proof-of-concept, we translated CSIRO's telehealth platform into Vietnamese and demonstrated the platform and its capability (including AI-based DR detection) to potential stakeholders in Vietnam to facilitate the project activities.

This project was selected as a winner of the World Health Organization's (WHO's) first-ever Western Pacific Innovation Challenge "Innovation for the Future of Public Health". Over 400 public health innovators participated in the challenge and 29 were awarded. Recognition for this from the WHO, the world's leading organisation in the field of public health, is testament to the appeal of telehealth and AI solutions for increasing patient accessibility to DR screening and management, and a better understanding of the barriers and opportunities related to their uptake.



Remote-I Platform translated into Vietnamese language for demonstration to project stakeholders.

Prostate cancer detection and grading using deep learning on while slide biopsy images

Collaborator: AI4Path

In this CSIRO kickstart project in collaboration with the start-up AI4Path we have developed a deep learning-based system for automated assessment of prostate cancer using whole slide biopsy images (WSIs).

Prostate cancer is the second most common form of cancer in men, with more than 1 million new diagnosed cases worldwide every year. Diagnosis of prostate cancer typically involves histopathological assessment of biopsy tissue. Manual assessment of biopsy tissue is time consuming and requires specific expertise, of which there is a growing worldwide shortage. In recent years there has been an overall increase in cancer incidence and a dramatic increase in the number of biopsies reviewed per case. For these reasons, there is an emerging need to develop automated screening and decision support tools for prostate cancer assessment.

We developed and validated a deep learning prostate cancer assessment system that not only performs cancer detection but also detects perineural invasion and measures cancer portion to meet clinical reporting needs. The algorithm was integrated into a web-based visualisation tool developed by the team, which handles displaying the large volume of data with seamless integration of processing workflow allowing the users to process, visualise and generate reports from WSIs using just a web-browser. Accuracy for cancer vs benign classification was 91% on a novel test dataset. The system also computes slide level measures such as minor/primary/secondary tumour pattern area (in mm2).

Remote management of diabetes mellitus pilot in Chile

Collaborator: CSIRO Chile

In collaboration with CSIRO Australia and CSIRO Chile, the project is developing a convolutional neural network-based system for automated segmentation and detection of diabetic foot and wounds.

Diabetic wound is an open sore on the foot due to neuropathic and/or vascular complications in patients with diabetes mellitus and represents a major health problem around the world. Early detection of wounds progression is crucial to ensure proper treatment and management of diabetic foot and to prevent amputations. As part of the diagnosis and care protocol in diabetic foot management, images captured from digital cameras and mobile phones can be used for remote assessment of the healing process. Automatic segmentation of wounds from images captured from the patients can play a major role in the management of the condition. Automatic segmentation facilitates quantitative measurements of the wound region, which is crucial to assess the progression of wound over time.

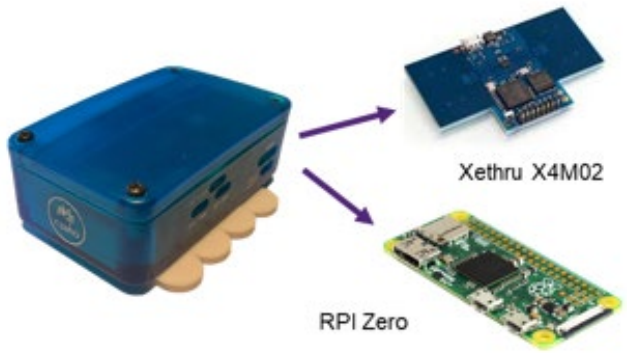
In recent years there has been an increased interest in developing deep learning techniques for automated segmentation of wounds. CSIRO has developed a system with a 2-step approach utilising convolutional neural networks (CNNs) for fully automatic segmentation of diabetic wounds. An innovative CNN named Amended-UNET (A-UNET), which improves upon U-NET was developed for this method. Segmentation of the wound is performed in the second step, followed by segmentation of foot. In each step, following A-UNET, advanced image processing techniques are applied to refine the outputs. An annotated dataset containing 3,450 diabetic foot images with wounds was collected and used for this study. Comprehensive evaluation was undertaken with state-of-the-art methods namely SegNet, U-NET, Mast R-CNN. The developed system outperforms other methods in terms of precision and speed.

Feasibility study of UWB sensor to classify falls in a home environment

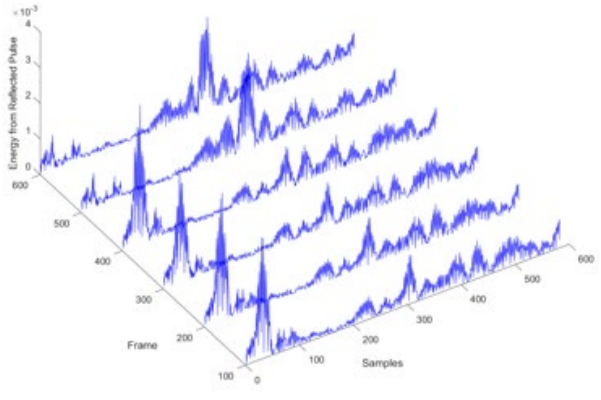
Collaborator: University of Queensland

For the elderly, falls can cause hip and wrist fractures and head injuries, which can lead to permanent damage and even death. For people over the age of 65, walking and standing around their own homes is one of the most dangerous of activities, accounting for 81% of all falls (Robinovitch et al., 2013). Fall detection systems solve this problem by alerting staff and family the moment a fall occurs.

In collaboration with University of Queensland, we explored the feasibility of an ultra-wideband impulse radar (UWB), developed by CSIRO's Mineral Resources research team, to detect a fall. We tested the UWB fall detection system in a realistic living environment. This was done by differentiating UWB data that contain participants performing either a fall, or an activity of daily living (ADL). We conducted a controlled lab-based trial to collect 60 fall samples, 20 discrete ADL samples and 40 continuous ADL samples from 10 young participants of varying genders and heights. An effective pre-possessing algorithm was developed that removed background elements from raw UWB samples via empty background plates. Four fall detection algorithms based on machine learning models were developed. Ultimately, the ConvLSTM algorithm saw the best result, with an accuracy of 93.78% and 4.2 million trainable parameters indicating that an optimal balance between performance and complexity was achieved.



Radar sensor prototype



Example of motion with static frames

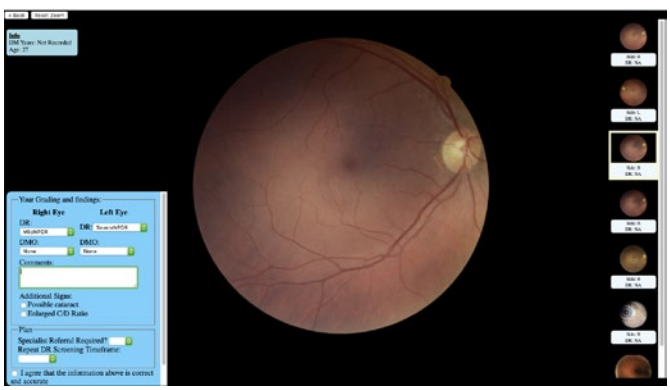
Remote eye care delivery in northern Australia

Collaborators: Queensland Health, Laynhapuy Homelands Aboriginal Corporation, Marthakal Homeland and Resource Centre Aboriginal Corporation, Gidgee Healing and NT Eye Specialists

This complex multi-year project co-funded by the Cooperative Research Centre for developing Northern Australia was completed in June 2022. A secure telehealth service now connects metropolitan-based ophthalmologists to patients in several regional and remote communities in Northern Territory and Queensland. The telehealth platform incorporates AI-based image quality and disease detection algorithms to complement and support decisions of eye health assessment teams. This service helps in closing the gap in providing specialist eye care to rural and remote communities, preventing needless blindness.

Over the course of the project, screening exams from 378 patients were uploaded to the comprehensive telehealth system developed by the team ('Remote-I') and diagnosed by ophthalmologists, exceeding the project target of 350. Almost all cases of sight-threatening diabetic eye disease can be avoided by having regular eye checks, and the project demonstrated improved health outcomes by earlier identification of disease in 64 patients. The project also resulted in cost savings relating to avoided patient travel to metropolitan areas, improved patient health awareness where the retinal camera was used as an educational tool, and capacity building of northern Australian healthcare workers to perform eye screening and obtain new knowledge about eye diseases. Health workers and patients reported being satisfied with the Remote-I system and the overall service offered.

The team also leveraged its learnings in validating and establishing tele-ophthalmology services and AI-based image reading in locations in rural and remote northern Australia to partner with the Fred Hollows Foundation to successfully win a tender issued by the Department of Foreign Affairs and Trade (DFAT) under its Australia-Vietnam Enhanced Economic Engagement Grant Pilot Program. In 2021-22, the Remote-I application was also broadened beyond retinopathy to other eye diseases (glaucoma, trauma etc.) and a new telehealth prison service was commenced with Queensland Correctional Services and Central Queensland Hospital and Health Service.



Health Services: Project Updates

Rehabilitation for pulmonary disease (m-PR)

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

Mobile pulmonary rehabilitation (m-PR) is the first Australian specific mobile health platform that allows people with chronic obstructive pulmonary disease (COPD) to complete a home-based pulmonary rehabilitation (PR) program supported by technology.

The m-PR platform is being evaluated through three research projects. The first evaluated the messages used to provide support for improved COPD self-management. The second project was user testing that showed the app was well received by participants with COPD (n=12). Results demonstrated excellent overall usability of the app, 91% (n=11) enjoyed using the app and found it easy to use.

A clinical trial is now underway (n=100) to evaluate effectiveness of m-PR compared to centre-based pulmonary rehabilitation. m-PR won Best Physiotherapy SIG research poster presentation at the 2022 Thoracic Society of Australia and New Zealand conference.

HAPPI MIND

Collaborator: Monash University

In 2020, an estimated 459,000 Australians were living with dementia. This number is expected to increase to more than one million by 2058. While there is currently no cure for dementia, there is evidence that some health conditions and lifestyles may increase the risk of developing dementia.

We're evaluating a new approach for assessing dementia risk and reducing dementia risk factors in middle-aged adults using practice nurses in the primary care setting. In this setting, individuals at high risk of developing dementia can be identified early, and targeted education, management and referrals can be organised. Currently, patients are being recruited from 17 primary care practices/clinics in VIC and NSW. Intervention participants receive access to a purpose-built HAPPI MIND app to support self-management of dementia risk factors at home, and to track progress against their goals. To date more than 30 people have been set up on the app.

MoTER-HF Heart Failure Study

Collaborator: The Prince Charles Hospital

Increasingly, mobile health technologies increasingly used to support the monitoring of health and well-being of patients with chronic cardiac diseases such as heart failure, particularly during the COVID19 pandemic. Understanding the needs of patients and clinicians and implementation challenges is crucial for the development of mobile health solutions. We are developing an interactive digital platform to support patients with HF, which consists of a smartphone app for patients and a web-based portal for clinicians.

We have completed a pilot study which aimed to evaluate the functionality of a prototype of the platform. Usability testing with 9 heart failure patients and interviews with 8 clinicians from The Prince Charles Hospital Heart Failure service were conducted in 2021. All participants were positive about the usefulness and usability of the technology and suggested these as important factors contributing to patient interest and engagement in longitudinal monitoring. Potential benefits raised included improving patients' self-reporting, data visualisation, patient-clinician communication and heart failure education. Clinicians shared potential challenges of mHealth data monitoring and associated responsibilities as well as solutions for improving monitoring efficiency and supporting patients' self-management.

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

Collaborators: QIMR Berghofer Medical Research Institute, University of Queensland

This project will elucidate neurobiological, psychological and physiological changes at a very early stage of dementia. The lifestyle stream will 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 are indicators of cognitive decline. In total, sleep data from 124 participants were collected using EMFIT QS and analysed to extract sleep measures and resting heart rate. Data collection and data analysis are complete. The outcome of data analysis (the association between sleep restlessness, genetic, and neuroimaging biomarkers of Alzheimer's disease) was presented in the Australia Dementia Research Forum 2022 and the Alzheimer's Association International Conference 2022.

Australia Dementia Network Lifestyle study

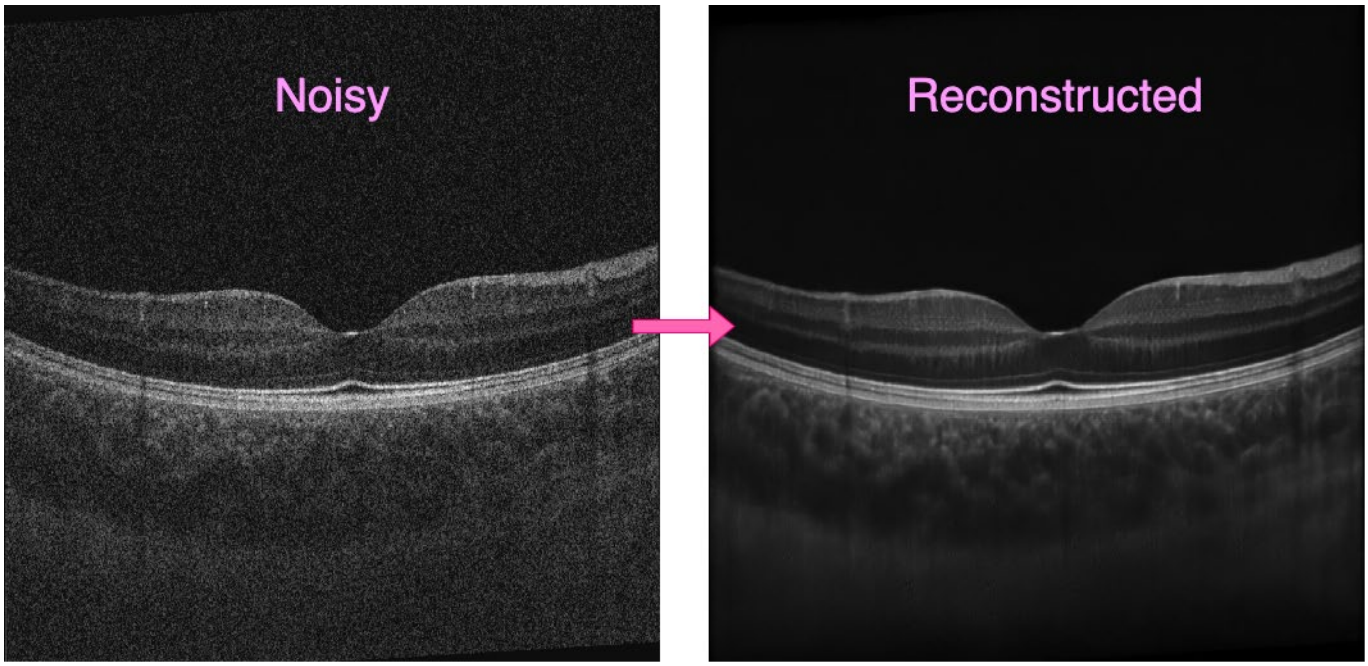
Collaborators: University of Sydney, Murdoch University, Australian Alzheimer's Research Foundation, Edith Cowan University, Royal Brisbane and Women's Hospital (RBWH), The University of Newcastle

This project will deliver novel insights regarding the role of sleep-wake disturbance over time and how it contributes to dementia risk. Ours is the first study to comprehensively characterise sleep-wake disturbances in older adults regarding their inter-relationships with dementia pathology progression, other modifiable risk factors, brain structure and function alterations, and cognitive changes in domains such as memory and language. The current study will be offered as an optional add-on study at the three institutions (Australian Alzheimer's Research Foundation, University of Newcastle, Royal Brisbane and Women's Hospital) that are current, established ADNeT recruitment sites. In Brisbane, the ethics approval has been received from RBWH Human Research Ethics Committee and reciprocal ethics has been approved by University of Queensland and CSIRO. Site Specific Approval (SSA) and privacy applications are in progress.

Retinal image reconstruction in optical coherence tomography

Collaborator: Queensland University of Technology (QUT), QUT Contact Lens and Visual Optics Laboratory (CLVOL)

Speckle noise, an inherent limitation of optical coherence tomography (OCT) images, makes clinical interpretation challenging. The recent emergence of deep learning techniques could offer a reliable method to reduce noise in OCT images. We investigated the application of OCT image reconstruction/denoising employing generative adversarial networks (GAN). We looked at the problem of OCT image denoising as a neural style transfer (NST) which is the process of using convolutional neural networks (CNNs) to render a content image in various styles. Specifically, in the problem of OCT image reconstruction, the aim is to render the noisy OCT image with the style of the averaged gold standard OCT image. The network training and results are completed and we are in the process of publishing the work and getting expert feedback from our collaborators.



A noisy image reconstructed using our technology

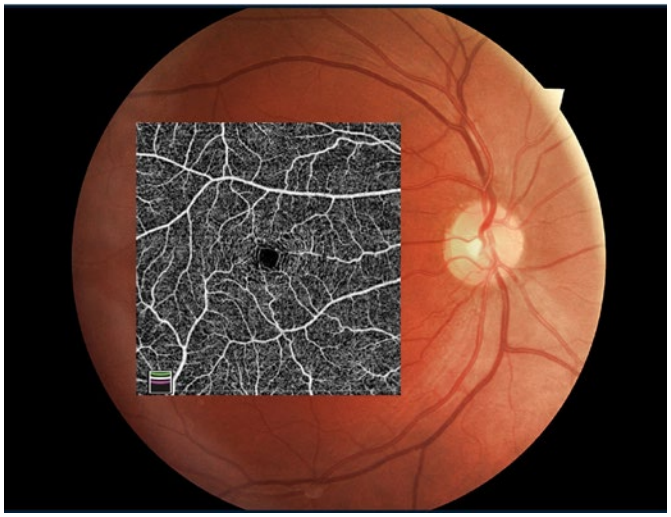
Retinal imaging for cardiovascular risk assessment

Collaborator: Dobney Hypertension Centre, Royal Perth Hospital

Hypertension remains the biggest killer worldwide, with >10M deaths per year directly attributable to uncontrolled blood pressure (BP). This can be improved through precision stratification of risk and individualised patient management. The retina – the light sensitive layer at the back of the eye, is unique in allowing us to directly image blood vessels and nerve tissue. By collecting retinal imaging data at the Dobney Hypertension Centre we advanced understanding of how eye imaging may provide precision, dynamic assessment of cardiovascular risk, leading to better outcomes for patients.

Retinal signs were found to associate with early hypertensive organ damage in the large arteries and kidneys. Retinal markers were also identified in those with increased cardiovascular risk due to abnormal nocturnal blood pressure changes. Additionally, we found participants with pre-diabetes exhibited early retinal vascular changes, supporting the concept that microvascular damage may already occur before the diagnosis of diabetes in this vulnerable cohort.

Non-invasive retinal imaging may provide an integrated measure of cardiovascular burden, allowing a precision medicine approach leading to better outcomes.



Optical Coherence Tomography Angiography image of the retina

Detection of osteomyelitis and toe amputations and patient management through AI in x-ray imaging

Collaborator: South Metropolitan Health Service, Western Australia

X-ray imaging of the foot is often used to diagnose diabetic foot infection. Assessment of osteomyelitis infections and its progression using x-ray is a challenging task even for experts. Along with our collaborators, Edith Cowan University and South Metropolitan Health Services, this project aims to analyse over 13,000 images of foot x-ray images and develop a deep learning-based AI model for determining the presence of osteomyelitis and toe amputations.

Funded by the Department of Health, WA, the project activities cover automated extraction of information from textual x-ray reports for disease conditions and correlate with image pattern recognition to identify the disease. A longitudinal analysis of the progression of the disease will also be explored in the project along with the development of a detection tool in clinical practice which is expected to streamline the diagnosis and prognosis process of the disease in the South Metropolitan Hospital environment.

AI in dental images and radiographs

Funder: WA Health Research and Innovation Office

We will develop AI to detect dental caries from dental radiographs (bitewing and panoramic x-ray images) and colour dental photographs. Data for the project was collected from various clinics across the Perth region. Several deep learning-based artificial intelligent feature detection models were developed and tested against the dataset. Several calibrated dental specialists were involved in labelling the data. With the bitewing radiographs and colour dental photographs, the project aimed to develop and validate deep learning (DL) system for automatic detection of caries. With the panoramic x-ray images, the project aimed to evaluate automated detection system for the detection and classification of permanent teeth in orthopantomogram (OPG) images. A total of ~4000 images were used to train multiple detection and classification AI networks. Research outcomes were published in conference, journal and client reports.

Evaluation of a tele-dental mHealth model in dental trauma environment

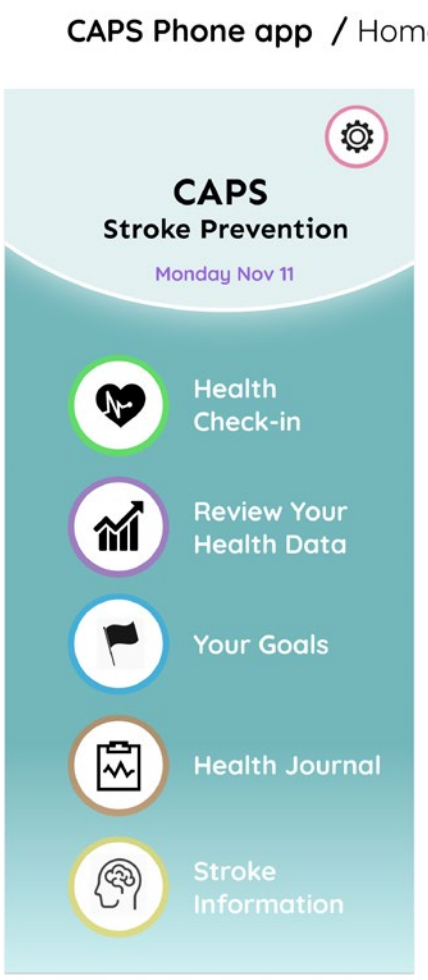
Collaborator: University of Minnesota

Funded by the International Association of Dental Research (IADR), we're collaborating with the University of Minnesota to determine the efficiency of the tele-dental and mobile-dental models in urgent dental trauma care. The project will capture data from the United States of America and Thailand hospitals and will capture photographs of dental trauma cases using smartphones through the mobile app (CSIRO-developed technology). The images will be reviewed by multiple dental therapists using a cloud solution (a web-based tele-dental dashboard developed by CSIRO) and the results will be compared with the on-site dental specialists' outcomes. The project started in 2022 and is scheduled until 2024.

CAPS – Completed mHealth app design, development and testing for stroke and TIA

Collaborator: Monash University

We developed a Care Assistant and support Program for people after Stroke (CAPS) or transient ischaemic attack (TIA). The CAPS program will be delivered via an app, with health and lifestyle data collected via digital consumer devices and will include a clinician to set-up, monitor and tailor the program to individual needs through a clinical portal. The main needs to be addressed by the CAPS program were identified in preliminary surveys with people who have experienced stroke or TIA (n=86) and healthcare professionals (n=76). We also finalised the design and development of the digital program and user interface via co design workshops. This program will be evaluated during feasibility trials to determine which components are utilised and accepted by people who have experienced a stroke or TIA. Evidence will also be collected to confirm the relevance of the electronic health data to facilitate secondary prevention of stroke, cardiovascular disease, and mental illness.



CAPS App Home screen

Robotics in residential aged care

Collaborator: Healthovation

Robotics is an area of digital innovation that has shown potential for wide impact. This project explored the potential challenges and opportunities for the implementation and long-term uptake of robots in the Australian residential care sector. This study was conducted via interviews and focus groups with stakeholders working in the aged care domain and residents living in aged care facilities. This was undertaken at a time when the COVID-19 pandemic was posing significant challenges to staff and residents, as well as having a significant impact on the quality of care.

Our findings demonstrate significant opportunities for robots in aged care, with particular interest from participants for the introduction of socially assistive robots and mobile telepresence robots to provide companionship, social and emotional support to residents. An appropriate implementation will need to take a strategic approach to the sustainable uptake of robots, with the robot's appearance, behaviour and capabilities playing a major role in user acceptance. The long-term economic, societal and health impacts of robots in aged care need to be demonstrated through large-scale longitudinal studies to maximise the uptake of the technology by both residents and staff.

Determination of behaviour health framework

Collaborator: CSIRO

Behaviour change techniques (BCTs) can be used to motivate behaviour change, but it's not known which BCTs contribute to the intervention efficacy with different individuals.

We're developing a platform that correlates an individual's lifestyle, physiology and personality make up with effective BCTs to trigger personalised interventions that optimise behaviour change. To date, we have completed a survey-based study to determine the correlation between an individual's lifestyle, physiology and personality make up with effective BCTs. More specifically, we investigated the use of mobile health (m-Health) to deliver personality-based behavioural change interventions. Our results suggests that extraversion positively predicts the use of all groups of BCTs, conscientiousness predicts the use of data related BCTs and agreeableness predicted the use of support, practice and encouragement. Future work will evaluate the outcomes from this work in a feasibility trial.

Health Services: Postdoc and Student Highlights

Postdoctoral fellows

Dr Kaley Butten

Kaley is evaluating the M♡THer platform, specifically exploring the uptake and acceptability of mHealth for gestational diabetes in a regional and remote context. She has completed a study at the Mt Isa Base Hospital and is currently working with Cairns Hospital. The Cairns study will incorporate satellite health sites within the hinterland, providing insight to the barriers and facilitators of mHealth within the region.

Dr Mohamed Estai, AEHRC

Mohamed has developed, conducted, and delivered research on improving the health of all Australians through precision health. Mohamed's research focuses on using mHealth and AI to improve the detection/diagnosis of chronic problems (oral and eye problems) to facilitate referrals and accessing timely treatment. He has made key achievements in science excellence, collaborations, and project/people leadership.

Dr Angelina Duan

Angelina is currently researching ocular biomarkers in Alzheimer's Disease with collaborators at The University of Melbourne. Recruitment has begun through the Australian Imaging, Biomarker, and Lifestyle Flagship Study of Ageing (AIBL). She is also involved in a project looking at use-case for retinal imaging in tertiary Hypertension care.

Dr Wei Lu

Wei is analysing the data from previous smart home trials, with a focus on functional monitoring and automatic health assessment based on smart home data. He is collaborating with researchers from University of Queensland and Melbourne University to investigate the sensor technologies and machine learning techniques for fall detection, posture detection, human identification, and agitation detection (for people living with dementia).

PhD students

Janis Nolde, University of Western Australia

Janis is working on data science and machine learning approaches to cardiovascular risk assessment. Efficient prediction methods for patient outcomes are necessary to identify dominating risk factors, efficient ways to reduce morbidity and mortality and to offer the right treatment to every patient. Pairing data such as retinal images, sympathetic nervous system activity and end-organ damage estimates with typical clinical data offers detailed, data-driven perspectives on patients enabling us to build sophisticated artificially intelligent risk analysis tools.

Vera Buss, University of New South Wales

Cardiovascular disease and type-2 diabetes mellitus are two of the most prevalent chronic diseases. Vera developed a smartphone application to help laypeople without cardiovascular disease or type-2 diabetes mellitus to understand their current risk of these two conditions and motivate them to reduce their current risk or to remain on a healthy track.

Yashodhya Vachila Vijesinghe, Queensland University of Technology

This study aims to predict falls among the elderly patients using 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

Committed to increasing our 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 organisations 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.

Central to the vision and research activities of the Indigenous Health team is the understanding and respect that Indigenous people conceptualise health as holistic, dynamic and interconnected – as opposed to the dominant mainstream model on which many health interventions are based.

In 2021–2022 the Indigenous Health team have established several projects that leverage CSIRO technology to address issues in cardiovascular health and gestational diabetes management. These two health issues have a significant gap between Indigenous and non-Indigenous health outcomes. A feasibility trial using CSIRO's Smarter Safer Homes platform is also underway to support housing and health for Aboriginal communities in Central Australia. Additional contributions to eHealth research by the Indigenous Health team include leading the establishment of rigor, relevance and sustainability around eHealth with Indigenous people and the development of a prototype of a standards based MBS715 Aboriginal and Torres Strait Islander Annual Health Check template that is consistent and interoperable across different systems and applications whilst allowing for local adaptation.

Team highlights 2021–2022

- In November 2021, the Indigenous Health Team (Dr Ray Mahoney, Andrew Goodman, Jed Fraser, Georgina Chelberg and Dr Kaley Butten) received The CSIRO Aboriginal and Torres Strait Islander Engagement Impact Excellence Medal. The medal was awarded for championing the co-design and co-development of potential e-Health solutions as prioritised by Aboriginal and Torres Strait Islander peoples and community controlled models of care. **CSIRO Awards – CSIRO**
- In July 2021, the Indigenous Health projects and personnel were featured in a CSIRO's ECOS article titled "Designing digital health with community". The piece highlights the co-design approach of the Indigenous Health Team in its work with Aboriginal and Torres Strait Islander Communities. **Designing digital health with community – ECOS (csiro.au)**
- In June 2022, a collaborative publication led by the team established a program of research for the co-design of culturally safe eHealth. **Protocol for a Best Practice Framework**

Ray Mahoney

Team Leader, Senior Research Scientist, Indigenous Health

Ray is a descendant of the Bidjara people of Central West Queensland and has a background in cardiovascular disease research and policy leadership. Ray is passionate about leading research into culturally safe care and addressing racism in the health system. He is currently a member of the Expert Advisory Panel for the MRFF Mission for Cardiovascular Health, the Heart Foundation Research Committee, a member of the AIHW Human Research Ethics Committee and the Australian Cardiovascular Alliance. Ray is also a member of the Steering Committee for the Queensland Cardiovascular Research Network.

Photo: (L-R): Jed Fraser, Georgina Chelberg, Kaley Butten, Andrew Goodman, Ray Mahoney

The AEHRC and Indigenous Health: Project Updates

Strong-eH: mHealth feasibility study, North Queensland

Collaborators: Wuchopperen Health Service, Mulungu Aboriginal Corporation Primary Health Care Service and The University of Queensland

Acknowledgement: We acknowledge and pay respects to the Muluridji (Mareeba), Yirrganydji (Cairns), Yidinji (Cairns), Turrbal and Yuggera (Brisbane) Peoples as the Traditional Owners and ongoing custodians of the land and seas on which this learning and research is being undertaken.

The Indigenous Health team have partnered with Mulungu and Wuchopperen Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHO) to question if mHealth can improve awareness, understanding and clinical management of hypertension for Aboriginal and Torres Strait Islander people. The Strong-eH mHealth-platform developed at AEHRC integrates a smartphone app and clinic portal. The app allows patients to record clinical measurements while accessing appropriate health promotion materials at a place and time of their choosing. The clinic portal extends healthcare providers surveillance of CVD, allowing at hand information to initiate therapy and the prioritisation of care. The aim of this project is to assess the appropriateness, feasibility and effect of an mHealth platform using a co-design approach for the clinical management of hypertension, for patients accessing care at two (2) ATSICCHOs, Wuchopperen in Cairns and Mulungu in Mareeba.

Following ethical clearance (FNQHREC/HREC/2021/QCH/61500-1511), qualitative data collection commenced with interviews and focus groups being held in person at partner sites. The Strong-eH mHealth-platform went live in March 2022 and is currently being used by patients and service providers in Cairns and Mareeba.

Strong-eH platform with Bluetooth blood pressure readings and clinician portal.

Georgina Chelberg and Ray Mahoney on site in Alice Springs for SSH and weather station installs.

Thermal Comfort SSH feasibility project with Tangentyere Council, Alice Springs

Collaborators: Tangentyere Council Aboriginal Corporation (Tangentyere Council)

Acknowledgement: We acknowledge and pay respects to the Arrente Peoples (Alice Springs and surrounds) and as the Traditional Owners and ongoing custodians of the lands on which this learning and research is being undertaken.

This project, originally funded by CSIRO's Health and Biosecurity Indigenous Opportunities ACORN grant, is contributing toward a broader climate change adaption and heat mitigation project in partnership with Tangentyere Council in Alice Springs.

A successful scoping phase in 2020 established the feasibility of data upload to cloud storage using local satellite internet or 4G. Installation of pared-down Smarter Safer Homes (SSH) systems with access to real-time sensor data on temperature, humidity and power usage was confirmed, and a feasibility trial commenced in 2021 with ethics approval with CHMHREC (2020_058_HREC). Pared down SSH systems were installed by Tangentyere senior research staff in a total of 20 houses in Town Camp residences in mid-2021 for data collection of temperature, humidity and power usage over 12 months. Several site visits to Alice Springs by AEHRC Indigenous Health personnel have enabled research planning, SSH training, trial installations and troubleshooting, focus group discussions and strategic meetings with local health and aged care service delivery providers.

Weather stations were also installed at three Town Camp Community Centres to capture ambient temperatures and humidity to enable more accurate environmental data than reliance on Bureau of Meteorology stations located at a distance from Town Camps.

Goondir InReach Kids project evaluation

Collaborators: Goondir Health Services and Darling Downs Hospital and Health Service

Acknowledgement: We acknowledge and pay respects to the Traditional Owners and ongoing custodians of the lands on which this learning and research with Goondir Health Services is being undertaken.

InReach Kids is an integration model developed between Goondir Health Services (primary health care) and Darling Downs Hospital and Health Service (Darling Downs Health) to provide patient-centric seamless flow of journey for Indigenous patients across two systems, and to streamline services, ensuring less duplication of services, identification of service gaps and improved health outcomes.

The InReach intervention focussed particularly on improving health service usage and health outcomes for children, young people, and women who are pregnant or new mothers. We were contracted in 2021 by Goondir Health Service to co-design and conduct this evaluation with continued engagement and close collaboration in partnership with them. The mixed-method evaluation will assess process and impact of the InReach Program according to the proposed objectives and strategies. It will involve the assessment of quantitative deidentified service process and access data; as well as qualitative deidentified patient experience data collected by GHS and DDHHS. Additionally, qualitative interviews will be conducted with health and program staff to gather their insights into facilitators and barriers of appropriate and effective program delivery.

(L-R) Kate Ebrill, Paul Penumala, David Hansen, Kelvin Duiker, Floyd Leedie (CEO of Goondir), Ray Mahoney, Andrew Goodman, Marlien Varnfield at the Goondir clinic in St George.

SMART health checks to close the gap for Aboriginal and Torres Strait Islander People

Collaborators: Royal Australian College of General Practitioners (RACGP), National Aboriginal Community Controlled Health Organisation (NACCHO) and Department of Health (Australian Government)

The AEHRC Health Data Semantics and Interoperability group is partnering with the Indigenous Health team to develop a SMART Health Check form consisting of interoperable templates for MBS Health Assessments, primarily the MBS ITEM 715 Aboriginal and Torres Strait Islander Peoples Health Assessment (health check).

This project will develop a common data model and publish a Fast Healthcare Interoperability Resources (FHIR)-based standard for recording health information in annual health checks. Smart phone apps and a FHIR-based clinical information system will be used to collect the data locally and explore the ability for this to inform data analytics, and reporting based on aggregated and deidentified data stored in a central repository. The long-term outcome is that the SMART Health Check forms will contribute to simplifying, standardising (with regional OR demographic bespoke features) and streamlining primary health care, including data collection, in Aboriginal and Torres Strait Islander community controlled health/medical services. This first phase of the project has developed a prototype SMART Health Check form to demonstrate these potential capabilities. The Indigenous Health Team led the co-design phase of this project that included meetings with and facilitating workshops with Aboriginal and Torres Strait Islander community controlled health/medical services. Community co-design was limited to Queensland due to compliance with COVID-19 travel restrictions. Participating health services included, Wuchopperen Health Service, Mulungu Aboriginal Corporation Primary Health Care Service, North Coast Aboriginal Corporation for Community Health (NCACCH), Charleville and Western Areas Aboriginal and Torres Strait Islander Community Health (CWAATSICH), Apunipima Cape York Health Council and Goondir Health Service.

Queensland Cardiovascular Research Network (QVCRN)

Queensland Cardiovascular Research Network

CSIRO's Australian e-Health Research Centre (AEHRC) have commenced a partnership with the QCVRN. AEHRC co-funds and hosts the QCVRN program manager position which enables a collaborative approach to CVD research in Queensland. QCVRN was launched by the Governor of Queensland in 2015 to provide a framework that strengthens cardiovascular research in Queensland. The QCVRN is the sole entity representing cardiovascular research across Queensland. QCVRN comprises government, industry and academic stakeholders who are united in their vision to sustain the network as the established entity representing cardiovascular research across Queensland. Dr Ray Mahoney is a member of the QCVRN Steering Committee and Mr Andrew Goodman is the QCVRN Program Manager.

eHealth Research Collaboration for Aboriginal and Torres Strait Islander Health

The eHealth Research Collaboration for Aboriginal and Torres Strait Islander Health (the Collaboration) was established in 2019 and led by AEHRC's Indigenous Health team. The Collaboration's approach emphasises co-creation and co-design methodologies where the voices, values, and priorities of Aboriginal and Torres Strait Islander communities and people are upheld. The Collaboration aims to promote an evidence base for technology in health care specific to the interests and needs of Aboriginal and Torres Strait Islander people through the facilitation of eHealth research (with respect to consultation, co-design, trial, and evaluation) and the co-development of technologies. The Collaboration includes CSIRO scientists, University of Queensland and Queensland University of Technology academics, and Queensland Health participants.

A significant output of the Collaboration, led by the AEHRC in 2021-2022, was the publication of a scientific protocol to guide the development of a best practice framework for eHealth with Aboriginal and Torres Strait Islander people. The program of research outlined in the protocol will guide the co-design, implementation, and evaluation of culturally safe eHealth interventions within existing models of care with Indigenous people.

AEHRC and Indigenous Health: Team Highlights

Andrew Goodman, PhD candidate: The University of Queensland/CSIRO

PhD Project title: Strong-eH: a smartphone and Internet based interactive system (mHealth) for the management of hypertension for Aboriginal and Torres Strait Islander peoples: a feasibility study.

Andrew is leading our collaborative project with Wuchopperen Health Service in Cairns and Mulungu Aboriginal Corporation Primary Health Care Service in Mareeba. The project will assess the appropriateness, feasibility and effect utilising a smartphone and web-based interactive system (mHealth platform) specifically tailored for the clinical management of hypertension with patients and service providers in an Aboriginal and Torres Strait Islander Community Controlled Health Organisation.

Research highlights 2021–2022:

- Deployment of the Strong-eH mHealth platform with AEHRC research partners (2 sites)
- Commencement of data collection (qualitative and quantitative) for the Strong-eH feasibility trial
- Awarded first place – 2021 QCVRN Symposium, 'Lightning pitch and poster presentation'

Georgina Chelberg, Research Officer: CSIRO and PhD Candidate: The University of Queensland

PhD Project title: digital health to enhance access and delivery of quality care with Aboriginal and Torres Strait Islander people, including persons living with dementia

Georgina's research established the need for a best practice framework to guide future research and deployment of digital health with Aboriginal and Torres Strait Islander people, including persons living with dementia.

Research highlights 2021–2022:

- Awarded ACORN grant – Culturally safe eHealth interventions with Aboriginal and Torres Strait Islander people
- Completion of data collection (qualitative) with AEHRC research partners (3 sites)
- Guest speaker for 'WildHealth' podcast - "Dementia app research reveals big gaps for the market"
- AEHRC Colloquium presentation – 'Leading best practice for digital health with Aboriginal and Torres Strait Islander people'

Jed Fraser, PhD Candidate: The University of Queensland/CSIRO

PhD Project Title: co-creating an Aboriginal and Torres Strait Islander youth health assessment

Jed's research sought to understand the health priorities of Aboriginal and Torres Strait Islander youth and to co-create a youth-specific health assessment for primary health care. Jed has contributed to other research projects within the Indigenous Health Team including scoping reviews and the SMART Health Check project. Jed was a recipient of the CSIRO Indigenous Postgraduate Top Up Scholarship.

Research highlights 2021–2022:

- Attained PhD Confirmation with The University of Queensland

Sophie Wright-Pedersen, Research Officer: CSIRO and PhD Candidate: Queensland University of Technology

Project title: InReach Kids Project Evaluation

Sophie has been a key contributor to the Goondir InReach Kids project evaluation being conducted by AEHRC. The Goondir InReach Kids project evaluation aims to assess the appropriateness of and effectiveness of an intervention to improve health service use and health outcomes for children, young people, and women who are pregnant or have become new mothers. Sophie is currently working as the key research officer co-ordinating collaborative meetings, finalising research design, ethics and governance documentation.

Sophie holds a Bachelor of Nutrition and Dietetics (Hons) and is a current PhD candidate with the Queensland University of Technology. She has over four years of experience working for charitable, non-government and government organisations as a public health dietitian within Alice Springs and the Illawarra region.

Laura Stephensen, PhD Candidate: Queensland University of Technology

PhD Project title: Characteristics and outcomes for Aboriginal and Torres Strait Islander people with suspected acute coronary syndrome

Laura's research aims to improve the evidenced-based emergency department assessment of Aboriginal and Torres Strait Islander people who have symptoms of suspected acute coronary syndrome.

Research highlights 2021–2022:

- Publication in *Heart Lung and Circulation*
- Abstract accepted for Annual Cardiac Society of Australia and New Zealand (CSANZ) scientific meeting

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 focussed 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 provides 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 – artificial intelligence, statistics and operations research to increase productivity and patient safety, evaluation of health service interventions and disease surveillance and response.

Science and impact highlights for 2021/22

- Comprehensively evaluated the HealthLinks Chronic Care program, in collaboration with the Victorian Department of Health, highlighted key drivers to inform future health policy and shape the direction for new models of care delivered by hospital to patients with chronic and complex conditions.
- Deployed a validated web app comprising bed demand prediction algorithms, user guide and dashboards to Western Australia Country Health Services for Bunbury Hospital.
- Published a paper on the development and validation of an algorithm for predicting patient deterioration in *Nature Scientific Reports*. Also commenced work with Logan hospital and Westmead Neonatal Intensive Care Unit (NICU) to extend this work.
- Extended current work with Queensland Health exploring typical and atypical longitudinal COVID patient journeys to look at specialty based pathways and understand and analyse medication orders.
- The team working on the ECMOCARD project declared a finalist in the Metro North Research Excellence Awards in June 2022.

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 strategies, platforms and policies that 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. The team also has a strong track record of developing and implementing precision clinical decision support at point of care for patient management in acute care and primary care settings.

Scientific Lead:
Antimicrobial Resistance

Dr Teresa Wozniak

The recently established Antimicrobial Resistance (AMR) science stream conducts research into the impact of AMR on the population using epidemiological and health informatics tools. The focus of our research program is to define the health and economic burden of AMR in Australia and to implement digital solutions in regions of need. Working closely with clinicians, remote area staff and policy makers, we continue to deliver programs that track and respond to changes in AMR disease across northern Australia.

Health System Analytics: Platform Technologies

Predictive modelling for operational and clinical decision support

Predicting demand is a vital component of improving efficiency and access performance of health services, especially as the population ages and health budgets get squeezed. Adequate hospital capacity is particularly crucial during crises such as the current coronavirus pandemic, other viral outbreaks such as influenza, and the pressures winter places on hospital operations.

Since 2008 we have been developing and validating models to predict demand for health services such as ED presentations, inpatient admissions and separations and operating theatres. These models can assist planners and schedulers to improve the delivery of services. For example, daily demand can typically be predicted with over 90 percent accuracy and can be used 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, and providing early warning of disease outbreaks. In 2021–22, the team implemented models to generate forecasts of ED presentations, inpatient admissions and separations for WA Country Health Services.

Demand for hospital beds is not random and can be predicted at a daily level with an accuracy of around 90 percent

With the increasing implementation of electronic medical records (EMRs) in hospitals, there is growing potential to use the data to inform clinical decision-making in real-time. We have been developing a series of real-time explainable machine learning algorithms for precision decision support at the point of care. These use data captured in electronic medical records and administrative systems to identify patient cohorts of interest for clinical streaming/intervention. Several past and current projects focus on clinical decision support to help reduce hospital readmissions and predict patient deterioration. In 2021–22, we also commenced work with the Westmead Neonatal Intensive Care Unit (NICU) to develop models to predict adverse outcomes using clinical and physiological data collected from critically ill preterm newborns.

Syndromic surveillance and aberrance detection to support early detection

Syndromic surveillance aims to give early warnings of disease outbreaks and other healthcare issues – but can also assist with day-to-day hospital capacity management and operations and policy related decision making. Traditional approaches to monitoring disease outbreaks involves tracking daily or weekly counts of disease but recent work has demonstrated that monitoring the time between events may give earlier warning of disease outbreaks.

The AEHRC, in partnership with CSIRO Data61, has applied a set of algorithms and tools that can be used for syndromic surveillance and incorporate anomaly detection research from Data61.

In healthcare, seasonality and day of the week influences are a variation source that leads to non-homogeneous processes, and during disease outbreaks, there are generally stronger seasonal trends and within-day influences. These aspects make designing a monitoring plan for disease outbreaks a challenging task in practice. Our solution applicable to non-homogeneous processes is monitoring based on Weibull-distributed Time Between Event values and incorporating differing levels of temporal memory to cover outbreaks of different sizes. The time between event approach to statistical process control is a very new concept, and to our knowledge, we are the only group working on its application to non-homogeneous processes worldwide.

In 2021–22 additional techniques adapted from the financial sector were investigated for their ability to detect the start of the first wave of the COVID-19 pandemic in Queensland including a trend-following momentum indicator and standard deviation approaches. This supplements previous efforts by the team using EWMA and CUSUM approaches.

Early warning of disease outbreaks or higher than normal workload is paramount for health jurisdictions.

Simulation based operational scenario modelling and optimisation

The ability to create realistic digital representations of physical systems (or “digital twins”) can support improved decision making by providing answers to what-if scenarios and generating insights from an organisation’s actual data on how potential changes impact the real system. A well developed simulation model can allow an end user to assess the impact of implementing an operational change more quickly and cheaply than implementing the change.

The AEHRC has developed several simulation based scenario models. These typically use discrete event simulations for assessing the flow of patients through the health system. An important step in simulation modelling is to ensure the model captures accurately the flow of patients through a process. The team created multiple models to demonstrate how to use routinely collected hospital data to build validated simulation models. These assess impacts such as the configuration of inpatient beds or the timing of patient discharge from hospital.

In 2021–22, the team started building a digital twin of the state-wide patient flow control hub to run what-if scenarios of different operational policies. The digital twin considers all major hospitals and emergency and elective flows to/from them to form a realistic model of the system. Different scenarios can be tested such as changes in demand, hospital capacity, the proportion of elective surgeries undertaken, patient discharge time, etc. This tool assesses the impacts of policies in near real-time. This will provide decision makers with real time situational intelligence to understand current and potential demand impacts on Queensland Health facilities and ensure an optimal system-wide response.

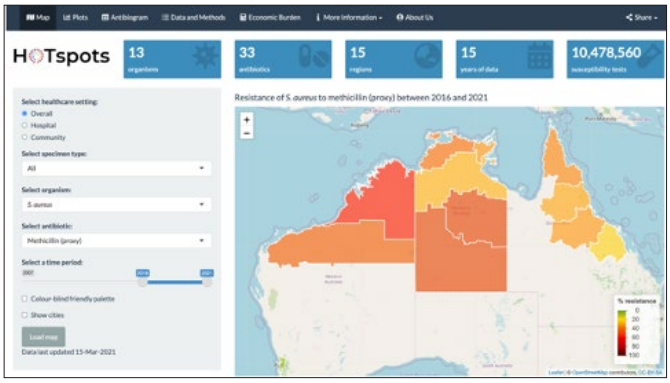
Simulation models can help quantify the impact of operational changes on efficiency performance.

HOTSpots: A region-specific public health surveillance and response platform

To curb the threat of antimicrobial resistance (AMR), effective monitoring and rapid response to local changes in prevalence is critical to increasing community resilience and disease preparedness. However, the inability to easily access pathology data regarding local AMR patterns and for these data to be available and used at the point of care, is a recognised barrier to an effective public health response.

HOTspots is a digital, geospatial, interactive analytics platform that uses spatial temporal epidemiology to visualise trends over time and space. In 2019–20 and with close engagement with local stakeholders, the HOTspots tool was trialled in Northern Territory hospitals and primary healthcare clinics. A formal evaluation in 2021 found that the digital tool meets its purpose for detecting AMR patterns and supports evidence-based antibiotic treatment decisions and local guideline updates.

The strategic ongoing development of HOTspots and application of AI driven decision support models and algorithms, will strengthen technology readiness for future developments of this tool.



Region-specific digital solutions support local clinicians and policy makers in reducing the treat of AMR in remote Australia.

Health System Analytics: Project Reports

HealthLinks: Chronic Care Evaluation

Collaborator: Department of Health Victoria

With the Department of Health Victoria (DH) we undertook a 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.

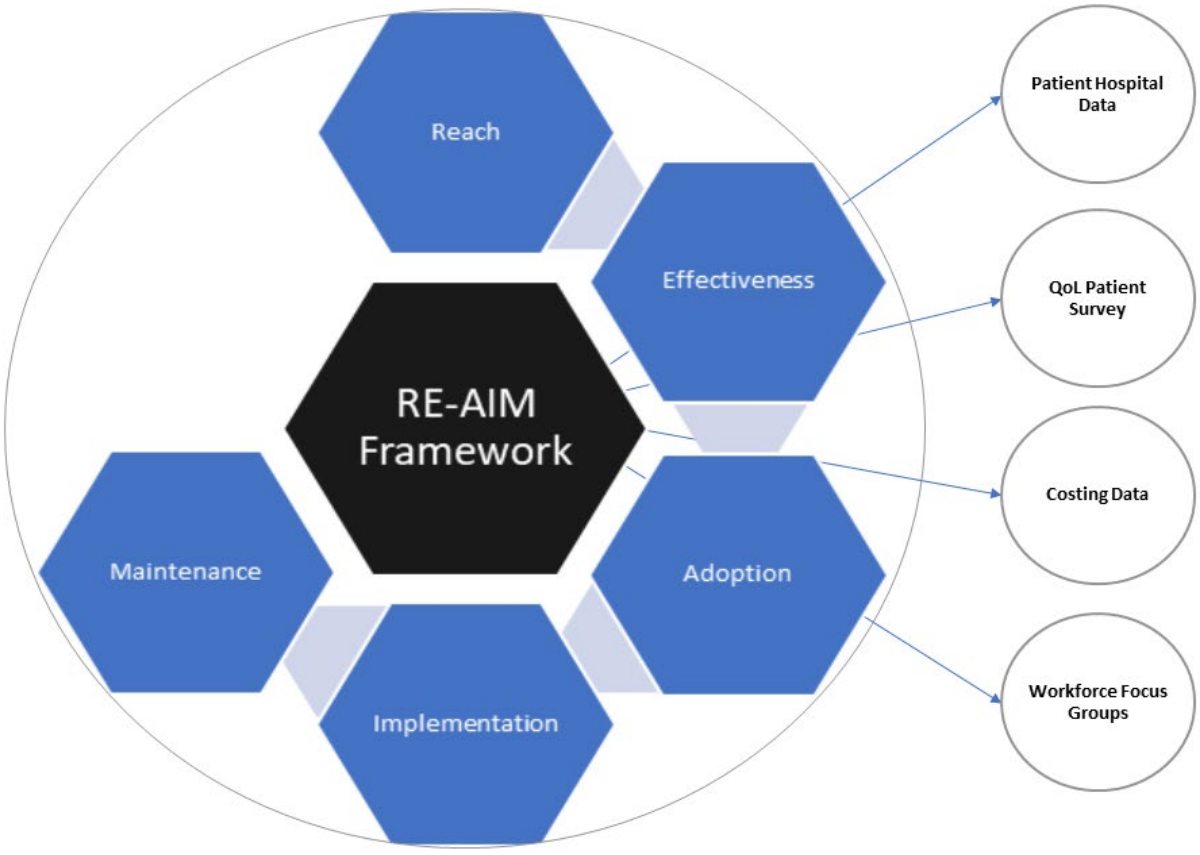
The overall aim of the HLCC evaluation was to determine if flexible funding enables health services to develop and implement alternative models to inpatient acute care that provide better experiences and outcomes for patients with chronic conditions, at equal or lower cost.

The final report was delivered in May 2021 along with a presentation to the HLCC Clinical Collaborative consisting of principal investigators from participating health services in the Melbourne metropolitan area, DHS staff and invited guests. A final workshop and forum were given in August 2021 to disseminate results to a wider audience.

Download the full public version of the report from the DH website: **HealthLinks: Chronic Care Evaluation. Final Report (public version)**

Approximately 50,000 patients were enrolled in HealthLinks with 2,500 streamed into interventions undertaken by five participating health services. The findings were mixed with no clear benefit in clinical outcomes for intervention patients compared to controls apart from observed reduction in ED and inpatient length of stay for one health service. Intervention patients experienced more streamlined non-admitted specialist service journeys than control patients suggesting intervention patients are receiving more appropriate care.

There was an overall view from workforce participants that for an intervention model like HealthLinks to succeed there needs to be a change in mindset of chronic disease management and acknowledgement that the acute setting has a significant role in the care of patients with chronic and complex care needs.



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

Antimicrobial Resistance Mortality Study

Collaborators: CSIRO AMR Initiative, MTPConnect

We were commissioned by the CSIRO AMR Initiative and MTPConnect to conduct a desktop review of the current burden of antimicrobial resistance (AMR) mortality in Australia and to evaluate potential options for improving data collection and linkage that will enable accurate, longitudinal estimates of the AMR mortality burden and increase the effectiveness of this country's responses to the global challenge of AMR.

While there have been multiple global studies of the AMR burden in terms of mortality, morbidity, and economic consequences, little is currently known about the impact of AMR in Australia. To date, the only published estimate for the annual AMR-related mortality in Australia comes from a two-page 2018 report[1] from the Organisation for Economic Co-operation and Development (OECD). The report estimated a total of 290 people die each year in Australia due to infections from eight drug-resistant bacteria. However, the approach by which this figure was calculated remains unclear and so the accuracy of the estimate is difficult to judge.

Our aim was to facilitate discussion of data-driven strategies that might be adopted within Australia to better measure and monitor the impact of AMR. This report represents a call to action for greater collaboration and coordination and less duplication of efforts.

We proposed several approaches to improve the data collection, linkage and estimate of AMR mortality in Australia with the preferred option of developing a national data linkage program based on national-level data infrastructure such as the NIHSI Analysis Asset with the addition of pathology datasets.

[1] https://www.oecd.org/australia/Stemming-the-Superbug-Tide-in-Australia.pdf

Queensland Patient Access Coordination Hub (PACH)

Collaborator: Healthcare Improvement Unit, Clinical Excellence Queensland, Queensland Health

The Queensland Patient Access Coordination Hub (PACH) is a Queensland Health initiative designed to enhance operational performance and assist with patient flow, utilising real-time intelligence of ambulance and hospital operations across the major Southeast Queensland Hospital and Health Services. It provides visibility of patient journey commencing with Queensland Ambulance Service, through the emergency department (ED), to admission and subsequent discharge. The PACH operational systems provide real-time data and tactical information that gives a higher level of visibility to better understand the current and potential demand impact on the local EDs and other portals of entry into Queensland Health facilities.

The Health Intelligence team have delivered algorithms to Queensland Health to enhance the intelligence embedded within the Q-PACH dashboards for assisting in the management of the patient journey and coordinating patient flows. Specifically, this includes algorithms to predict daily and hourly ED and inpatient demand; detecting outbreaks of 'influenza-like-illness' (using ED records filtered by primary diagnosis); monitoring ED workload monitoring to flag periods of high workload stress (using ED data aggregated to daily counts) and monitoring inpatient capacity risk to detect capacity challenges (using inpatient admissions and inpatient separations aggregated to daily counts).

In 2021–22, the team kicked off a new project with the Healthcare Improvement Unit of Queensland Health to develop a digital twin of the PACH unit. This involves developing models to simulate the flow of patients through and across hospitals and capturing processes involving queueing, to optimise organisational objectives such as LOS or patient waiting time. This will allow for real-time situational intelligence to support scenario planning and informed decision-making to ensure an optimal health system response. It can also establish an evidence base to identify solutions that can improve emergency access across the state.

PAPT @ Bunbury Hospital

Collaborator: WA Country Health Service (WACHS)

Throughout 2021–22, many hospitals around the country, including in Western Australia, paused elective procedures due to overcrowding and system pressures from increases in COVID-19 cases. With hospital occupancy rates approaching 100% on a regular basis, more efficient management of inpatient beds to reduce overcrowding is imperative.

To assist with this, the Health Intelligence team developed, validated and implemented algorithms for one of WA's large regional hospitals (Bunbury Hospital) that predict counts of ED presentations, inpatient admissions and discharges for time and day of the year. Following ethics and WACHS research governance approvals, six years of ED presentation and admission data were used to develop a prediction tool that forecasts daily bed demand within an accuracy of 90% when validated on a separate dataset held out from model development. In 2022, a web app comprising predictive algorithms and dashboards was deployed on a WACHS server and made available to hospital staff, where demand information is presented graphically via several dashboards.

The web app provides Bunbury Hospital with a forecasting tool which projects bed requirements for the current and next day and several days into the future. The team demonstrated to hospital staff how the predictions can be used in conjunction with knowledge of how many beds are open to determine the number of 'free' beds across forthcoming days which allows decisions to be made to open or close beds to create capacity or save costs. Hospital staff were also shown how the predicted net flow of patients admitted compared to discharged can be used for long-term planning to identify times within the upcoming year (for example) where there are consecutive days of more patients admitted than discharged, causing capacity challenges for the hospital.

Predicting patient deterioration

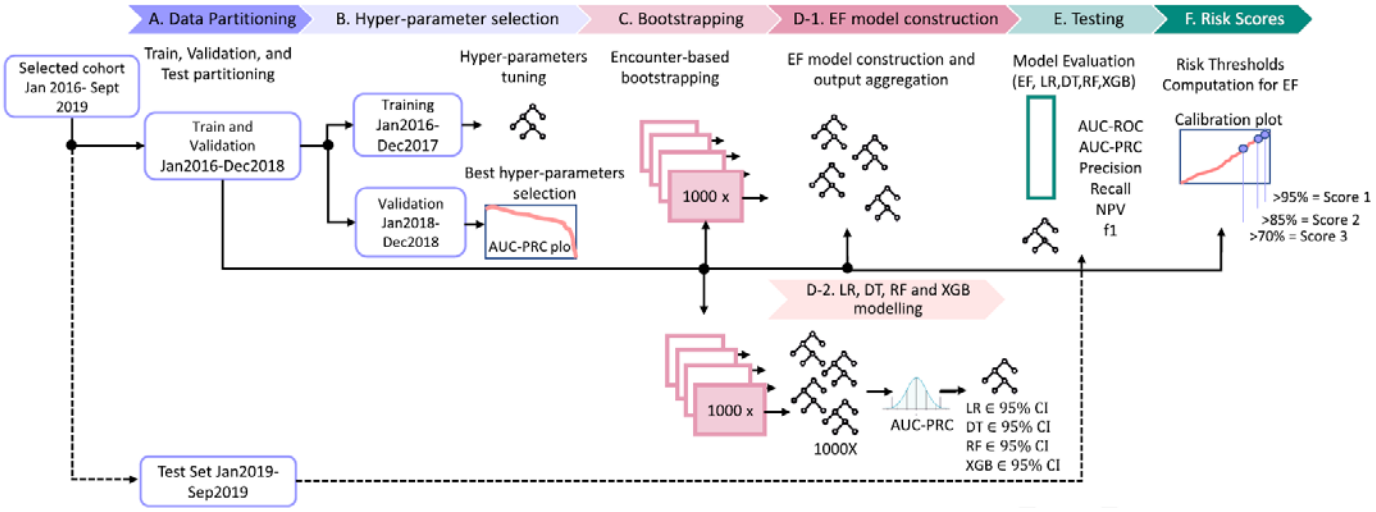
Collaborator: Queensland Health

The electronic medical record (EMR) provides an opportunity to manage patient care efficiently and accurately. This includes the development of clinical decision support tools for the timely identification of adverse events or acute illnesses preceded by deterioration.

The main aim of this project was to develop a tool that:

- helps identify patients who are likely to get sicker, allowing clinicians to pre-emptively evaluate and intervene
- provides a guide to the influential factors that describe the pattern of their deterioration, and inform the possible cause and guide the choice of intervention

To address these outcomes, this project focused on the development of a predictive machine learning-driven risk model, utilising digital hospital data and representing a real-time setting that could be used as an aid in clinical decision making at the bedside. The resulting model achieved 100% sensitivity for a patient who was identified at an 85% risk of deterioration within the next 4 hours. A manuscript describing the development and validation of the model has been accepted for publication in the *Nature Journal Scientific Reports*.



Health System Analytics: Project Updates

Fiona Stanley Hospital operating theatre analysis

Collaborator: Fiona Staley Hospital, Perth

This multi-faceted project provided a holistic approach to better understand and deal with the bottlenecks for patients accessing critical care at operating theatres. Working closely with the operating theatre management team and consultant anaesthetists, we developed a series of clinically informed solutions to optimise theatre efficiency at Fiona Stanley Hospital. These included:

- Daily surgery caseload prediction – with the ability to explore this at the level of emergency cases, elective cases, and caseload for individual specialties.
- Prediction of theatre over-runs.
- Prediction of Operation duration (supported by a successful Health & Biosecurity ACORN grant).
- Exploration of booked versus actual operation time at an individual specialty level.
- Development of a digital twin of operating theatre flow.

Predictive appointment notification tool

Collaborator: Austin Health in Victoria

The aim of this project is to better predict appointment loads for specialist clinics with realistic scheduling, increased productivity of staff, and timely care delivery for patients. The first objective towards achieving this is to improve the appointments booking system currently used at Austin Hospital by providing doctors with accurate real-time availability of their next appointment. The second objective is to provide a new tool to optimise clinic "templates" and explore the effect of "what if" scenarios on key performance indicators.

Two research prototype grade tools, a Next Available Appointment Tool (NAA) and a Template Planning Tool (TPT) were implemented and deployed in Austin Health in Mar 2022, and documentation describing the use and configuration of these tools were delivered to the client. Austin Health is currently preparing to undertake a feasibility study in several selected specialist clinics as part of the implementation-evaluation.

Virtual baby (VBaby): predictive physiological modelling of critically ill preterm newborns

Collaborator: Westmead Neonatal Intensive Care Unit (NICU), Cerebral Palsy Alliance, University of Sydney

Extremely preterm infants and very low birth weight (VLBW) babies have a higher risk of death and permanent disabilities. Providing early warning alerts several hours before clinical diagnosis can be crucial to prevent mortality and permanent injuries. Physiological markers such as heart rate variability (HRV) characteristics provide crucial information relating to adverse outcomes.

The aim of this project is to develop predictive models using high-fidelity physiological signals collected at Westmead NICU to predict adverse outcomes earlier than clinical diagnosis time. Over the past few months, data extraction and exploration has been carried out in consultation with expert clinicians. HRV analysis has also commenced. This research has immense translational significance in predicting likelihood of permanent brain injury states such as cerebral palsy, severe gut necrosis and physical disabilities.

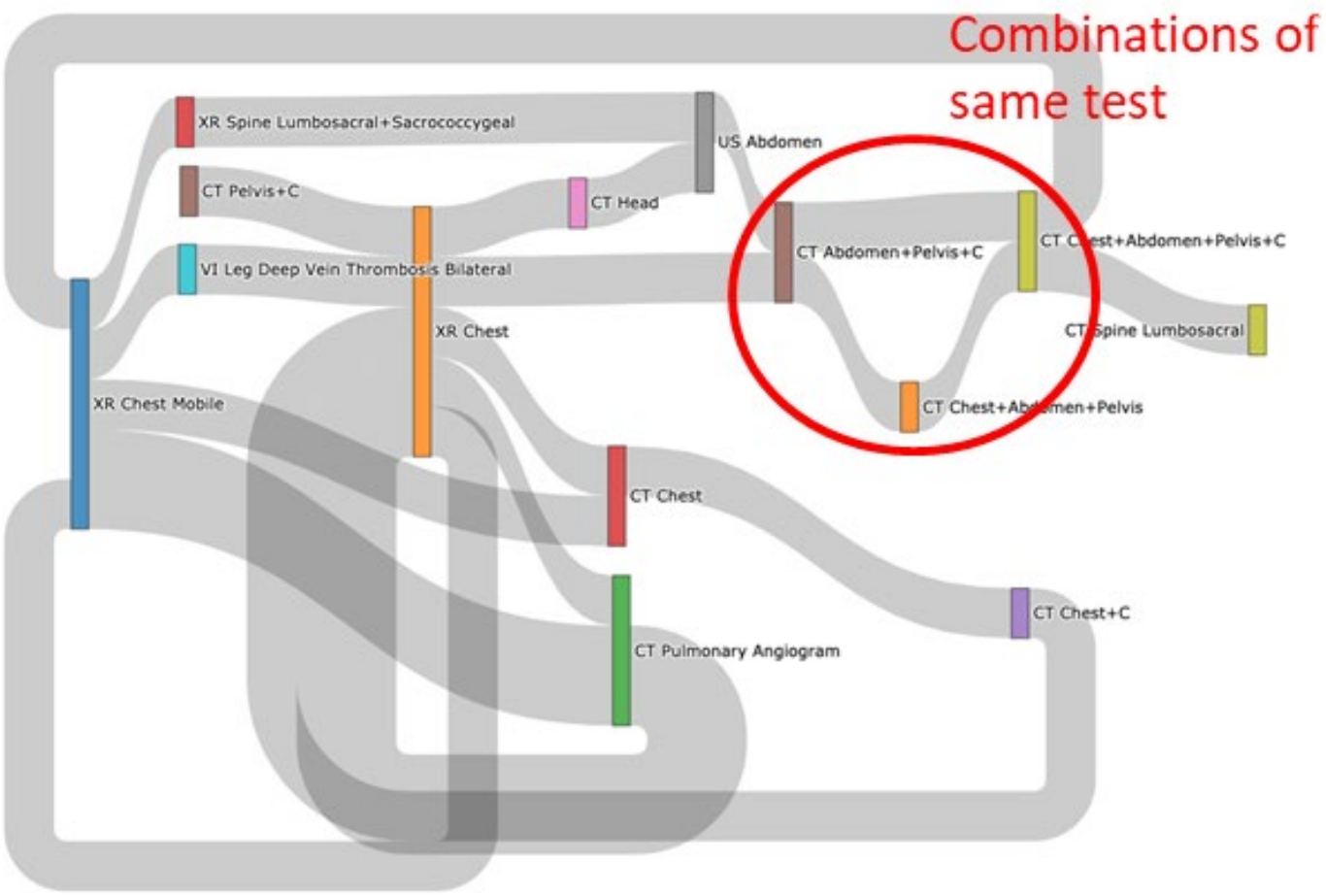
Patient Journey

Collaborator: Queensland Health

The Patient Journey project is aimed at developing a novel set of tools to obtain a comprehensive view of care provided to patients across the health system. This project started by focusing on COVID patients to allow in-time identification of the “typical” and “atypical” longitudinal patient profiles and characteristics.

Tools like Theographs, for understanding the historic and post recovery healthcare utilisation of patients, and parallel coordinate plots, for analysing the patterns in multivariate longitudinal data, were employed to enable more informed care delivery and care planning. Exploring post-recovery healthcare utilisation patterns provides a proxy for better understanding of long-term complications and related demands on the health system due to pandemics or seasonal outbreaks.

In 2021–22, we have started adding additional data sources to the patient journey analysis toolkit and expanded our focus to explore specialty based pathways and understand and analyse medication orders.



Key radiology pathways for COVID patients in Queensland

Syndromic Surveillance for Influenza Like Illnesses and COVID-19 related symptoms

Collaborator: Queensland Health

The team continued their investigations into syndromic surveillance and the use of the primary diagnosis field within ED data systems as a signal to flag outbreaks. Algorithms for flagging departures from normal influenza activity were delivered to Queensland Health which are based on the time between consecutive ED presentations getting shorter than a dynamic threshold (specifically the PRESENTATION_DATETIME field matching a list of principal diagnosis field codes that were agreed by consensus of the Queensland Health Syndromic Surveillance Working Group and additional COVID-19 related codes).

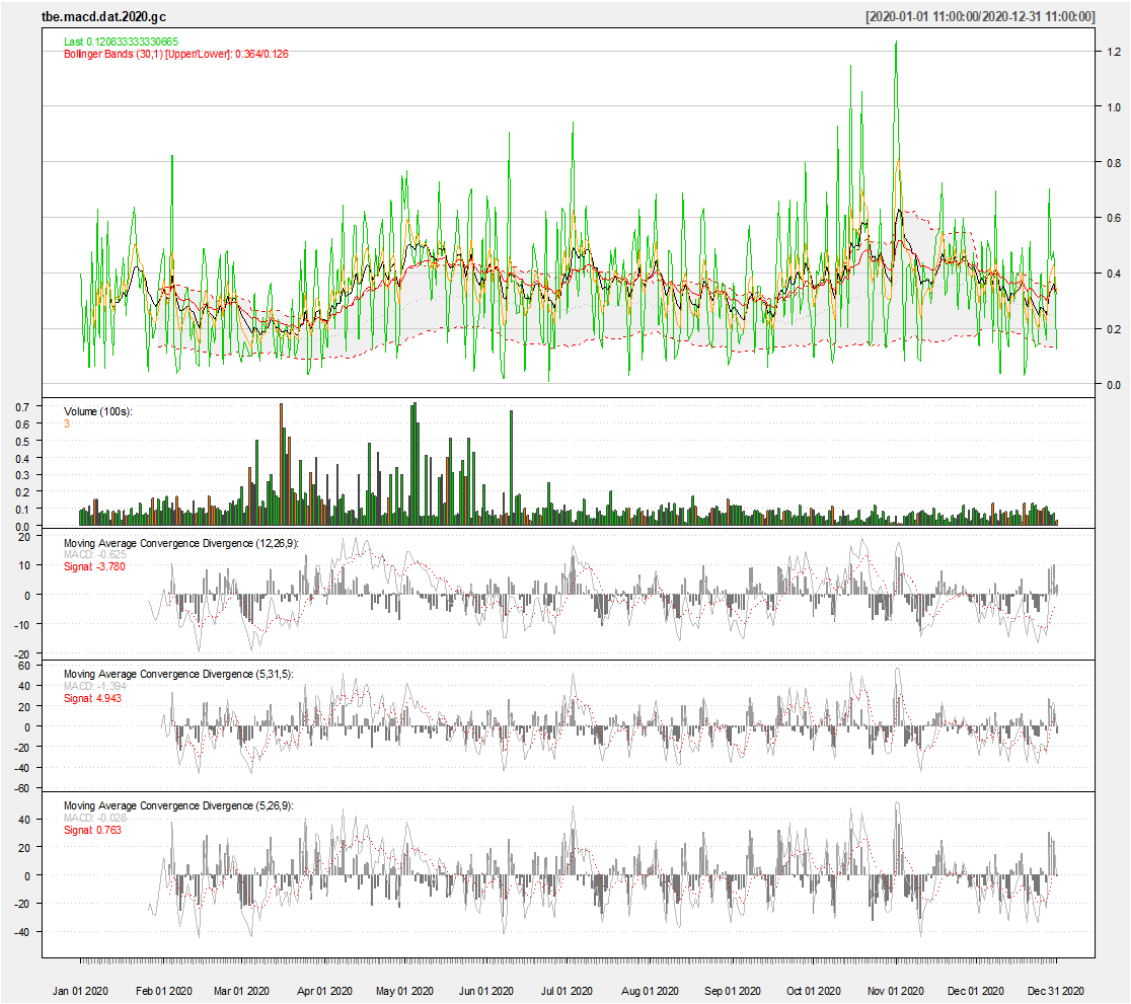
In 2021-22 additional techniques adapted from the financial sector were investigated for their ability to detect the start of the first wave of the COVID-19 pandemic in Queensland. These included a trend-following momentum indicator – Moving Average Convergence Divergence (MACD), and Bollinger bands based on standard deviation which were originally used in financial markets as an oversold or overbought indicator for stock. This supplements previous efforts by the team using EWMA and CUSUM approaches.

Rauland falls prevention

Collaborators: Hunter New England LHD, Maitland Hospital NSW, Northern Health Vic and Rauland Australia

Rauland Australia have developed technology that supports falls prevention management in hospitals. Specific workflows have been designed within their Responder 5 Nurse Call and Hospital Communications Platform that provides functionality to manage patients with falls risk in hospital wards. The system will provide the platform for new workflows to be implemented on these wards to assist with providing care to high risk falls patients.

Rauland Australia have commissioned CSIRO to undertake an independent evaluation of the implementation of their Responder 5 at two hospitals. The team will undertake a mixed-methods evaluation to understand the effectiveness of the fall prevention workflows delivered in these hospitals on patient and health service outcomes. The ethics approvals and privacy reviews were completed and evaluation commenced at Maitland hospital with staff surveys in June and planned to continue with interviews as well as starting activities at Northern health through 2022.



Anomaly detection approaches from the financial sector applied to daily counts of influenza-like illness at an hospital emergency department.

Living with COVID Program Evaluation

Collaborator: Healthdirect Australia

Healthdirect Australia has developed a national approach to connect COVID positive patients with the right level of care – the 'Living with COVID' program. The model of care commenced in early 2022 and assists low and medium risk COVID positive patients to self-manage their care at home and/or in consultation with their usual GP. The Health Implementation Science team are leading the evaluation of the program, using a mixed methods framework to evaluate the engagement with, and satisfaction and efficiency of, the program in Queensland, South Australia and New South Wales. The evaluation focusses on the assessment of outcomes from the patient and GP perspectives and will triangulate findings from a range of new and existing routinely collected data sources.

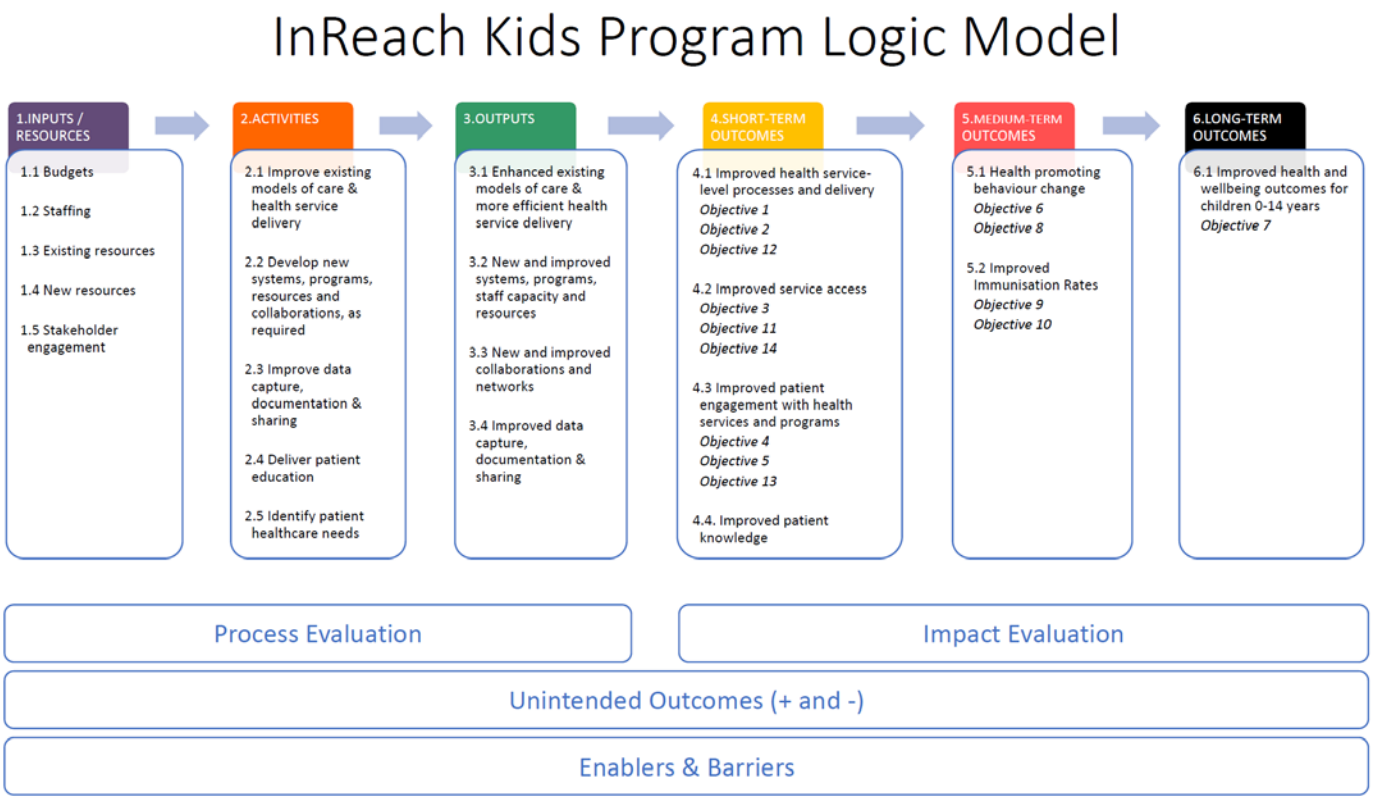
InReach Kids Program Evaluation

Collaborator: Goondir Health Services and Darling Downs Hospital and Health Service

The InReach Kids Program is an integrated model of care developed between Goondir Health Services and Darling Downs Hospital and Health Service. The program provides a patient-centric care pathway for Indigenous patients across the two health systems by streamlining services, reducing duplication, and identifying service gaps. In doing so, the program will improve health and development outcomes for children and adolescents 0–14 years.

The Health Implementation Science team collaborated with the AEHRC's Indigenous Health team to develop a comprehensive mixed methods evaluation framework that focusses on both process and impact outcomes of the program.

The team has also developed a semi-structured interview discussion guide to facilitate the collection of qualitative data to understand the key barriers and enablers of the program's implementation from the perspective of health and program staff.



InReach Kids Program Logic Model

HotSpots program

Collaborator: Australian Commission of Safety and Quality in Health Care, Menzies School of Health Research, Global Research on AntiMicrobial (GRAM) program

The HOTspots program delivers synthesised data to clinicians on evolving antimicrobial resistance (AMR). These data are accurate for local needs, up to date (every 6 months) and readily available at point of care, which is particularly important in regional Australia. The HOTspots program was developed to address a lack of AMR surveillance in the northern part of Australia, focused on the Northern Territory but also including the northern parts of Western Australia and Queensland.

A major milestone over the past 12 months has been the contribution of disease surveillance data to the National Antimicrobial Usage and Resistance (AURA) surveillance program published in AURA 2021 report. These data are critical to informing Australia's response to the antimicrobial resistance. In addition, the HOTspots program contributed important data to the Global Research on AntiMicrobial (GRAM) program which published the first estimate of the global impact of AMR (Lancet, 2022) as well as other notable publications.

AI-enabled AT Framework for the National Disability Insurance Scheme

Collaborator: The National Disability Insurance Agency

The Health Implementation Science team provided technical expertise to the Health Services groups development of a "Framework and Roadmap for Artificial Intelligence enabled Assistive Technology". This included contributing to a review of current literature to inform the framework constructs and guidance on the development and facilitation of the qualitative component of the study to understand the views of people living with a disability. The team led the thematic analysis of the interview transcripts and drafted a summary of findings that described participants current use of assistive technology products, the role of the NDIS in facilitating access to assistive technology products, participants perceptions of discoverability of assistive technology products, and AI-enabled assistive technology characteristics that are important to participants.

ECMOCARD

Collaborator: COVID-19 Critical Care Consortium incorporating ECMOCARD led by Prof John Fraser

The study, Extra Corporeal Membrane Oxygenation (ECMO) for 2019 novel Coronavirus Acute Respiratory Disease (COVID-19 Critical Care Consortium), is a prospective/ retrospective multi-centre observational study of patients in intensive care units with COVID-19. Collaborating with more than 380 worldwide centres, the study's objectives are to describe clinical features, the severity of pulmonary dysfunction, ECMO technical characteristics, duration of ECMO, complications and survival of patients with COVID-19. Collaborating alongside frontline ICU clinicians, we have been working across several projects to address specific research questions of ECMO use on COVID-19 patients. The insight derived from our work will be disseminated via conference presentations as well as high impact peer reviewed journal publications.

Blood-based protein biomarker panel for early detection of colorectal cancer

Collaborator: Molecular Diagnostic Solutions, CSIRO Health & Biosecurity

Currently, the only blood-based protein biomarker used clinically to determine patients who are potentially at risk of an adverse outcome following diagnosis of colorectal cancer is carcinoembryonic antigen (CEA). CEA is also the current clinically accepted marker for monitoring of treatment efficacy. The objective of this cross-research-program project is to identify a panel of protein biomarkers that performs better than CEA at predicting patient outcome from colorectal cancer across two different studies. Over the past 12 months, we have delivered over 12 reports depicting study data exploratory analyses, validation of CEA biomarker across both studies, investigation of patient survival time across all biomarkers over several outcomes and proposed further analyses to identify novel biomarkers in comparison to CEA and carry out validation analyses. Due to the IP and commercial strategy nature of this project, deliverables consist of confidential reports.

Reach, change, maintain

Collaborator: CSIRO Nutrition and Health, Public Health and Wellbeing

Engagement is key to interventions achieving successful behaviour change and improvements in health. There is scarce evidence in the literature on applying predictive ML models to data from commercially available weight loss programs to predict engagement which could help in supporting participants to achieve their goals. The aim of this study was to develop explainable machine learning models and exploit their capability to predict weekly engagement over 12 weeks on a commercially available, online, weight loss program.

Health System Analytics: Postdoc and Student Highlights

Postdoctoral fellows

Dr Vahid Riahi

Vahid is working on multiple projects that involve improving decision-making processes using simulation, optimisation and machine learning: (1) project for Austin Health in Victoria to improve their appointment booking system, which is in the implementation phase, (2) improving the estimation of surgical operation duration using machine learning techniques, and (3) developing deep reinforcement learning approaches for elective surgery scheduling in operating rooms.

Dr Jessica Rahman

Jessica is working on the VBaby project at Westmead. This research aims to provide early warning signs of clinical deterioration linked to neonatal mortality and morbidity. She is working on building predictive models with high fidelity physiological signals using the data from the neonatal intensive care unit at the Westmead hospital. Currently she is experimenting with different heart-rate variability analysis techniques to identify a robust set of physiological markers for the predictive models.

PhD students

Marko Simunovic, School of Biomedical Sciences, Faculty of Health, Queensland University of Technology

Marko's PhD studied the effect of airborne grass pollens on asthma emergency department (ED) presentations in Queensland. Time series and spatiotemporal analysis investigated burden, seasonality and trends for ED presentation and risk for hospital admission. The burden was largely driven by female children and lightning showed an independent effect on asthma ED presentations during the period studied. The burden of allergic respiratory disease in subtropical regions is significant and with increasing pollen exposure and a growing population, risk of thunderstorm asthma in QLD cannot be disregarded. Marko has published his findings in three journal papers and has a fourth under review. In 2021–22, Marko submitted his thesis and was awarded a PhD in April 2022.

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

AEHRC Industry PhD, scholarship University of New South Wales (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. This project will apply machine learning techniques to whole-of-population Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data sets held by the Department of Health.

James has one paper in review and is currently working on his second methods paper using graphical association analysis.

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.

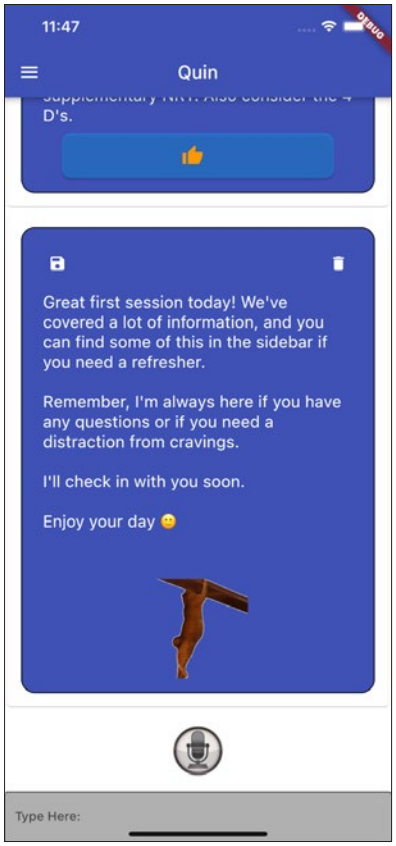
Vacation Student Projects

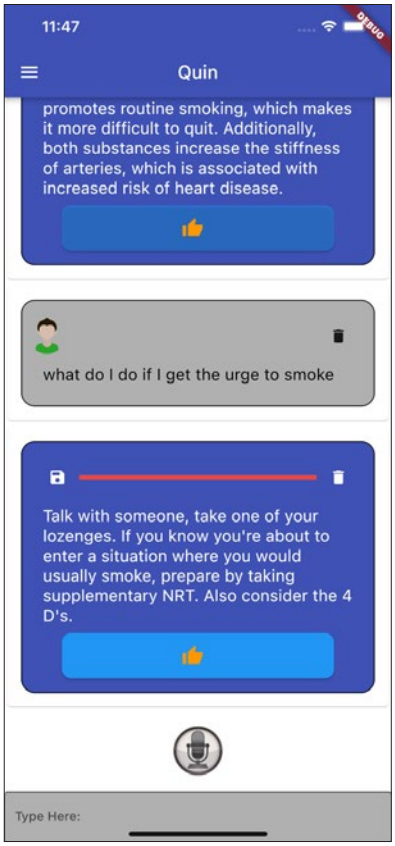
Project: Informing personalised gamification interventions through a novel gamified quiz

Student: Christiaan Dippenaar, University of Queensland

Supervisor: Marlien Varnfield

Nonadherence to medical interventions and other advice leads to increased care costs and poorer health outcomes across a range of medical fields. An approach to increasing adherence is gamification, which is the use of game elements in non-game contexts. The need for more personalised implementations of gamification motivated the creation of the Online Personality Determiner (OPD), which is planned for integration into existing mHealth solutions with the possibility for further integration and/or stand-alone use.





Project: Development of a smoking cessation chatbot called 'Quin'

Student: David Oates, University of Queensland

Supervisor: David Ireland

This project involved the development of a virtual companion in the form of a chatbot called 'Quin' to help people wishing to cease smoking. Quin's brain was created from a collection of Quitline counselling sessions and medical expert input.

Project: Simple image annotation and deep learning in wrist-fracture detection

Student: Sam Warner, Edith Cowan University

Supervisor: Janardhan Vignarajan

The project will develop an interactive visualisation tool for detection and labelling of wrist fracture from x-ray images. The team developed SIANNO tool (Simple Image ANNOtation) is now available free to download (GitHub link: https://github.com/aehrc/sianno-xray) and is open sourced. Through this project, we also explored incorporating AI based ML algorithms using deep learning techniques in detecting wrist fracture and working with our collaborators on further training the network to improve accuracy in a clinical environment.

Project: A python package: scalable population-based randomised feature selection for classification tasks

Student: Mark Chiu Chong, University of Queensland

Supervisor: Aida Brankovic

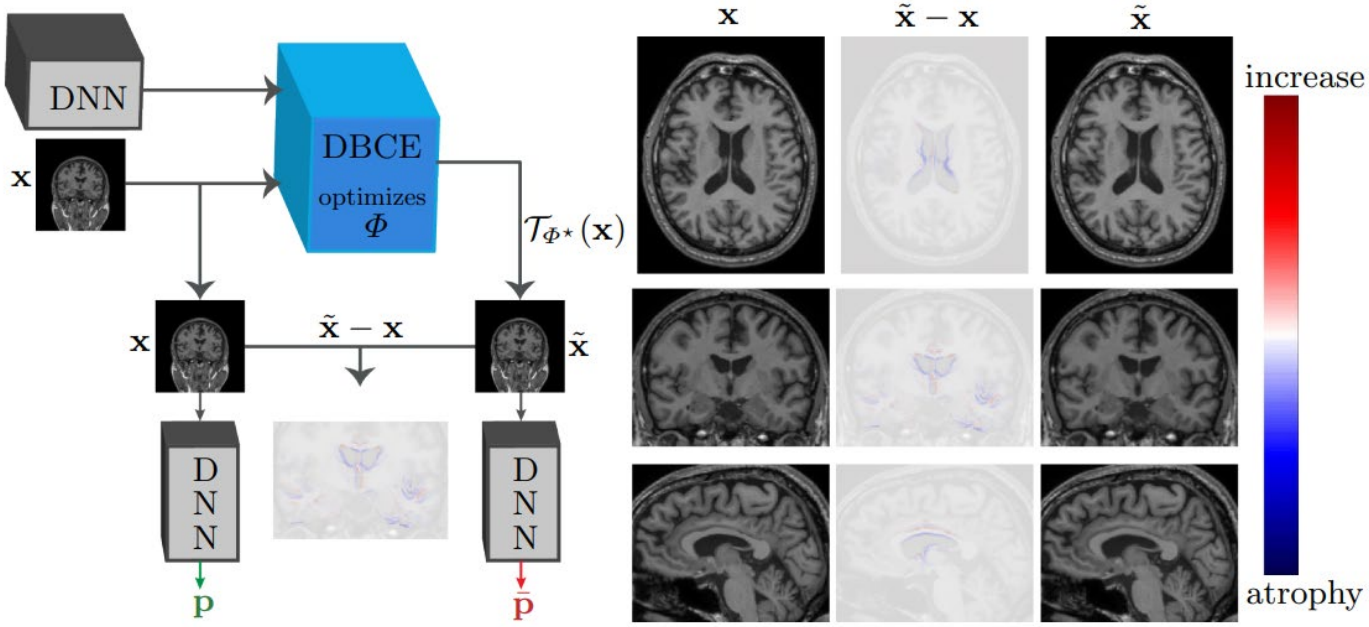
We developed a new open-source Python package that implements a scalable version of a recently introduced feature selection (FS) algorithm for classification tasks and extends it to a new ensemble approach. The developed method is domain agnostic and widely applicable to various fields of science that aim at building predictive models.

Project: DBCE A saliency method for medical deep learning through anatomically consistent free-form deformations

Student: Joshua Peters, University of Queensland

Supervisor: Rodrigo Santacruz, Gregg Belous, Léo Lebrat

Deep learning models are powerful tools to address challenging medical imaging problems. However, for an ever-growing range of applications, interpreting a model's prediction remains non-trivial. The understanding of decisions made by black-box algorithms is a critical topic and assessing their fairness and unbiasedness is a key step to healthcare deployment. In this paper, we propose DBCE (Deformation Based Counterfactual Explainability). Our use case is a deep neural network trained to classify neurodegenerative diseases from brain MRI. We optimise a diffeomorphic transformation that deforms a given input image to change the prediction of the model. This provides anatomically meaningful, and thus easily interpretable by clinicians, saliency maps showing tissue atrophy and expansion that would change the model decision.



Project: Association of sleep and circadian rhythm with structural brain changes in mid-life to older adults

Student: Po-Chen Liu, University of Melbourne

Supervisor: Mahnoosh Kholghi

This project investigated any association between objective measures of sleep & circadian rhythm with structural brain volumes in the UK biobank dataset. A pipeline, including big raw acceleration data processing and statistical modelling, was developed. We found a significant association between circadian rhythm and the changes in structural brain volume.

Project: A digital twin for a state-wide patient flow control room

Student: Nhi Van Kieu, Queensland University of Technology

Supervisor: Hamed Hassanzadeh

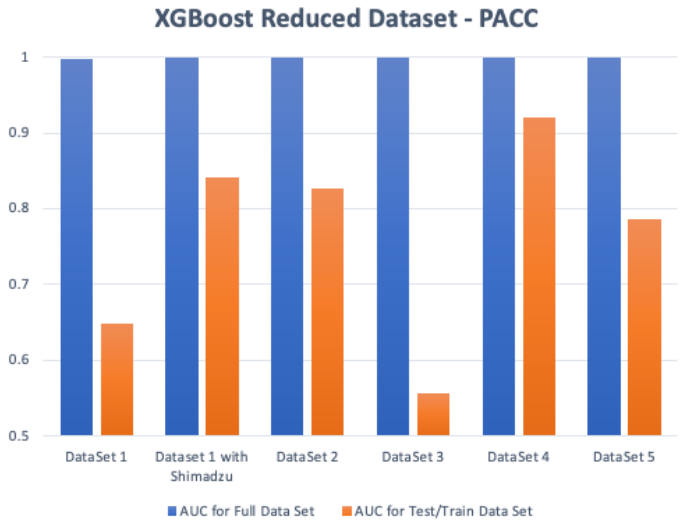
This project investigated the application of digital twins for a state-wide patient flow control room. A proof-of-concept web application was developed that employed a discrete event simulation model to process data in real-time and test what-if scenarios. An interactive dashboard was designed to visualise the geospatial factors and the impacts of scenarios on several KPIs.

Project: Could AI and a drop of blood predict Alzheimer's disease

Student: Vanesa Divet, Australian National University

Supervisor: James Doecke

This project investigated the application of ML/AI methods to identify blood-based biomarkers that would predict participants who would decline cognitively towards Alzheimer's disease. Multiple statistical workflows were produced to merge and analyse data from the Australian Imaging, Biomarkers and Lifestyle (AIBL) study of ageing. A short list of markers was identified with area under the curve values reaching 0.9 to predict those AIBL participants who have cognitive decline. The figure below shows the AUC values from validated as compared with non-validated models for five different data sets to predict those AIBL participants with cognitive decline. Data set 4 produced the highest validated AUC values.



Project: Internet of robotic things in aged care

Student: Kayla Wong, University of Queensland

Supervisor: David Silvera, Qing Zhang & Vanessa Smallbon

This project investigated the potential of integrating care robots into smart environment to support aging in place. A proof of concept was developed using a QT Robot, a raspberry pi and external sensors and actuators connected directly into the raspberry pi. Several modules were developed to facilitate social human-robot interaction with QT through speech, body movement and distributed sensors place within the environment.

Project: FHIRed up: SMART apps to counter superbugs

Student: Leonie Dickson, University of New South Wales

Supervisor: Anthony Nguyen

One element of antimicrobial stewardship programs is to assist clinicians in making informed and personalised decisions around prescribing antibiotics to their patients. To aid this process, two SMART on FHIR applications have been developed as an interoperable method to generate and visualise antimicrobial susceptibility information.

The first application is launched from an EHR to provide a convenient and clear visualisation of a patient's microbiological culture sensitivity history. The second provides hospital-level susceptibility data in the form of a dynamic antibiogram, which allows users to visualise susceptibility rates (generated using Pathling, an analytics FHIR server) and apply filters to personalise data to certain demographics and infection types.

Patient-level microbiology results app

Antibiogram app

Project: UWB radar for posture detection

Student: Christopher Bird, University of Queensland

Supervisor: Wei Lu

The objective of this project was to develop signal processing and machine learning techniques for the real-time classification of different work and stretch types from raw UWB radar data (Figure 1). Different data processing methods were considered, to extract both distance and doppler frequency shift information. The deep learning model comprises two parallel sets of convolutional layers, taking both distance and doppler images (Figure 2 and Figure 3), and achieves 93.2% test accuracy (Figure 4). The proposed signal processing and machine learning model can be run in real time on a raspberry pi 4 Model B (Figure 5).

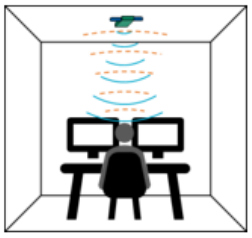


Figure 1. Experimental setup

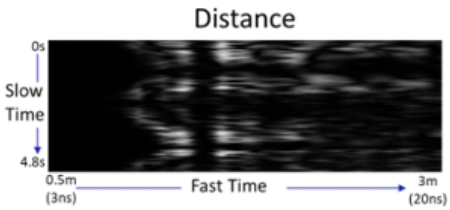


Figure 2. Distance image

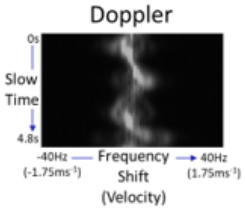


Figure 3. Doppler image

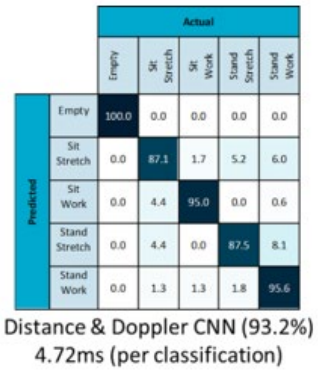


Figure 4. Distance and doppler combined CNN

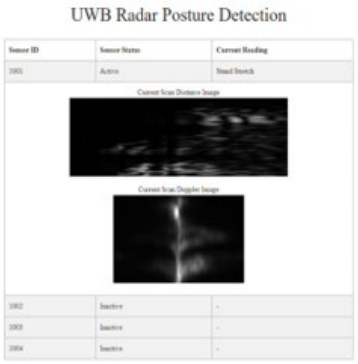


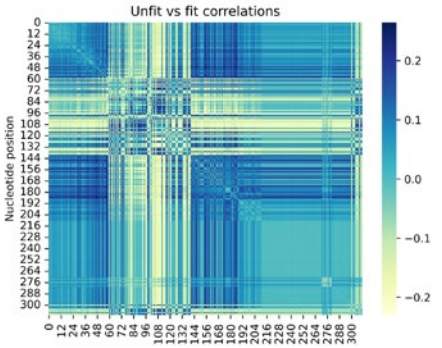
Figure 5. Real-time web server

Project: Modelling effective viral vector capsids to improve gene therapy applications

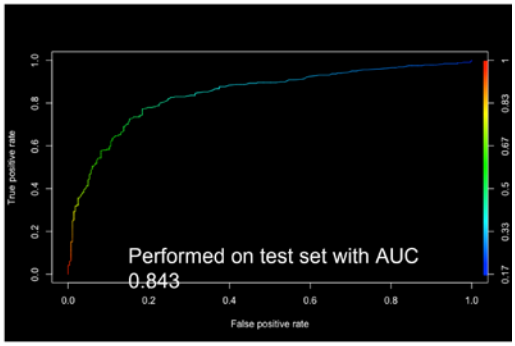
Student: Aravind Venkateswaran, UNSW

Supervisor: Laurence Wilson

Gene therapy applications require the delivery of therapeutic cargo to the target tissue which is usually done through the use of a viral capsid, a protein shell into which the cargo can be packaged. The sequence and structure of this capsid is critical to the overall effectiveness of the application however very little is known about the sequence determinants. This project used machine learning to investigate how changes to sequence contributed to overall effectiveness, identifying trends and rules which can be used to improve future manufacturing.



Differences in sequence features between fit and unfit targets



Predictive power of machine learning model

Project: Development of low complexity machine learning/deep learning model for smartphone-based biomedical image analysis

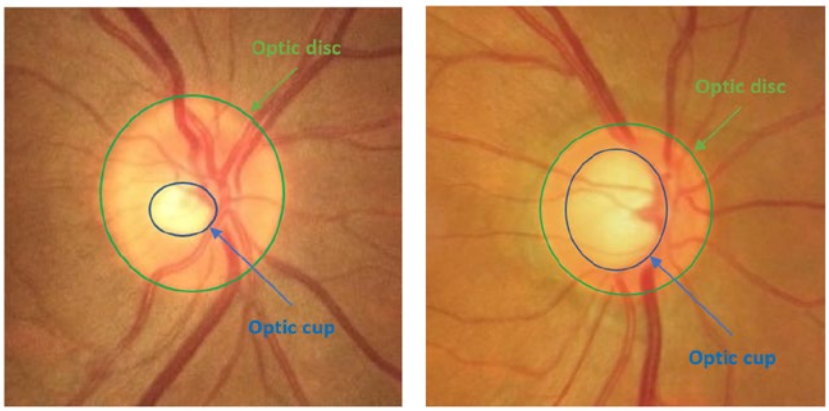
Student: Isaac Colleran, Curtin University

Supervisor: Sajib Saha

Glaucoma is a silent killer of eyesight that affects people of all ages. The loss of sight from glaucoma is irreversible and usually gradual in nature, with treatments limited to slowing down its progression. Early detection is important to save vision loss.

Colour fundus photographs (CFPs) are often used to diagnose glaucoma. In recent years there has been an increasing interest to develop convolutional neural network (CNN)-based approaches for automated assessment of glaucoma using CFPs. CNN models vary notably in network depth, computational cost, and performance.

This project aimed to justify whether low computationally intensive CNNs are capable of detecting glaucoma as well as high computationally intensive CNNs. With that aim, this study evaluated the performance of seven state-of-the art CNNs with varying computational intensity – MobileNetV2, MobileNetV3, Custom ResNet, InceptionV3, ResNet50, 18-Layer CNN and InceptionResNetV2. The publicly available large-scale attention-based glaucoma (LAG) dataset was used for experiments. With its 1,711 "glaucomatous" and 3,143 "nonglaucomatous" sample images, LAG database is the largest publicly available glaucoma dataset to date. Experiments reveal that despite being significantly less computationally demanding, MobileNetV3 outperforms all others, and produces an accuracy, specificity and sensitivity of 97.7%, 97.8% and 97.6%, respectively.



(a) Case I (b) Case II

Two cropped fundus images showing a healthy optic disc with a small CDR on the left and a glaucomatous optic disc with a much larger CDR on the right.

TABLE I
RESULTS FROM TRANSFER LEARNING. ALL VALUES IN THE TABLE ARE CALCULATED AS AN AVERAGE OF TEN-FOLD CROSS VALIDATION.

Architecture	Acc (%)	Spec	Sens	F1	AUC
ResNet50	97.4	0.974	0.973	0.971	0.993
InceptionV3	95.0	0.944	0.954	0.946	0.985
InceptionResNetV2	97.4	0.968	0.980	0.971	0.994
MobileNetV2	96.1	0.949	0.973	0.962	0.992
MobileNetV3Small	97.7	0.978	0.976	0.975	0.995

TABLE II
RESULTS OF TRAINING FROM SCRATCH. SIMILAR TO THE TRANSFER LEARNING CASE, TEN-FOLD CROSS-VALIDATION IS USED FOR PERFORMANCE EVALUATION.

Architecture	Acc (%)	Spec	Sens	F1	AUC
ResNet50	93.5	0.938	0.935	0.936	0.979
InceptionV3	95.1	0.955	0.946	0.949	0.988
InceptionResNetV2	95.4	0.961	0.949	0.951	0.988
MobileNetV2	94.9	0.951	0.945	0.945	0.985
MobileNetV3Small	95.4	0.953	0.955	0.952	0.989
18-Layer CNN	94.9	0.949	0.945	0.947	0.986
Custom ResNet	93.9	0.943	0.936	0.939	0.980

Project: Using health tracking sensors to improve health care delivery: Co-designing interventions with researchers and health care professionals

Student: Meaghan Ferguson, Royal Melbourne Institute of Technology

Supervisor: Christian Redd

The market for consumer wearables is experiencing exponential growth, however, significant gaps in transdisciplinary knowledge means that the technology is not capitalised on for eHealth application. This project saw the development of a visual tool and workshop series to support the co-design of health interventions between clinicians and technologists, building momentum for the continual development of the AEHRC's mobile health platforms.

Project: Coronary artery disease genotype risk modelling

Student: Sam Bagot, University of New South Wales

Supervisor: Letitia Sng

This project aimed to improve current risk scoring systems for coronary artery disease (CAD) by integrating genetic data and carotid thickness. To develop a risk model, random forests (RFs) were built using the CAD cohort within the UK Biobank, thus accounting for epistatic interactions inherently. This provided an insight into the additional value genetic data and carotid thickness measures would provide over current phenotype-based scores in the prediction of CAD. Results suggested including carotid thickness and genetic information improved the accuracy of the prediction models, although added only limited prediction power.

Project: Synthetic hospital simulation – generating a realistic real-time feed of synthetic FHIR data and demonstrating streaming processing for analytics

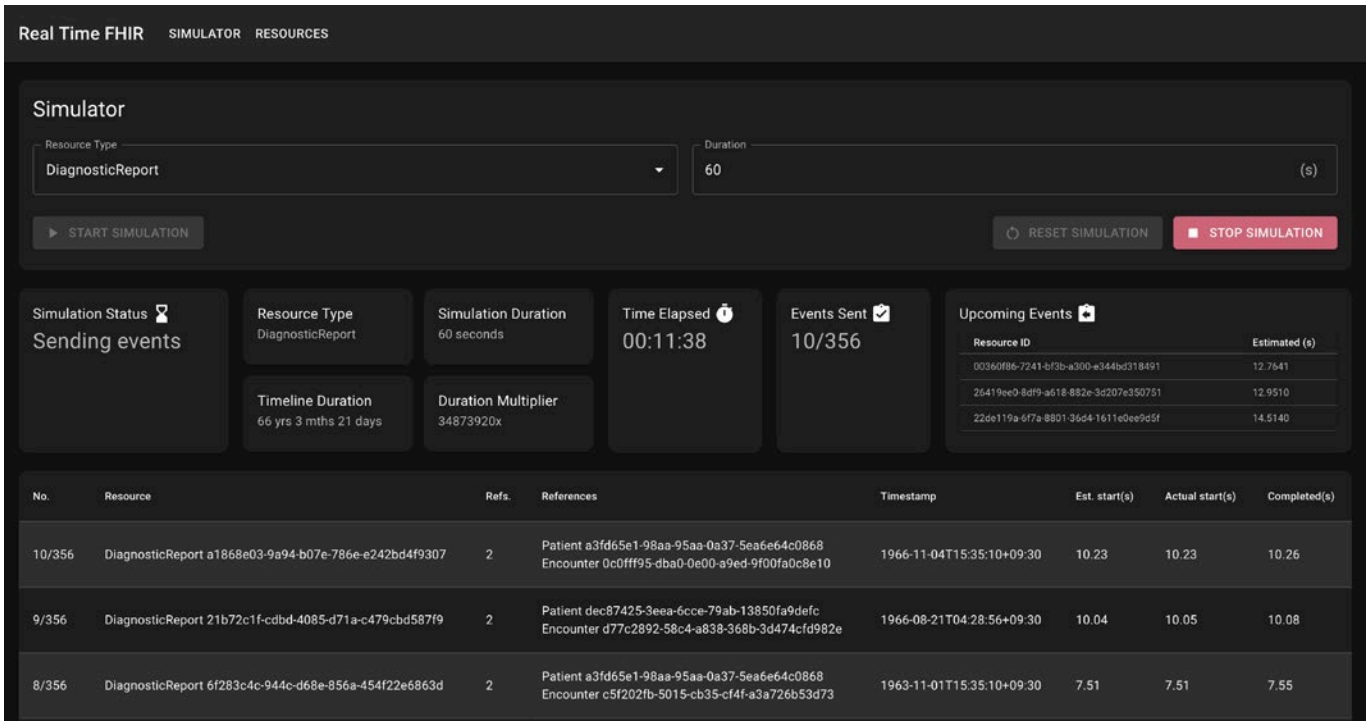
Student: Sean Fong, University of Adelaide

Supervisor: John Grimes

This project developed a simulated real-time source of FHIR EHR data, which can be used to assist with the development and testing of real-time applications.

In addition to this, a new feature was built within Pathling to allow for the real-time ingest of FHIR data, enabling real-time analytic query.

	TP	FP	TN	FN	MCC (0 – 1)	F1	MCCF1
Age Sex BMI	194	653	2696	113	0.6436	0.2872	0.436
Carotid thick	4	31	3318	303	0.505	0.0234	0.240
All Pheno	79	80	3269	228	0.6587	0.3391	0.474
Geno only	0	0	3349	307	-	0	-
Geno & Pheno	0	0	3349	307	-	0	-



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: New frontiers in personalised prevention of CAD

Years funded: 2021–22

Chief Investigators: Professor Gemma Figtree, University of Sydney

AEHRC Investigators: Dr Denis Bauer, Dr Natalie Twine

The proposed CAD Frontiers Program harnesses cross-disciplinary teams of clinicians, researchers, healthcare workers and industry partners to develop new approaches in the prevention and management of patients presenting with coronary artery disease.

MRFF Future Frontier Stage 1: Australian Phage Network: developing solutions for antimicrobial resistance

Years funded: 2021–22

Chief Investigators: Professor Jonathan R Iredell, University of Sydney

AEHRC Investigators: Dr Denis Bauer, Dr Natalie Twine, Dr Laurence Wilson

CSIRO will supplement the bioinformatics activity to guide clinical diagnosis and therapy and assist the forced evolution and bioengineering of phages. Building upon their existing software approaches the team will develop bespoke machine learning algorithms able to guide the design of "programmable phages". CSIRO will also contribute towards the phage characterisation and application hub, by adapting approaches from their technology developed for human health applications to associate desirable phage properties with genetic features.

MRFF Future Frontier Stage 1: sySTEMs Initiative: systems biology-augmented rapid screening for potential COVID-19 treatments

Years funded: 2021–22

Chief Investigators: Dr Alex McAuley, CSIRO

AEHRC Investigators: Dr Laurence Wilson

This project takes a systems biology approach to understand how SARS-CoV-2 infections respond to treatment with currently available drugs, with the goal of finding and repurposing FDA/TGA approved treatments. The project will involve modelling how the host responds to SARS-CoV-2 infections and the effect of treatment using new developments in machine learning and deep learning, with the ultimate goal of predicting how future infections will behave.

MRFF Genomics Health Futures Mission: a national large scale automated reanalysis program to increase rare disease diagnosis

Years Funded: 2021–25

Chief Investigators: Professor Zornita Stark, Murdoch Children's Research Institute

AEHRC Investigators: Dr Denis Bauer, Dr Natalie Twine

The project will develop and evaluate a national program for automated, systematic reanalysis of genomic data to deliver improved diagnostic outcomes in large cohorts of rare disease patients. They will harness continuously updated knowledge bases of disease-associated cariants and genes, improvements in genomic data analysis and interpretation, and use of cloud-based distributed systems with machine learning approaches to scale up analysis nationally. CSIRO will supplement the bioinformatics activity for the project through expertise in cloud architecture and machine learning to improve platform efficiency and scalability. The grant will fund 50% salary for a postdoc within Genome Insights team for 3 years.

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 School readiness child outcomes of early neuroprotection/early neurorehabilitation for infants at high risk of cerebral palsy in the first 2000 days

Years funded: 2022–2026

Chief Investigator: Professor Roslyn Boyd, University of Queensland

AEHRC Investigators: Dr Kerstin Pannek

Early intervention trials for infants at high risk of cerebral palsy so far have assessed outcomes up to 2 years age. In this study, we will follow-up children who participated in RCTs of early neurorehabilitation/ neuroprotection (recruited at <6 months age) at 4–5 years old to determine school readiness and longer term effectiveness of interventions. CSIRO will contribute image analyses of newborn brain MRI, to determine whether children with specific brain injuries are more responsive to certain interventions.

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 Jurgen Fripp

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 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.

MRFF Music attuned technology care eHealth (MATCH): a music based mobile eHealth solution to support care of people with dementia

Years funded: 2021–2026

Chief Investigator: Professor Felicity Baker, University of Melbourne

AEHRC Investigators: Dr Marlien Varnfield

This project aims to improve address agitation levels of people living with dementia by using wearable sensor technology to capture behavioural markers of agitation. Developing algorithms that are aimed at learning the preferences of the people living with dementia, music will be auto-suggested and adapted to match and attune to the detected arousal, thereby reducing agitation levels for the person living with dementia. This will be delivered through the already developed MATCH App.

MRFF Dementia, Ageing and Aged Care Mission: Blood testing to predict and discriminate dementias

Years funded: 2021–2026

Chief Investigator: Professor Ashley Bush, University of Melbourne

AEHRC Investigators: Dr Jurgen Fripp, Dr James Doecke, Dr Vincent Dore

A predictive blood test for Alzheimer's disease (AD) is urgently needed. Our project will bring together Australia's leading dementia researchers and the largest dementia-related research cohort ever assembled in this country to accelerate the use of blood tests in clinical settings (e.g., hospitals, memory clinics) that can help to diagnose, and predict the onset of, AD. We will also examine the impact of having a diagnostic blood test for AD on health and management outcomes.

National Health and Medical Research Council (NHMRC): Early diagnosis and early intervention for infants with cerebral palsy: implementation of international evidence based guidelines into practice

Years funded: 2022–2023

Chief Investigator: Associate Professor Alicia Spittle, University of Melbourne

AEHRC Investigators: Dr Dana Bradford, Dr Kerstin Pannek, Dr Alex Pagnozzi

Brain MRI forms an important part of the diagnostic workup of cerebral palsy. In this project, we will develop automated approaches to quantitatively evaluate clinical brain MRI of newborns and toddlers with cerebral palsy. These automated tools will support clinicians by making information in MRI more easily accessible and less time consuming.

NHMRC Marshall and Warren Ideas Grant Award: Exploiting anti-capsid humoral immunity induced in infants receiving gene therapy for spinal muscular atrophy

Years funded: 2021–2023

Chief Investigator: Professor Ian Alexander, University of Sydney

AEHRC Investigator: A/Prof Denis Bauer

Exploiting anti-capsid humoral immunity induced in infants receiving gene therapy for spinal muscular atrophy to engineer the next generation of gene transfer vectors.

After 25 years of incremental progress the possibility of treating genetic disease by gene therapy has become a therapeutic reality. This has been achieved by harnessing the gene transfer power of viruses made harmless by genetic engineering. A major limitation is that up to 50 percent of patients are currently excluded by pre-existing immunity to these powerful tools. Using 'evolution in a dish', we will engineer a new generation of these tools capable of bypassing pre-existing immunity by stealth.

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 Pierrick Bourgeat

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 are developing novel multi-view learning strategies that relate 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 Project Grant: Developing and innovative mobile health avatar to enhance smoking cessation

Years funded: 2020–2025

Investigator: Dr. Henry Marshall

AEHRC Investigators: Dr David Ireland

Our multidisciplinary team of computer scientists, psychologists, public health and clinical medicine specialists will develop a state-of-the-art artificial intelligence (AI) based mHealth app (AI Avatar, akin to Apple's Siri) to deliver tailored counselling and expert smoking cessation advice to smokers.

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 PROTECTMe: Assessing antenatal maternal melatonin supplementation in fetal growth restriction to improve neurodevelopmental outcomes

Years funded: 2020–2024

Chief Investigator: Dr Kirsten Palmer, Monash University

AEHRC Investigators: Dr Kerstin Pannek, Dr Alex Pagnozzi, Dr Javier Urriola Yaksic

Fetal growth restriction is a risk factor for adverse neurodevelopmental outcome. This randomised clinical trial investigates whether maternal melatonin supplementation during pregnancy can improve outcomes. We will determine whether there are any observable differences in brain structure and microstructure between newborns in the treatment group compared to placebo group and investigate whether these brain changes lead to differences in outcomes at 2 years age.

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

Years funded: 2019–2022

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

AEHRC Investigators: Dr Dana Bradford, Dr Kerstin Pannek, Dr Alex Pagnozzi

This new pragmatic, single blind randomised controlled trial (RCT) in 300 infants with cerebral palsy or at high risk of cerebral palsy will 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 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: Prediction of childhood brain outcomes in infants born preterm using neonatal MRI and concurrent clinical biomarkers

Years funded: 2019–2024

Chief Investigator: Roslyn Boyd

AEHRC Investigators: Dr Dana Bradford, Dr Alex Pagnozzi, Dr Kerstin Pannek

Preterm birth is a risk factor of adverse neurodevelopmental outcomes. In this project, preterm-born children who were previously recruited into our PPREMO and PREBO studies (2014 – 2019) and assessed using MRI and clinical assessments in the newborn period and at 2 years, will return for follow-up MRI and clinical assessments at 6 years age. This will enable us to predict longer-term outcomes at school age from newborn data.

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

Years funded: 2019–2022

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

AEHRC Investigators/Chief Investigator E: Dr Vincent Dore

This study combines 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 will 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 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) will continue development one of the world's largest longitudinal studies into Alzheimer's disease (Australian Imaging, Biomarker & Lifestyle Flagship Study of Ageing, 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: 2018–2022

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 HABIT-ILE: A randomised trial of hand arm bimanual intensive training including lower extremity training for children with bilateral cerebral palsy

Years funded: 2018–2021

Chief Investigator: Dr Leanne Sakzewski, University of Queensland

AEHRC Investigators: Dr Dana Bradford, Dr Kerstin Pannek, Dr Alex Pagnozzi, Dr Javier Urriola Yaksic

Intensive intervention leads to changes in brain structure and microstructure. In this study, we will examine this neuroplasticity in children with cerebral palsy who undergo 2 weeks of intensive HABIT-ILE intervention, compared to children receiving standard intervention. This will help us understand why some children may respond better to intervention, and in future will help select the best intervention for the individual child.

NHMRC Centre for Research Excellence in Cerebral Palsy

Years funded: 2017–2022

Chief Investigator: Professor Roslyn Boyd, University of Queensland

AEHRC Investigators: Dr Dana Bradford, Dr Kerstin Pannek

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

Years funded: 2016–2022

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 examines 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 Australian Genomics Health Alliance

Years funded: 2016–2023

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

AEHRC Investigators: Dr David Hansen, Dr Denis Bauer

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 Targeting Treatable Traits in COPD to Prevent Hospitalisations (TERRACOTTA)

Years funded: 2021–2024

Chief Investigator: Dr Johnson George, Monash University

AEHRC Investigators: Dr Rajiv Jayasena

Demonstrates the efficacy and cost-effectiveness of an interdisciplinary practice nurse-coordinated intervention targeting treatable traits in moderate-severe COPD in general practice for improving quality of life (QoL) and reducing hospitalisations/emergency department (ED) visits. TERRACOTTA will focus on a national roll-out of the interdisciplinary model of care, cost-effectiveness analysis and program evaluation, to inform its scale-up as a routine service.

NHMRC Ideas Grant: Imaging, fluid and genetic markers of Alzheimer's disease

Years funded: 2021–2024

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

AEHRC Investigator: Dr Pierrick Bourgeat

Markers of pathology and inflammation are useful tools for the diagnosis and staging of neurodegenerative conditions such as Alzheimer's disease. This approach will deepen our basic understanding of this disease, improving early detection and prediction of cognitive impairment. This work will make possible more accurate diagnosis, and improved monitoring of therapeutic interventions.

Australian Research Council: 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.

ARC: Training Centre for Next-Gen Technologies in Biomedical Analysis

Years funded: 2022–2026

Chief Investigator: Prof Killugudi Swaminatha Iyer, Western Australia University

AEHRC Investigators: Dr Denis Bauer

The ARC Training Centre for Next-Gen Technologies in Biomedical Analysis, led by UWA, will deliver a workforce trained in the development of transformative technologies that will rapidly expand the Australian pharmaceutical, diagnostic and defence sector.

AEHRC Publications 2021–22

Journals

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Dr Dana Kai Bradford, Team Leader and Principal Research Scientist

Dr Sam Burnham, Principal Research Scientist

Ms Jessica Bugeja, Postgraduate Student

Dr Ying Xia, Research Scientist

Dr Pierrick Bourgeat, Principal Research Scientist

Dr Ashley Gillman, CERC Postdoctoral Fellow

Dr Kerstin Pannek, Senior Research Scientist

Dr Alex Pagnozzi, Research Scientist

Dr Lee Reid, Research Scientist

Dr Parnesh Raniga, Senior Research Scientist

Dr Amir Fazlollahi, Research Scientist

Dr Saba Momeni, Postgraduate Student

Dr Michael Vacher, Research Scientist

Ms Julie Trinder, Research Technician

Dr Rodrigo Santa Cruz, Postdoctoral Fellow

Dr Rosita Shishegar, Research Scientist

Dr Simon Puttick, Senior Research Scientist

Dr. Léo Lebrat, Postdoctoral Fellow

Dr Shenpeng Li, CERC Postdoctoral Fellow

Dr Timothy Cox, CERC Postdoctoral Fellow

Dr Janine Walker, Senior Research Scientist

Dr Hang Min, Affiliate Postdoctoral Fellow

Ms Szenung Leung, Postgraduate Student

Mr Siyu Liu, Postgraduate Student

Dr Philip Mosley, Research Scientist

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Ms Nancy Kaur, Postgraduate Student

Darren Fu, Industrial Trainee

Mr Febrio Lunardo, Postgraduate Student

Dr Javier Urriola Yaksic, CERC Postdoctoral Fellow

Jake Palmer, CERC Postdoctoral Fellow

Filip Rusak, Postgraduate Student

Caroline Faucher, Postgraduate Student

Dr Andrew McKinnon, Visiting Scientist

Jonathan Flintoff, Postgraduate Student

Rodrigo Canovas, Research Scientist

Dr Gregg Belous, CERC Postdoctoral Fellow

Ms Hilda Chourak, Postgraduate Student

Dr Bowen Xin, CERC Postdoctoral Fellow

Matthew Dean, Industrial Trainee

Laeeq Hamid, Postgraduate Student

Vanessa Divet, Vacation Student 2021–2022

Transformational Bioinformatics Group

Dr Denis Bauer, Group Leader and Principal Research Scientist

Dr Natalie Twine, Team Leader

Dr Laurence Wilson, Team Leader

Mr Brendan Hosking, Software Engineer

Dr Aidan Tay, Visiting Scientist

Mr Yatish Jain, IT Advisor

Mr Mischa Lundberg, Postgraduate Student

Mr Andrey Verich, Postgraduate Student

Dr Letitia Sng, CERC Postdoctoral Fellow

Dr Priya Ramarao-Milne, CERC Postdoctoral Fellow

Aravind Venkateswaran, Industrial Trainee

Dr Carol Lee, CERC Postdoctoral Fellow

Kilian Salomon, Postgraduate Student

Dr Anne Klein, CERC Postdoctoral Fellow

Edwina McDonald, CERC Postdoctoral Fellow

Camille Sayoc, Postgraduate Student

Anuradha Wickramarachchi, Research Software Engineer

Dr Mitchell O'Brien, CERC Postdoctoral Fellow

Dr Roc Reguant Comellas, Research Engineer

Reevanshi Sharma, Masters Student

Health Services Group

Dr Marlien Varnfield, Group Leader and Senior Research Scientist

Dr Mohan Karunanithi, Group Leader and Principal Research Scientist

Dr Qing Zhang, Team Leader
and Principal Research Scientist

Dr Shaun Frost, Team Leader and Senior Research Scientist

Mr Janardhan Vignarajan, Team Leader and Senior Engineer

Dr David Silvera-Tawil, Team Leader
and Senior Research Scientist

Dr Jane Li, Senior Experimental Scientist

Dr Christian Redd, Research Scientist

Ms Vanessa Smallbon, Engineer

Dr Mahnoosh Kholghi, Research Scientist

Dr Kaley Butten, CERC Postdoctoral Fellow

Ms Julia Bomke, Project Support Service Centre Officer

Ms Liesel Higgins, Project Manager
Research and Development

Dr Mohamed Estai, Postdoctoral Fellow

Dr Wei Lu, CERC Postdoctoral Fellow

Dr Angelina Duan, CERC Postdoctoral Fellow

Dr Sajib Saha, Research Scientist

Ms Maryam Mehdizadeh, Senior Software Engineer

Ms Vera Buss, Postgraduate Student

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Eve Martin, Postgraduate Student

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Future Science Platform

Prof Stephen Rose, Future Science Platform Leader

Vacation Scholarship Students

Kayla Wong, University of Queensland

David Oates, University of Queensland

Tian Dippenaar, University of Queensland

Meaghan Ferguson, University of Queensland

Po-Chen Liu, University of Melbourne

Chris Bird, University of Queensland

Isaac Colleran, Curtin University

Vanessa Divet, Australian National University

Leonie Dickson, University of NSW

Sean Fong, University of Adelaide

Sam Bagot, University of New South Wales

Aravind Venkateswaran, University of New South Wales

Nhi Kieu, Queensland University of Technology

Mark Chiu Chong, University of Queensland

Joshua Peters, University of Queensland

Samuel Warner, Edith Cowan University

Visitors

Prof Mark Braunstein, Georgia Institute
of Technology, Atlanta, USA

Kun Huang, Site Visitor

Dr Linda Bird, Visiting Scientist

Support staff

Finance
Kellie Tighe

HR
Laurie Mackenzie

Finance Support
Rebecca Mok

Contract Support
Sandy Farnworth

HSE Support
Megan Tilley

Special Purpose Financial Report

THE AUSTRALIAN E-HEALTH RESEARCH CENTRE
(An unincorporated joint venture)

SPECIAL PURPOSE FINANCIAL REPORT

30 JUNE 2022

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 2022 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

Brisbane
Date: 9/8/2022

Director

Brisbane
Date: 12 AUG 2022

Director

Brisbane
Date: 16/8/2022

Director

Brisbane
Date: 17 August 2022

Trumans
CHARTERED ACCOUNTANTS

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 2022, 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 2022 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
Partner

Chatswood

Dated: 18 August 2022

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