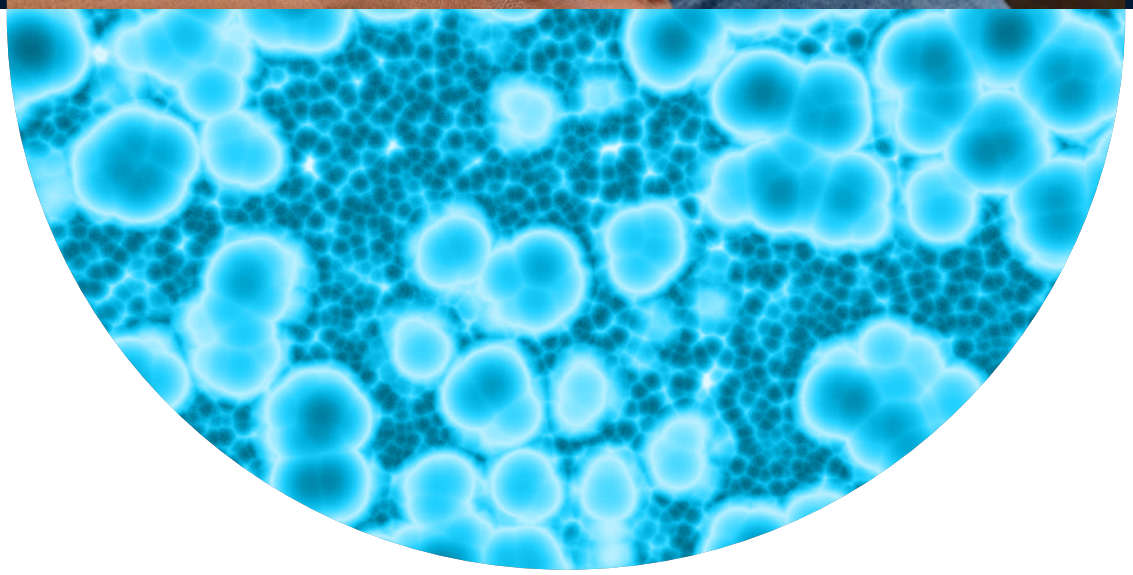
Australian e-Health Research Centre



The Australian e-Health Research Centre

Annual Report
2020–2021

Queensland Government

Contents

The Australian e-Health Research Centre

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

Established in 2003 with initial funding from the 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 for an additional five years with a further contribution of $15 million from CSIRO and Queensland Health.

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

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

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

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

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

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

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

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 in Nutrition and Health, Biosecurity and Precision Health and the emerging CSIRO mission programs on Antimicrobial Resistance and Infectious Disease Resilience.

Foreword by the Chair and CEO

COVID-19 has continued to dominate the world in the past year – and while the AEHRC has made a significant contribution to Australia's response to the pandemic, the centre has also continued to deliver impact for our stakeholders, collaborators and customers.

The AEHRC contribution to Australia's COVID-19 response includes continuing to work with Queensland Health to develop COVID-19 analytics approaches to understanding the pandemic in Queensland. Our bioinformatics team have continued to work with the Australian Centre for Disease Preparedness and other collaborators to track variants of the SARS-COV-2 virus genome and their impact.

The world's response to the pandemic has been an acceleration of the need for the research that the AEHRC undertakes. There has been an increased digitisation of healthcare as patients and providers seek to use technology to deliver care to people where they are; while everyone has seen the value of having high quality health data in managing healthcare.

The AEHRC is ideally positioned to play a leading role as Australia increases the digitisation of healthcare in the wake of the pandemic.

The move to Virtual Care will be underpinned by technology to allow patients to be connected to a health service – through a mobile phone, tele-health consult or remote monitoring – and the sharing of data between the patient and the health service in a meaningful way. Over the past 12 months the AEHRC has conducted a number of Virtual Care trials – including mobile health for women with gestational diabetes, patients undergoing total knee replacement, aged people living alone and many others. The results from these trials are showing the value of Virtual Care to the person and to health services.

In addition, the AEHRC has continued to work with Australia's health departments, peak bodies and health IT software vendors to agree on data standards to support the sharing of data using data standards – a vital component of safe and efficient Virtual Care interactions.

The value of data informing healthcare decision making has become obvious during the pandemic. Across the AEHRC our projects on health surveillance, health system performance, clinical decision support and our many projects which use artificial intelligence and data analytics, show that the AEHRC understands how to use data to aid decision making in healthcare. Our data teams have worked with Queensland Health and many other health agencies to support COVID-19 data analytics, while also making significant contributions in other areas such as antimicrobial resistance and hospital performance over the past 12 months.

The world also continues to accelerate the use of new technologies to drive precision healthcare. This year our groups have continued to work with clinical research and clinical collaborators on a large number of trials and implementations of technology to support precision health approaches. Despite COVID-19 often pausing recruitment and monitoring of trials, our teams have worked with our collaborators to ensure that the trials can resume and continue when safe.

The last 12 months have also seen a significant increase in licensing of AEHRC technologies. This included an increase in international licensing of our clinical terminology server, Ontoserver – including winning an internationally competitive tender from the UK's National Health Service for a national clinical terminology service. We licensed our Smarter Safer Homes innovation to an Australian SME specialising in technology supporting the aged care industry. Our various Smarter Safer Homes trials have shown the value of this technology and we hope that this approach to getting the technology used helps address some of the issues in the Aged Care Royal Commission.

Our staff continue to build collaborations across healthcare – and we have far too many collaborators to name them all here. Engagement with our key stakeholders – Queensland Health and CSIRO – continues to grow, with adoption of our technologies by Queensland Health as well as CSIRO. Nationally we continue to collaborate strongly with the Australian Digital Health Agency and we are forging stronger relationships in New South Wales, Victoria and Western Australia as our teams in those states grow. We invested in developing our Indigenous Health capability a few years ago and are seeing results from this investment with a number of new projects with Indigenous Health groups starting over the last 12 months.

We must acknowledge that an amazing group of scientists, engineers, project and support staff make up the AEHRC. Over the past 12 months they have excelled at looking after each other, themselves and their families while continuing to deliver for our partners. Both of us would like to thank them for the amazing energy, intelligence and commitment they bring.

We would also like to acknowledge the enterprise support that CSIRO provides. This has been particularly evident this year as we move into new offices in all our locations around Australia. In Brisbane we have moved into significantly bigger offices in the new STARS Hospital on the Herston Health Precinct; in Sydney we are consolidating with CSIRO Health and Biosecurity onto the Westmead Health Precinct; while in Melbourne we are moving into refitted offices at the CSIRO Parkville site; and in Perth we are moving into new offices at the CSIRO Kensington site. All of these moves support the continued growth of the AEHRC.

The 2020–21 AEHRC Annual Report provides a full overview of the research we undertake – including our research groups, platform technologies, project reports and project updates. This year we are reporting on over 75 projects across our five research groups – some of which we have highlighted in this foreword.

Even with COVID-19 continuing to dominate, the digitisation of healthcare continues to accelerate and the AEHRC is well placed to take advantage of this acceleration.

Richard Royle
Chair
The AEHRC

David Hansen
Chief Executive Officer
The AEHRC

Board of Directors

Richard Royle

Chair, the Australian e-Health Research Centre

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

Richard oversaw the successful implementation of Australia's first fully integrated digital hospital in Hervey Bay as the group CEO of UnitingCare Health in 2014. In 2016 he was asked to be the 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.

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

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

Rob Grenfell

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

Rob has broad-ranging public health experience including:

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

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

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.

Richard Symonds

Minutes Secretary

Kellie Tighe

Finance Manager, CSIRO

Meetings

Board Meetings for 2020–21 were held:

- 25 August 2020
- 27 October 2020
- 19 February 2021
- 17 May 2021

AEHRC around Australia

Since its formation in 2003, The Australian e-Health Research Centre has established a central role in the Australian 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 a number of Federal Government agencies – including the Commonwealth Department of Health and the Australian Digital Health Agency.

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

Queensland

Our AEHRC headquarters recently moved into new offices in the new STARS Hospital on the Herston Health Precinct. The new office is on the 7th floor with views over the city and the D'Aguilar range to the west and is well fitted out. It provides our Brisbane based staff and students with a wonderful space to work – and we're all hoping that we can enjoy it more over coming months with less lockdowns due to COVID-19.

We collaborate broadly across with Queensland Health – including with eHealth Queensland and Clinical Excellence Queensland, as well as 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 and Griffith University. New collaborations were established in 2021 with Sunshine Coast University and James Cook University.

All our research groups work with Queensland collaborators and they are acknowledged throughout this report.

Our Queensland Health engagement is led by CEO and Research Director David Hansen.

New South Wales

In early 2022 our NSW based staff will consolidate into a new office in 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 staff from our Transformational Bioinformatics, Health Services and Health Informatics groups.

We have a number of 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 a number of 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

Perth is home to our tele-health research teams – established in conjunction with the Department of Health Western Australia in June 2012.

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

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 our Team Leaders in Perth, Shaun Frost and Jana Vignarajan.

Victoria

Our Melbourne based staff are primarily located in the CSIRO offices at Parkville and are part of a number of different groups – including Health System Analytics, Biomedical Informatics and Health Informatics.

The AEHRC has a number of 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).

In Victoria the AEHRC Health System Analytics group works with the Victorian Agency for Health Information (VAHI) and a number of hospital partners to understand patient flow, optimisation of performance and reporting. In 2021 the group also finalised a multi-year project with the Victorian Department of Health to evaluate the Healthlinks Chronic Care program which involved 10 Victorian hospitals.

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

Management and leadership

Dr David Hansen

CEO, Australian e-Health Research Centre

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

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

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

Dr Jill Freyne

Deputy Research Director

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

Jill has significant research experience in the development and validation of digital health services, lifestyle interventions and recommender systems. Jill has worked with Australian and international industry partners to devise engaging and sustainable health technology solutions, aimed specifically at encouraging individuals to change the way they engage with their health. Through clinical trials, these technologies have been evaluated and have demonstrated 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 Informatics

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

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

Dr Jurgen Fripp

Group Leader, Biomedical Informatics

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

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

Dr Denis Bauer

Group Leader, Transformational Bioinformatics

Dr Denis Bauer is the Principal Research Scientist in transformational bioinformatics and an internationally recognised expert in machine learning and cloud-based genomics. 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 $31M in funding to further health research and digital health. She develops open-source bioinformatics software that has commercial impact through cloud-deployment.

Dr Mohan Karunanithi

Group Leader, Health Services

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

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

Dr Rajiv Jayasena

Group Leader, Health System Analytics and Victorian Lead

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

Rajiv leads the AEHRC's Health Systems Analytics group, comprising research teams specialising 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 also manages clinical trials in primary healthcare reform nationally and leads new areas of science in response to research opportunities and stakeholder priorities.

Dr Janet Fox

Business Development Manager

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

AEHRC e-Health Research Colloquium 2021

This year's AEHRC annual e-Health colloquium went national – and virtual! Held on 1st June, 200 people attended in person across sites in three different states – Royal Brisbane and Women's Hospital in Brisbane, Westmead Institute for Medical Research (WIMR) in Sydney and Fiona Stanley Hospital in Perth. In addition, over 150 people from across Australia tuned in to the live webcast, where the event reached its largest audience ever.

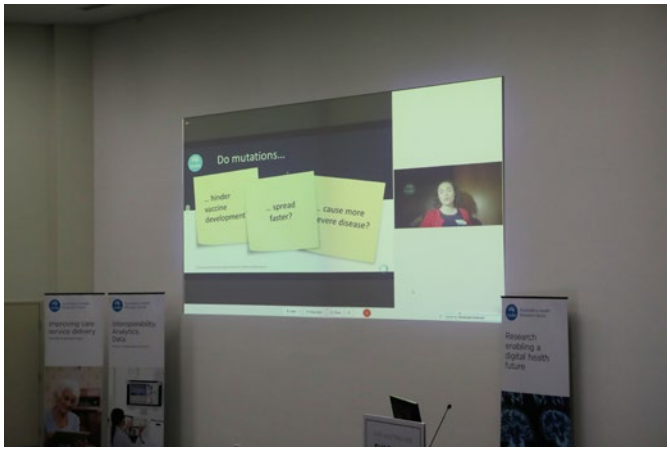
The colloquium showcased AEHRC's work in areas of national importance – including aged care, COVID-19 and pandemics, and health data interoperability – as well as highlighting the great science undertaken with our collaborators.

Australia's digital health vision and research in aged care

Rupert Lee, from the Australian Digital Health Agency, kicked off the first session and painted the huge vision from the Commonwealth government for digital health in Australia over the next three years – including addressing many issues in aged care.

Michael Lawley from AEHRC presented the large number of use cases of our clinical terminology technology, Ontoserver, with testimonials from around the world.

We then had four talks about various aspects of AEHRC work in the aged care sector. Isobel Frean (speaking via video from Melbourne), from the Digital Health CRC, described the Aged Care Data Compare project that the CRC and the University of Queensland is leading with support from AEHRC; Mohan Karunanithi gave an update on the 200 home aged care trial of our Smarter Safer Homes platform; Jurgen Fripp described the ADNet – the national Alzheimer's disease clinical trials network; and Marcela Cespedes gave an update of some of the great outcomes from analysing over 12 years of Alzheimer's disease data the AEHRC has collected in our role with various trials.



Health system resilience and pandemics

Branwyn Morgan started the session presenting from Sydney's Westmead Health Precinct, giving an overview of the CSIRO mission focus on Antimicrobial Resistance (AMR), with Anthony Nguyen from Brisbane describing one of the missions projects – the Queensland AMR hub. James Lind from Queensland Health and Justin Boyle from AEHRC then presented some of the data analytics to inform Queensland Health during times of disruption over the past 12 months. Denis Bauer, speaking from Westmead, described how AEHRC cloud genomics technology can accelerate genomic sequence comparison in times of pandemics. We then had Krispin Harkowiz from the RBWH Infectious Disease Unit and Damian Green from eHealth Queensland give a picture of how Queensland Health had dealt with the COVID-19 pandemic.

To round out the session, David Hansen chaired a panel about "Digital Health and the next pandemic" – with a range of opinions expressed from our panel of Branwyn, Denis, Krispin, Damian and Rob Grenfell, Director of CSIRO Health and Biosecurity, who joined the panel from Melbourne. It was great to hear about how digital technologies will be revolutionising our response to disruptions such as pandemics in the future.

Digital health research collaborations showcase

The third session highlighted collaborative research from across the Australian e-Health Research Centre. The first two talks were from Perth – with Jana Vignarajan joined by Graeme McLeod from Fiona Stanley Hospital (FSH), giving an overview of the Medical Image Communication Exchange (MICE) technology AEHRC has developed with the Fiona Stanley Hospital (FSH). Barbara Biki, from FSH, then spoke about the data analytics to improve operating theatre efficiency AEHRC has been doing – with Hamed Hassanzadeh demonstrating a simulation tool for understanding different ways of running the theatres.

Kaley Butten, from Queensland Aboriginal and Islander Health Council (QAIHC) and AEHRC, talked about our collaboration to use the M♡THER gestational diabetes platform for Indigenous communities around Mt Isa. Hang Min, another postdoc spoke about our collaboration with the Jamieson Trauma Institute, to characterise fractures from x-rays. Norm Good, from AEHRC, and Rosa Rocca, from Department of Health Victoria, then spoke about the evaluation of the DoH Victoria HealthLinks trial, which AEHRC has been conducting. The final talk was delivered by Bevan Koopman from AEHRC – and discussed some early work with Children's Health Queensland on searching literature for information about treatments for children with rare cancers.

It was fantastic to bring the colloquium to a national audience, reflecting the truly national reach of the Australian e-Health Research Centre. Next year, we will increase the number of in-person sites to include a location in Melbourne and continue the webcast to showcase our research and impact even further.

The AEHRC in the news

Our research and collaborations continued to make headlines this year, reaching key stakeholders around Australia and internationally through coverage in mainstream media and industry publications.

We also continued to raise awareness of our work through key engagements with partners and government.

News coverage highlights

- The AEHRC's contribution to SARS-CoV-2 research continued in 2021. Our research to understand the novel coronavirus and its mutations with the development of a standardised data collection template for the world's largest genome database generated global media coverage including an article in The Guardian, Xinhua and Medical Xpress.
- The AEHRC's involvement in the new Westmead Innovation Quarter in Sydney to bolster health and medical research across New South Wales was featured in the Australian Financial Review and Nine News.
- News of our Ontoserver technology underpinning the UK's National Health Service reached over 1.5M people through a media campaign. Highlights included stories in Healthcare IT, DigitalHealth.net and ZDNet.
- Our VariantSpark technology world-first efforts in processing one trillion points of genomic data appeared in several media outlets. Highlights included stories appearing in local technology trade publications such as ZDNet and PulseIT, as well as online international coverage.
- The successful commercialisation of the AEHRC's Smarter Safer Homes algorithm to HSC Technology was promoted via a targeted media campaign reaching almost 1M people. Highlights include stories in the Courier Mail and ABC News.
- Dr Jill Freyne provided expert commentary on our work with the CALD Assist app, updated with COVID-19 screening questions. Coverage appeared across SBS news and online, and was syndicated to a number of CALD community outlets. The media coverage led to the endorsement of the app for use across NSW.
- Dr Denis Bauer provided expert commentary about new strains of the SARS-CoV-2 virus, and was quoted in numerous stories including ZDNet and ABC.
- Dr David Silvera was interviewed on Nine News about his work with socially assistive robots.
- Dr Dana Bradford provided expert commentary about chatbots and neuroscience. She was interviewed on numerous radio stations including ABC Triple J Hack program, ABC Ballarat and ABC Life Matters.

Awards

Our socially assistive robot technology was featured on Channel Nine News.

Dr David Silvera with Minister Ayers in Sydney.

Government and partner engagement highlights

- Dr Jill Freyne and Dr David Silvera were integral in hosting Minister Ayers in Sydney to announce CSIRO's MoU with the NSW Government.
- We reached key stakeholders through eHealth Queensland's National Digital Health Update newsletters, with stories on our Indigenous health projects, data interoperability work with the National Health Services in the UK, and more.

- Our teams were again successful in being nominated for and winning a number of awards this year.
- The M♡THer mobile health app and the COVID-19 Barometer research projects were both finalists in the Queensland iAwards.
- Our Bioinformatics team was awarded a merit award in the NSW iAwards Public Sector category for VariantSpark.
- Dr Denis Bauer received the Professional Bioinformatician Award by the Australian Bioinformatics and Computational Biology Society.
- Dr Denis Bauer was also recognised as Australia's first AWS Data Hero, acknowledging global digital experts.

CSIRO recognition

- Our work received significant recognition amongst our peers at CSIRO this year.
- CSIRO Collaboration Medal: Dr Denis Bauer's work was recognised as part of CSIRO's COVID-19 vaccine development team and was awarded a CSIRO Medal.
- Health and Biosecurity Inclusion, Trust and Respect Award: Jill Freyne and team for their work with the CALD Assist communication tool updated with COVID-19 screening questions. The app had wide adoption across Victoria and NSW.
- Health and Biosecurity Breakthrough Innovation: Sankalp Khanna and the COVID-19 Dashboard team for the national impact of the platform in supporting government responses to the pandemic.
- Health and Biosecurity Health, Safety and Environment Award: The Dementia Aged Care Service team were recognised for incorporating health and safety as a core component for staff and participants.
- Dr Natalie Twine received the CSIRO Julius Award.

AEHRC research supporting the response to COVID-19

After contributing to the early stages of Australia's response to the COVID-19 pandemic through our data analytics and genomics expertise, the AEHRC has continued to support a number of Australian and international COVID-19 initiatives over the last 12 months.

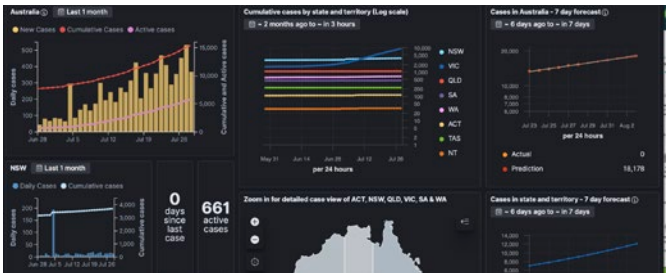
There are a number of reports throughout this Annual Report on how we contributed. Here we bring together a summary of that contribution.

While we are proud of our contribution to the response to the COVID-19 pandemic, we are just as proud that we have contributed to what is likely to be the biggest legacy of the pandemic – the accelerated transition to a digitally enabled health system and the adoption of Virtual Care.

Queensland Health COVID-19 analytics

Collaborators: Clinical Excellence Queensland

The AEHRC continued collaboration with Clinical Excellence Queensland and eHealth Queensland to support the development of novel analytics solutions like the COVID-19 Barometer, a dynamic monitoring tool that brought together data from health and non-health sources to create a holistic view of how each region in the state was responding to the COVID-19 cases in the community. Advanced visualisation tools were also created to obtain a comprehensive view of care provided to patients across the health system and allow for identification of "typical" and "atypical" longitudinal patient profiles and characteristics of COVID-19 cases. Statistical analysis was also undertaken to better understand the impact of COVID-19 infection on long term complications and related demands on the health system.



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

CSIRO Australian COVID-19 dasboard

The AEHRC continued to develop and maintain the CSIRO COVID-19 dashboard – used widely by state and federal health and related agencies through the first half of the pandemic. As Australia moved through the suppression stage of the pandemic the dashboard was used less by state health departments, however we have maintained the dashboard to provide continuity to a number of key users.

The dashboard contains three views: data on the status of the outbreak in Australia, a worldwide view and an advanced analytics view of the data.

CALD Assist

Collaborators: Western Health, NSW Multicultural Health Communication Service

CALD Assist, our communications app for clinicians engaging with people from non-English speaking backgrounds was enhanced with a COVID-19 screening tool. The tool assists staff at COVID-19 testing centres ascertain information about symptoms, exposure and testing as well as deliver key health messaging about recommended behaviours and restricted movement. The app, based on Victorian COVID-19 screening policies ensures Culturally and Linguistically Diverse (CALD) groups receive appropriate messaging and instructions to keep their communities safe. CALD Assist was endorsed by the NSW Health COVID-19 taskforce for use statewide and commended by Victorian Minister for Health Martin Foley who congratulated Western Health and CSIRO for innovating through the pandemic and finding new ways to support culturally and linguistically diverse patients.

Genomics informing vaccine testing

Collaborators: Australian Centre for Disease Preparedness

Our Transformational Bioinformatics team continued to work with the Australian Centre for Disease Preparedness (ACDP) in Geelong to support their work in the animal testing of vaccine candidates. The team are particularly proud to have contributed to the testing of the Oxford-AstraZeneca vaccine considering the contribution it has made to vaccinating Australians and many other countries around the world.

This work was undertaken as part of CSIRO's project funded by the Coalition for Epidemic Preparedness Innovations (CEPI).

Sharing genomic variants along with clinical information

Collaborators: GISAid

The international community has been fast to share the genome sequence of the COVID-19 virus which has greatly helped to understand the evolution of, and inform epidemiology, of the virus. However, while genomic sequence data is shared quickly, the sharing of information about the clinical outcomes of the people infected has considerable gaps – with data collections mostly containing un-informative free text.

In 2020, we worked with GISAID ('Global Initiative on Sharing All Influenza Data') to develop a 'Fast Healthcare Interoperable Resource' (FHIR) implementation guide which would support the standardisation of data collected at the same time as the genomic sequence data. The adoption of such as standard would likely have the biggest impact in the data-driven understanding of this virus.

PathSBeacon: Serverless computing supporting sharing of pathogen sequence data

Collaborators: NSW Pathology, Indonesia Department of Health

Building on our cloud-native implementation of the genomic data exchange protocol, sBeacon, we built PathSBeacon, to support the sharing of COVID-19 and other pathogen data by pathology labs and related organisations.

Linking multiple PathSBeacon around the world in a network will help improve our readiness to detect and monitor functionally distinct COVID-19 strains, such as vaccine escape mutants, and expand this ability to other infectious diseases, such as antimicrobial resistant bacterial infections.

Further information is available in the Transformation Bioinformatics project reports section.

Image: Twitter user @MindsEyeCCF

Virtual Care and heightened surveillance systems: the legacy of COVID-19

The introduction of federal government funding for tele-health consults and an increase in tele-health consults by our hospital systems have proven that Australia is ready for an increase in Virtual Care across our health system. The research and development that the AEHRC has undertaken over the past 17 years has enabled Australia's preparation for Virtual Care.

The AEHRC is a leader in the development of virtual care models using a range of virtual care platforms. Over the last decade our Health Services research team have carried out world leading virtual care trials in mobile health (including for cardiac rehabilitation and gestational diabetes), tele-health (including remote ophthalmology screening and chronic disease tele-monitoring) and recently the health internet of things, to support aged care in the home.

Virtual Care also requires that health data follows the person, so that their clinical team and the person, have access to the relevant data. Increasingly the data will be used by data analytics and artificial intelligence models to inform both the clinician and the person.

Moving on from COVID-19, AEHRC is establishing a national agenda to improve health outcomes for Australia via the APAIR initiative detailed in the CSIRO Initiatives section.

Throughout this Annual Report there are numerous reports on trials and technologies which will continue to contribute to the roll out of Virtual Care in Australia.

Artificial intelligence in healthcare at AEHRC

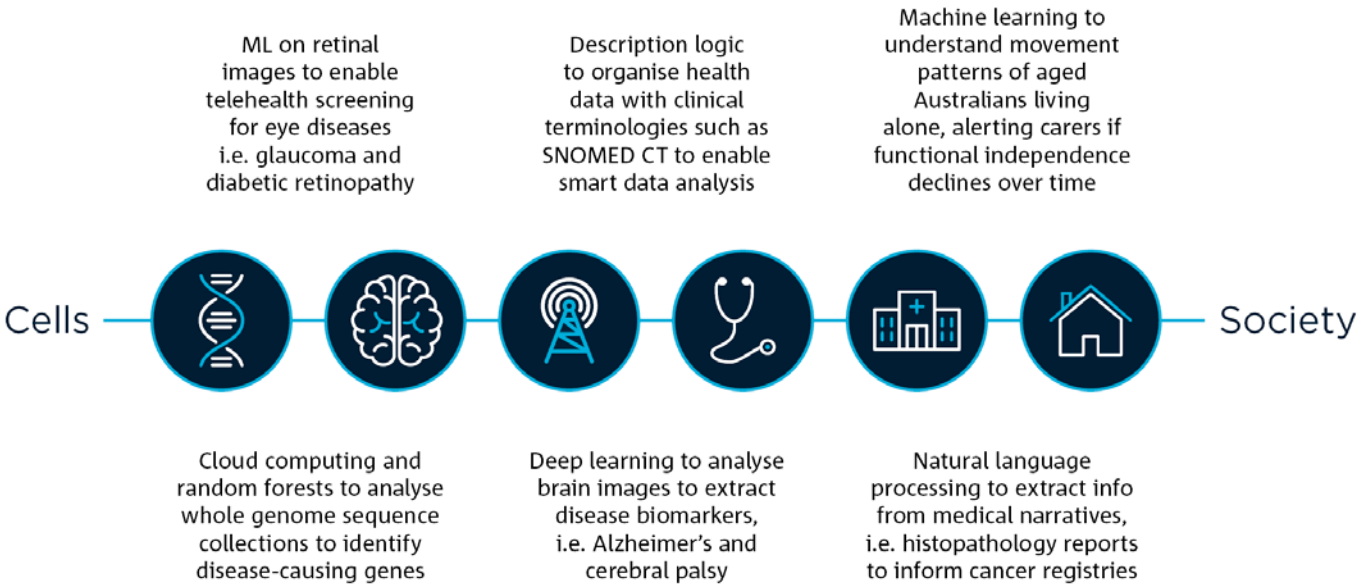
A large proportion of AEHRC projects now have some Artificial Intelligence(AI) or Machine Learning (ML) component; some actually developing new methods, others applying state-of-the-art methods to new problems. Recent advances in cloud computing along with increased data availability have resulted in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

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

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

For more visit aehrc.com/ai.



Advances in use of AI and ML at AEHRC

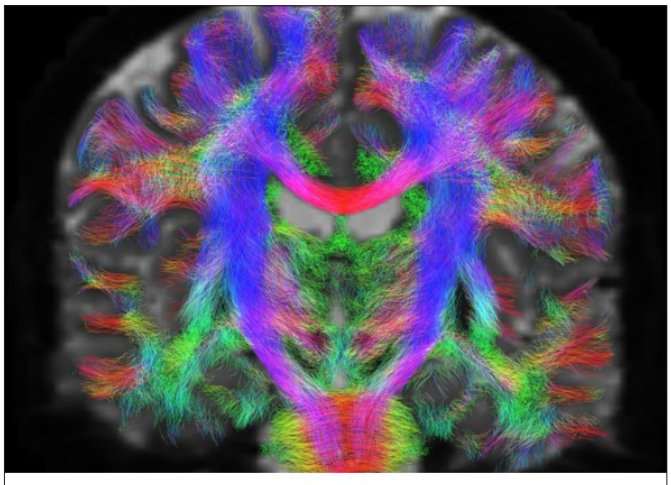
Throughout this Annual Report there are a number of projects where we have used AI and ML technologies. Here we highlight some of the AI and ML techniques that have underpinned those projects.

Knowledge representation and reasoning

Automation of Australian Medicines Terminology (AMT) Modelling

The Australian Medicines Terminology (AMT) is the national standard terminology for describing medicines. However, AMT is currently authored manually for monthly release which is an error-prone process. The aim of this project was to develop NLP-based algorithms to automatically produce AMT from drug registration information in the Australian Register of Therapeutic Goods (ARTG).

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.



Exemplars of Artificial Intelligence and Machine Learning in Healthcare

Improving the safety, quality, efficiency and accessibility of Australia's healthcare system

July 2020

THE AUSTRALIAN E•HEALTH RESEARCH CENTRE

Queensland Government

CSIRO

Imaging and vision

X-ray distal radius fracture detection and classification

This project involves the development of an AI screening system for x-ray images to identify patients who require a CT scan following distal radius (wrist) fractures. Our approach uses a YOLOv5 network for fracture detection. This network was pretrained on a large open source fracture database, and then refined on a subset of local RBWH cases. The fracture classification model was based on EfficientNet, which was pretrained on ImageNet and transferred to the RBWH dataset for further training. Classification performance was evaluated with 5-fold cross-validation, resulting in an average AUC of 0.74.

Human language understanding

Training a model to recognise cancer in clinical text.

Large amounts of valuable information on cancer is expressed in natural language in artefacts such as pathology reports, death certificates and patient notes. Extracting this information involves the develop of new methods to identify and classify cancer in natural language.

We have developed a hybrid deep learning method to recognise and categorise cancer types. We train a neural network to recognise both the presence and type of cancer (according the ICD-10 diagnosis classification). This neural network is coupled with explicit cancer diagnostic rules into a hybrid system that ensures the system accurately captures the nuances of cancer classification. The hybrid system is able to accurately classify rare cancers (93 percent recall) while minimising false positives (84 percent precision).

Predictive analytics and data-driven intelligence

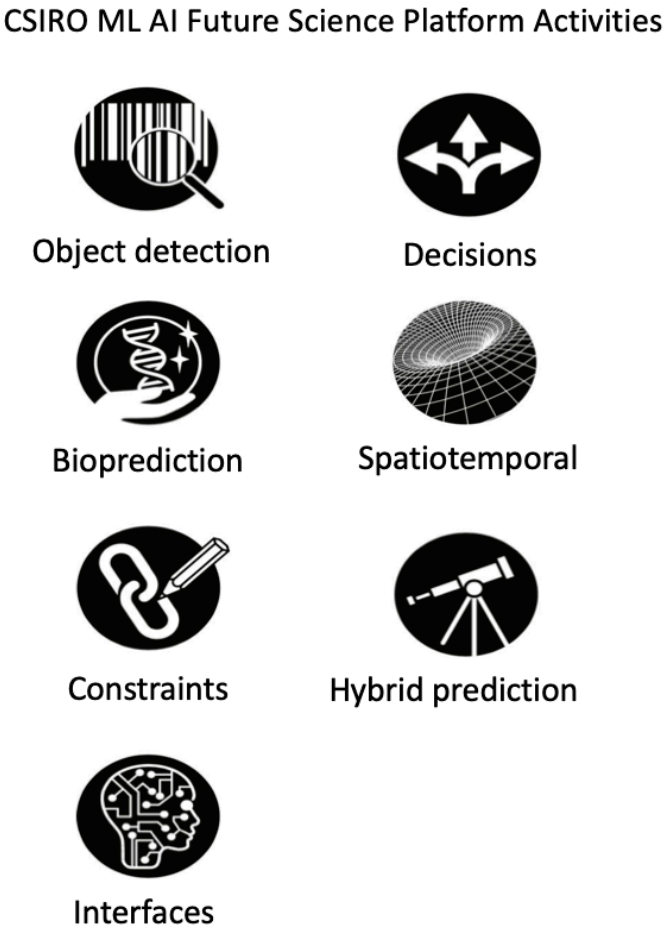
Predicting the risk of patient deterioration in a real-time clinical setting using patient demographic and clinical data including physiological signal data from electronic medical records.

We have developed a novel forest-like decision tree ensemble that ensures individual patient predictions are represented fairly without being biased towards patients who are sicker. This approach delivers comparable or better performance and model calibration when compared to existing machine learning approaches while still offering explainability for individual predictions.

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.

The AEHRC has been involved in both the inception of this FSP, as well as hosting a number of dedicated postdocs in this initiative. The FSP consists of a number of high-level activity areas, shown below.



AEHRC has significant involvement in three activities:

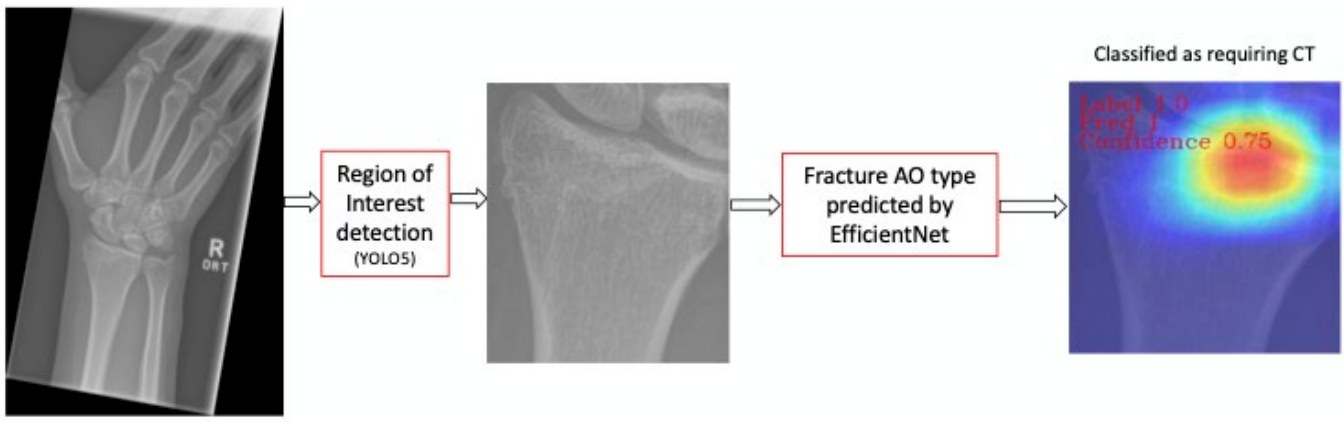
The **Object Detection Activity** is developing a general feature extraction platform, and methods to automate data labelling and synthetic data generation, for image and image-like data. We plan to combine image and natural language processing expertise to better search, classify and exploit mixed image/text health data. A new PostDoc (Dr Aaron Nicolson) has been dedicated to this project, which has:

- Developed a neural network-based method that automatically generates reports from medical images.
- Presented a demo of the automatic report generator at the AEHRC colloquium.
- Participation in an international medical image report generation competition and placed 3rd.
- Participated in postdoc pitch training and was amongst the top 10 finalists who presented at the MARS 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 a pool-based active learning framework to provide a cost-effective labelled data collection strategy for smart home trials
- Attended the postdoc pitch session at the FSP MLAI MARS conference and won the most inspiring pitch award.
- Investigated applying AI to two potential problems: 1) improving surgery duration through machine learning; and 2) solving health-related optimisation problem by reinforcement learning techniques
- Writing an ACORN grant proposal for "improving surgery duration".

The **Bioprediction Activity** looks at transforming biological production systems. We are using our VariantSpark tools to predict genomic traits in both humans and plants.



CSIRO Initiatives

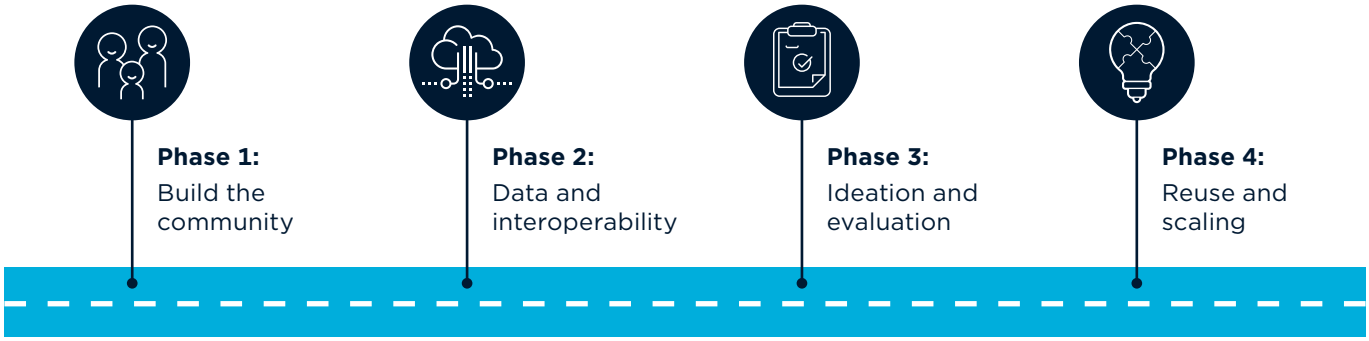
CSIRO Missions

CSIRO is currently developing a number of large scale, major scientific and collaborative research initiatives called Missions. A CSIRO Mission will be aimed at solving some of Australia's greatest challenges, focused on outcomes that lead to positive impact, new jobs and economic growth.

The AEHRC is contributing to the development of the Antimicrobial Resistance (AMR) Mission and the Infectious Disease Resilience (IDR) Mission. Projects which are contributing to the development of these missions are throughout this report.

CSIRO Annual Investment Initiatives

In 2020 CSIRO funded a number of initiatives through the annual investment review process. The AEHRC is leading an initiative in Virtual Care, bringing together initiatives across many of our groups into an overarching initiatives. Our Transformation bioinformatics group are contributing to an initiative to investigate the further use of the CRISPR technology.



Virtual Care

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. True virtual care proposes a system which is responsive to patient needs, where clinicians provide the best care possible, delivered by the latest digital tools and technologies.

The research and development that the AEHRC has undertaken over the past 17 years has enabled Australia's preparation for Virtual Care and uniquely positions AEHRC 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.

CRISPR

Genome Editing is a central capability for many domains ranging from human health to biosecurity and nutrition. As diverse as the application areas, so are the molecular protocols to perform these edits. This 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 initiative, AEHRC will develop 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 such as GT-Scan suite (see Transformational Bioinformatics: Platform Technologies) that have been published in the premier Genome Editing journals (e.g. The CRISPR Journal) and cited over 200 times.

CSIRO Future Science Platforms

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

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

Precision Health FSP

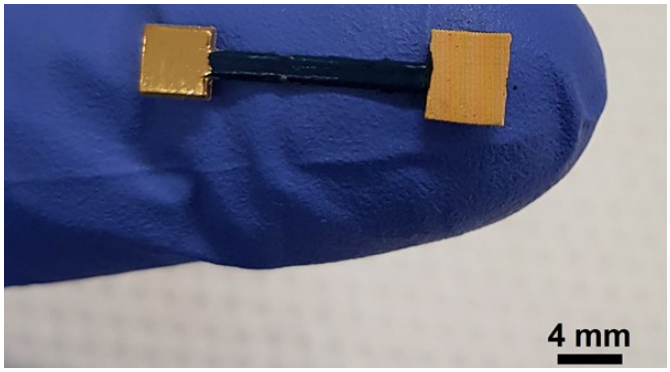
Australia's current healthcare system is focused on treating illnesses, but to keep up with our ageing population and the rise of chronic conditions like obesity the focus needs to switch to keeping healthy people healthy. The Precision Health FSP focuses on creating an integrated platform that can be 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 able to predict disease risk from genomic information. This will help identify at-risk groups and start interventions such as improving life-style choices. We are also investigating approaches for integrating a patient's genomic data with clinical information. This allows a patient's current health status to be assessed in light of genomic risk and resilience factors and allows a personalised view of outcome and progression.

Probing Biosystems FSP

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

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



Optical image of Si-MNA patch

Machine Learning and Artificial Intelligence (MLAI) FSP

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

Space Technology FSP

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

We are working with the Space Technology FSP to assist with the development of capabilities in space medicine and space life sciences research which align with the Australian Space Agency's Moon to Mars initiative. We also support efforts to develop analogue environments for terrestrial validation of these technologies. We have representation in the International Space Exploration Co-ordination Group, membership in the Australian Space Agency Space Medicine and Life Sciences Technical Advisory Group, and are founding members with the Australian Antarctic Division, University of Tasmania, and Tasmanian Government in the establishment of the Australian Human Research Institute for Space and Extreme Environments (AHRISEE) in Hobart.

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 IoT-based smart home systems, clinical data processing, wearable sensors applications, and development of mobile health platforms.

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.

Synthetic Biology FSP

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

We collaborated with Paul Thomas (University of Adelaide) to develop PETAL; an online platform for designing Prime-editing applications. This tool supports a new form of prime-editing, which allows the highly precise corrections of "misspellings" in the genome.

The Health Informatics group

Group Leader: Dr Michael Lawley

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

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

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

Health Informatics' science and impact highlights for 2020–21

- Our Ontoserver clinical terminology server was selected and deployed as the national terminology server for both the UK and the Netherlands.
- Medtex cancer notifications software improvements to Cancer Alliance Queensland incorporating ICD-O updates and specific synoptic and stage factor extraction for colorectal, prostate and recurrent cancers.
- Prototype SMART on FHIR Test Result Review app for emergency departments to review microbiology results for antimicrobial resistance.
- Winner, CSIRO Health and Biosecurity 2020 Breakthrough Innovation Award for the innovation in the creation, development, delivery/application of the COVID-19 Dashboard that supported government responses to the pandemic.

Clinical Terminology team

Team Leader: Kylynn Loi

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

Health Data and FHIR team

Team Leader: Jim Steel

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

Health Data Engineering team

Team Leader: Derek Ireland

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

Health Data Interoperability team

Team Leader: Dr Alejandro Metke

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

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

Health Text Analytics team

Team Leader: Dr Anthony Nguyen

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

Clinical Terminology Product Manager

Kate Ebrill

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

Health Informatics: platform technologies

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

Our technologies include:

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

Suite of FHIR native terminology tools

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

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

Ontoserver

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

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 which enables diagnoses recorded using SNOMED CT-AU to be mapped to ICD10-AM codes. We have developed two products:

- **SnoMAP Starter**: a simple SNOMED CT-AU diagnosis to ICD-10AM Codes FHIR ConceptMap, to support the use and reuse of SNOMED CT for analytics and research activities.
- **SnoMAP ED**: a mapping service for emergency department non-admitted patient reporting purposes, thus supporting the use and re-use of the standard clinical terminology for ED funding activities.

Read more in Health Informatics: Project Updates.

Snorocket

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

SHRIMP

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

Supporting users around the world

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

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

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

1. The FHIR Ontology External Module is an open-source plugin that can be installed in REDCap and can be used to turn a text field into an autocomplete-style field backed by a FHIR terminology server. This module provides a significant improvement over the capabilities provided by REDCap out of the box, by enabling the use of all the functionality available in the FHIR terminology module including, for example, the definition of value sets, which constrain the search space and improve the quality of the autocomplete results.

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

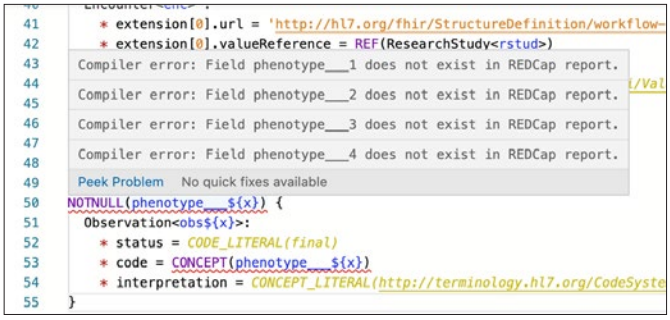
Read more in Health Informatics: Project Reports.

Redmatch

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

Clinical trials and studies are increasingly using electronic systems to capture data required to conduct a range of analysis, such as the effectiveness of a new treatment or its economic value. However, 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 currently used to capture research data is REDCap, a web application created at Vanderbilt University. Redmatch allows defining rules that describe how the elements in forms should be represented as FHIR resources without having to write any code. This functionality can be used to standardise clinical data captured in different REDCap systems.

Read more in Health Informatics: Project Reports.



Redmatch: Web editor

Leveraging 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 is a HL7® FHIR®-native analytic query engine, designed to ease the delivery of workflow and application development in the area of health data analytics.

Pathling makes use of FHIR on the way in, and on the way out. Bulk FHIR data can be efficiently loaded into the server, and analytic query functionality is exposed through a standard FHIR API. Pathling's FHIR interface provides additional operations that target capabilities that are not currently possible or not easily achieved using the core FHIR REST API specification. These operations use FHIRPath expressions to enable the aggregation and transformation of data, and more powerful and expressive search queries.

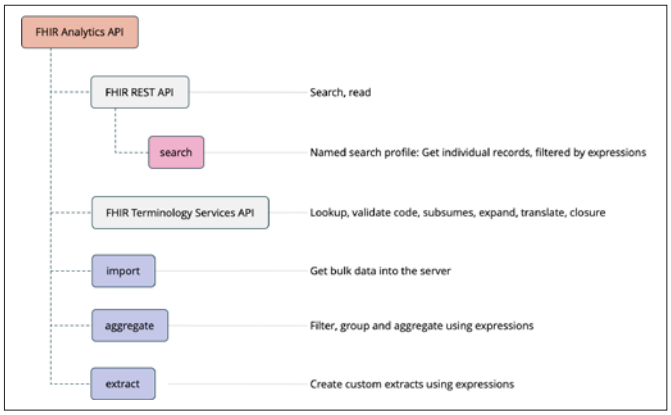
Pathling: Functions of the FHIR Analytics API

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.

Some of the use cases that Pathling has been designed to assist with are:

- **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.

You can learn more about Pathling at pathling.csiro.au.



Natural language processing

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

Medtex

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

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

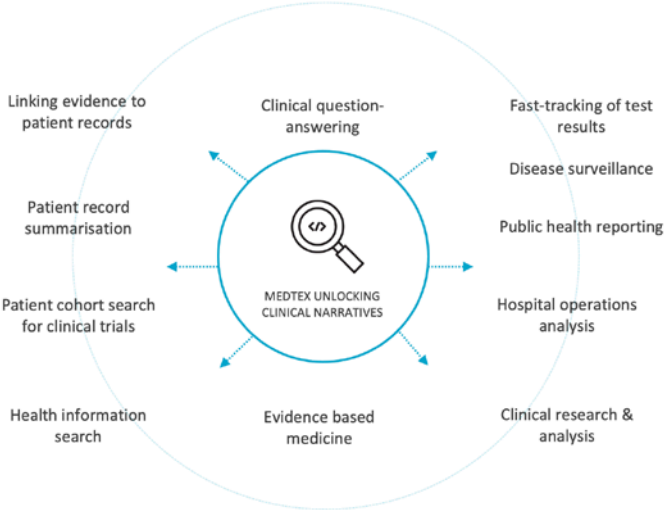
Analysis engines using the Medtex technology have been developed to:

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

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

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

Read more in Health Informatics: Project Reports.



Medtex: Unlocking clinical narratives

Search engines for health data

With a rapid increase in health data – in all its myriad of forms – there is an increasing need to be able to effectively search this data. At same time, much of this data is unstructured, making it difficult to search using methods tailored to structured data. Search engine technology was specifically designed to deal with large amounts of unstructured data, making it well suited to health domain.

We have developed a suite of different solutions to searching health data. We have taken the novel approach of exploiting clinical terminology (e.g,. 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 has been applied in a number of application areas:

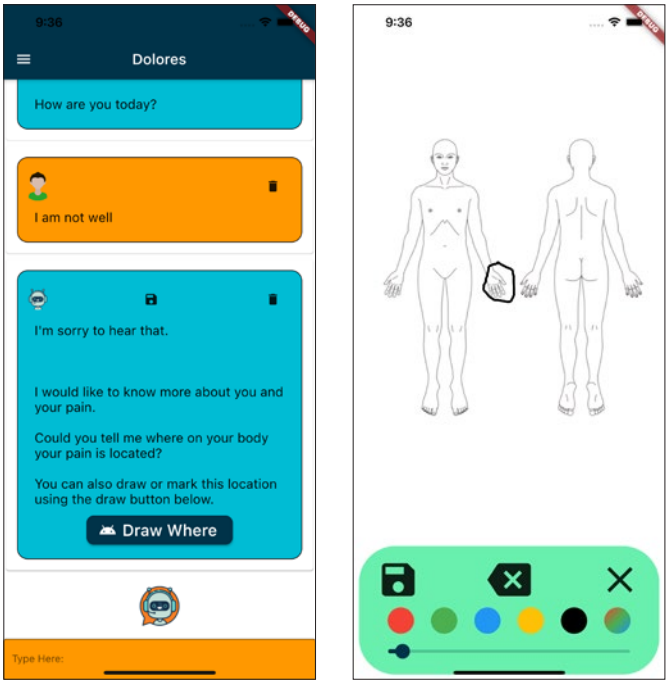
- Searching medical literature for clinical decision support.
- Searching radiology reports to identify cohorts of patients.
- Matching patient to clinical trials.
- Finding targeted treatment from literature and trials for paediatric oncology patients.
- Helping the general public search for reliable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

This technology has also proved to be 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 are increasingly being used for human-computer interaction to bolster user engagement. Healthcare provides a plethora of opportunities where chatbots can be used to support patients, carers and clinicians. A chatbot enables interactions between a knowledge base and a user in to enable natural language discourse via either 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 chatbot for a number of different 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 and Women's Hospital and Melbourne Children's Hospital in July 2021.
- "Quin" a smoking cessation chatbot built from 5,000 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 Informatics: project reports

UK NHS-Digital – the UK National Clinical Terminology Service

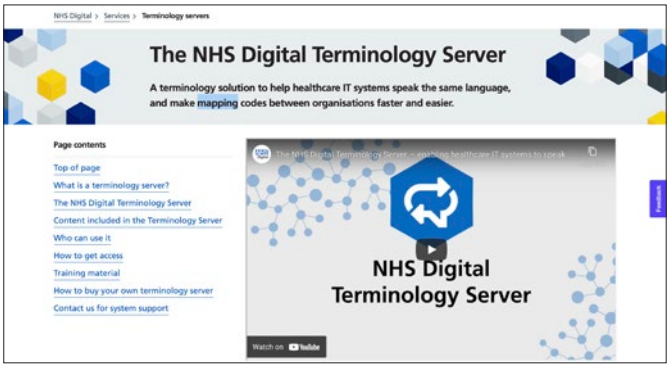
Collaborator: NHS Digital and Dedalus

In September 2020, it was announced that our FHIR-native terminology server, Ontoserver, had been 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 and now provides a nationwide service to enable easy access to terminologies, vocabularies and value sets which can be synchronised – ensuring that data collected across the UK is using the same "language".

The Terminology Server transforms the way in which data is captured, shared and analysed across the health and care system. At the heart of the solution is the ability to translate items into a common 'language of health' when professionals describe something using different terms. For example, a symptom could be described as "back-ache" or equally referred to as "lower lumbar pain". When such information is recorded and shared across the health and care system the Terminology Server can be used to match the disparate descriptions so that all the organisations and software involved in a patient's journey can 'talk' to each other and the patient data can be reconciled and compared effectively.



NHS Digital Terminology Server Landing Page

The benefits of the terminology solution are far reaching. Organisations from across the system can rapidly receive national code sets and updates, such as SNOMED CT, clinicians can code in the same language and input the data easier, researchers can use the improved coded data to facilitate better research and organisations can innovate and create new apps without the need to maintain large code sets, through a single API.

NHS Digital's terminology server creates a collaborative ecosystem and a hub of central infrastructure that reduces the cost to organisations wanting to benefit from a common health language.

We actively supported the NHS Digital implementation through a series of training and information webinars, connectathons and workshops as well as providing active support in loading the extensive number of CodeSystems, ValueSets and ConceptMaps now available through the terminology server.

In parallel with this, CSIRO is also working with NHS to formulate a product strategy for dm+d, the NHS's dictionary of medicines and devices. This builds on CSIRO's Health Informatics group's experience with the development and release of Australian terminologies including the Australian Medicines Terminology.

Collaborative authoring of Phenotypic concepts with SNOMED International

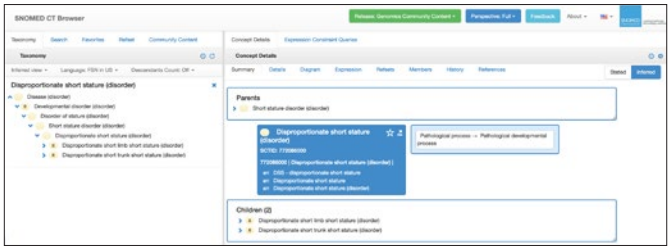
Collaborator: SNOMED International

AEHRC is working with SNOMED International (SI) to author phenotype concepts, into a dedicated Genomics Community Module, using SNOMED International tooling. This was new ground for both SI and CSIRO, as this was a first attempt at collaborative authoring of international content. This project focussed on creating terminology content that will support both frontline clinicians and the use of the recorded data for analytic purposes by genomic researchers and other healthcare organisations. SNOMED CT currently has many clinical phenotype concepts in the international release and is looking to expand the coverage through the addition of new concepts.

Expanding the clinical phenotype concepts enables:

- Improved clinical documentation utilising SNOMED CT for recording phenotypic data at the point of care.
- Interoperability.
- Improved clinical decision support.
- Enhanced reuse of coded data and data analytics.
- Reduced burden for healthcare organisations and software vendors as it minimises the number of terminologies to be implemented and maintained.

During this project, 2,141 new concepts were created with a number of descriptions and relationships across a range of hierarchies with mostly defined concepts created.



Example of content created in the SNOMED International community module for Genomics

Australian Genomics Health Alliance (AGHA)

Collaborator: Australian Genomics Health Alliance

The AGHA is a national initiative building evidence and developing a framework to support the implementation of genomics medicine in the Australian healthcare system. The AEHRC is part of Program 2 and leads the Phenotype Capture subgroup, which has worked towards the standardisation of patient phenotypic data relevant for genomics since the alliance started in 2016.

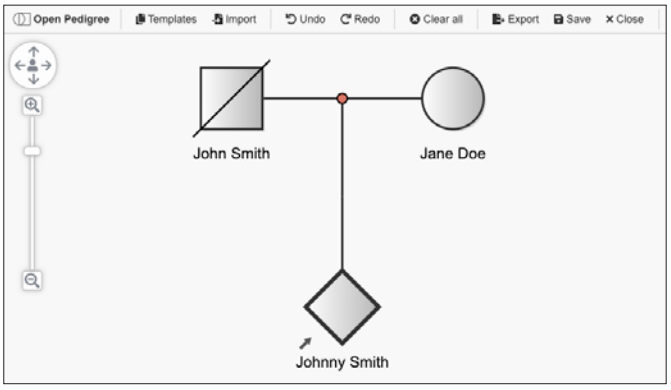
During the initial phase the team developed tools to support several clinical data standardisation tasks. Some of the highlights include:

- Redmatch, an open-source tool that facilitates the transformation of REDCap forms into the FHIR standard.
- FHIR-OWL, an open-source application that allows transforming ontologies in the OWL format into FHIR code systems.
- REDCap plugins to improve the quality of the data being collected (FHIR Ontology External Module and Pedigree Editor External Module).

The work on Redmatch and FHIR-OWL was published in top ranking conferences in the Health Informatics space and the team also co-authored journal articles in the clinical space with flagship collaborators.

In the past 12 months the team worked with the Mitochondrial Flagship to identify a use case where standardising the clinical data would prove most useful. A complex clinical score that was part of the inclusion criteria was chosen. A standardised implementation is useful because the phenotype of patients with mitochondrial conditions can overlap significantly with the phenotypes of patients from other flagships. Calculating the score can help identify undiagnosed patients that might suffer from a mitochondrial condition but were originally recruited elsewhere. The score was implemented using Redmatch and Pathling, and cross-flagship querying was demonstrated using data from the Mitochondrial and Acute Care flagships.

Overall, the excellent outcomes obtained during the initial phase have resulted in continued involvement and funding for the team in the next phase of the alliance.



The REDCap plugin allows capturing family history information electronically.

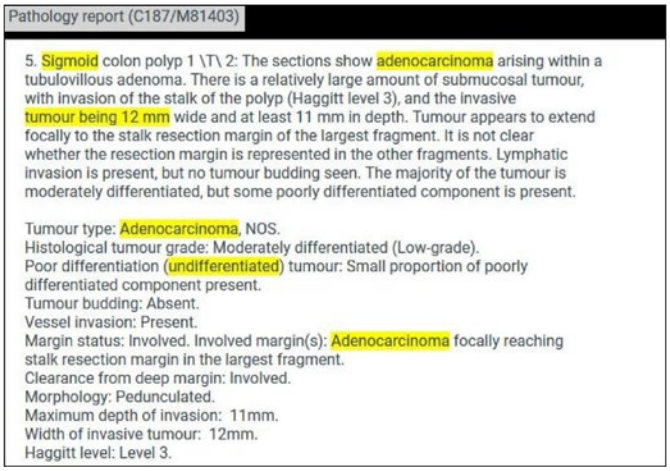
Automating cancer data registries

Collaborator: Cancer Alliance Queensland (CAQ), Queensland Health

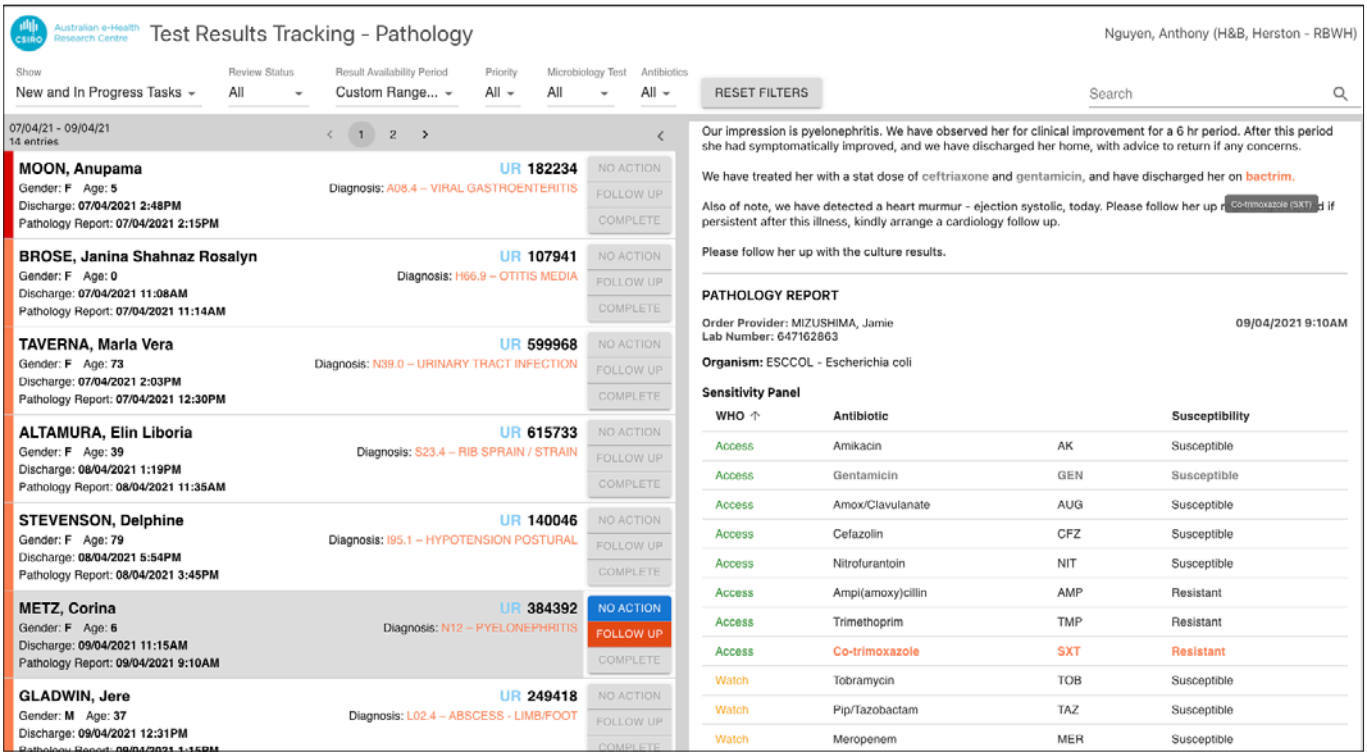
Statistics about cancer incidence and mortality continue to remain several years out of date. The extent of manual processing of patient records by cancer registry coders and outdated information collection systems are delaying the delivery of more timely cancer information.

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

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



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.



AMR decision support app (with obscured patient information) streamlining and prioritising microbiology test results for clinical review in Emergency Departments.

Queensland One Health AMR Hub – AMR Surveillance and decision support

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

The Queensland One Health Antimicrobial Resistance (AMR) Hub is developing an integrated AMR surveillance framework integrated with an AI-driven decision support system taking a One Health approach. The system will capture and integrate data across the health sector, agriculture, and the environment. 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 AI-assisted decision support for antimicrobial stewardship. Ultimately, this will help minimise the development and spread of AMR and ensure the continued availability of effective antibiotics.

To support AMR digital health solutions that are of high quality and interoperable with the wider health system, the project will establish standardised AMR data through data standards. This will be demonstrated on existing but disparate data sources from Pathology Queensland (HL7 microbiology test results and Antimicrobial Stewardship Data), which contain antibiotic susceptibility, utilisation and genetic testing results; ED information systems, which contain hospital interaction and antibiotic prescription information; and environmental data through the collection, monitoring and assessment of AMR pollution in wastewater ecosystems. AI-driven surveillance and decision support technologies will aim to solve unmet clinical needs.

Clinical decision support systems using AI and huge amounts of data are being used to track, trace and tackle drug-resistant infections using our genomics, AI and machine learning expertise.

We are developing a digital health standards-based tool, based on the FHIR healthcare interoperability standard to support the tracking, tracing and tackling of antimicrobial resistances in the emergency department. The tool reconciles information from microbiology test results and patient discharge summaries to alert the emergency physician of drug-bug mismatches and hence when a change of antibiotic treatment might be needed. From this, de-identified data can be used to create a dashboard of information about antimicrobial resistant infections and their location, which can give early indications of AMR hotspots.

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

Though the Queensland 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.

Precision Medicine search engine for paediatric oncology

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

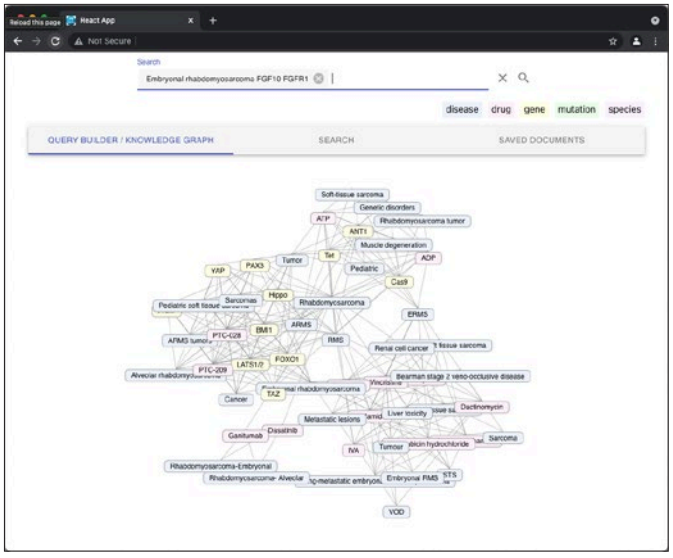
This project developed a search engine to help clinicians find targeted treatments for children with cancer.

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

We aim to help clinicians through a search system tailored to 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 result interpretability. The proposed system aims to both significantly reduce the effort of searching for targeted treatments and potentially find lifesaving 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 a number of years, we have been building search engine technology for the health domain, especially to support evidence-based medicine. But this work has many applications beyond health. In this project, we are applying our health research to the agricultural domain through a grant from the Grains Research Development Corporation in collaboration with the University of Queensland (UQ). The project will help growers search grain-related resources to answer their growing-related question.

We have developed AgAsk – a conversational search agent where growers can 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 Informatics: 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 off 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.

Through 2020–21 the team delivered eight (8) new versions of Ontoserver including the first FHIR Terminology Server with significant support for SNOMED post coordination as well as a novel per-Resource security model. We have also closely engaged with the FHIR community to clarify, refine and improve details of the Terminology Services subsystem of the HL7 FHIR Specification 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 1,300 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 have completed phase 1 of establishing the Queensland Clinical Terminology Service (QCTS) which adopts our Atomio and Ontoserver applications to support terminology content. QCTS is now going through an acceptance testing phase. A number of 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 QUEENSLAND digital hospital projects

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

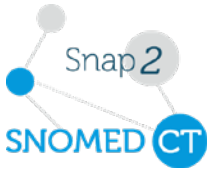
We have continued close collaboration with Queensland Health's Office of the Clinical Information Officer (OCCIO) to support the use of SNOMED CT in the Cerner ieMR product deployed in Queensland hospitals. This involves providing education and support to the team around the use of SNOMED CT in surgery,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

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

SNOMED International Mapping Tool and Internal Release Validation Framework Enhancements

Collaborator: SNOMED International

We are developing 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 is being produced with an agile methodology and is due to be completed at the end of 2021.



Snap 2 SNOMED CT mapping tool logo

We also delivered enhancements to SNOMED International's Internal Release Validation Framework (RVF) by using our Ontoserver's existing set of conditions for warnings and errors for when consuming RF2 files from SNOMED International. Ontoserver's set of conditions was analysed and compared with the RVF and any tests that were discovered to be missing from the RVF were implemented and tested. This was particularly anticipated to yield tests around the Module Dependency Reference Set in RF2 releases which is a known strength of Ontoserver and area lacking significant tests in the RVF.

OpenMRS

Collaborator: SNOMED International

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

OpenMRS is a very 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 that 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 that provides an additional tag that can be used in its HTML Forms to provide dynamic support for SNOMED CT-coded fields that are 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 can be easily extended to support any code system that is provided by a given FHIR terminology server.

OpenMRS
MEDICAL RECORD SYSTEM

Pan Asian Terminology services

Collaborator: Asian Development Bank

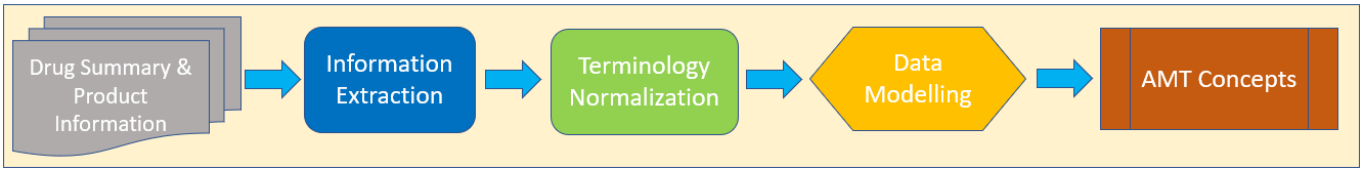
We have continued our collaboration with the Asian e-Health Informatics Network (AeHIN) and its member countries, through a project funded by the Asian Development Bank. As part of this work, we collaborated on a demonstrator project for the Global Digital Health Forum that combined the HAPI FHIR server with CSIRO's Ontoserver terminology server, and several bespoke tools to illustrate the transmission of data between different south-east Asian countries. We also provided a series of webinars to AeHIN's regular seminar series, covering both technology and content-related topics related to the use of clinical terminology. Finally, we worked with representatives from the health departments of the Philippines and Thailand about the use of terminology in specific areas of interest to their countries.

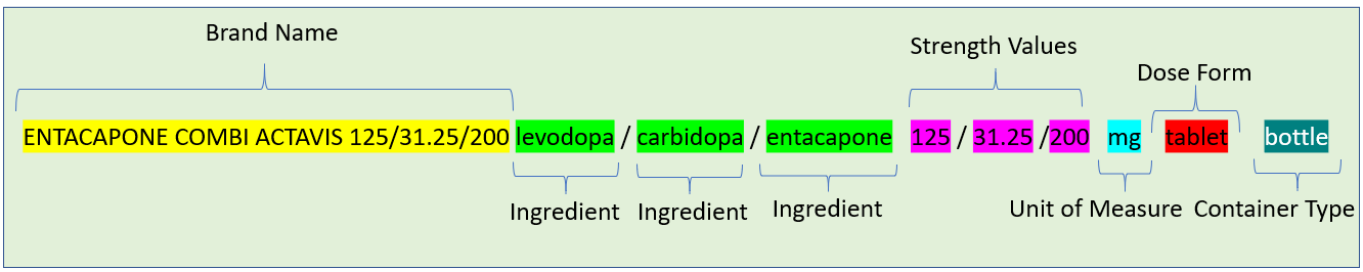
Automation of AMT Modelling

Collaborator: Australian Digital Health Agency

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

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





Global Alliance for Genomics and Health

Collaborator: Global Alliance for Genomics and Health (GA4GH)

The AEHRC continues to be involved in the Clinical & 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, which has developed a new standard to share family member history, vitally important information for genomic medicine. The AEHRC has also been 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

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

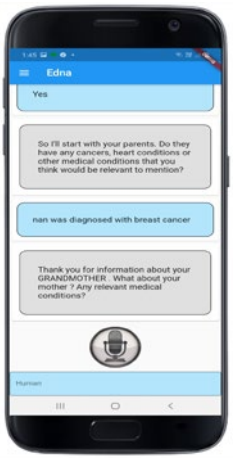
Two AEHRC team members have been seconded into the GenoVic team to contribute to the development of the platform. The AEHRC has also supported Melbourne Genomics with expertise in the use of FHIR for interoperability and SNOMED CT and Human Phenotype Ontology for clinical terminologies. The AEHRC has also undertaken bioinformatics projects with Melbourne Genomics and continues to work on patient facing a technologies such as a chatbot to facilitate informed decision making by patients in the provision of additional findings analysis (see below).

Edna the chatbot has the potential to augment genetic counselling for additional findings analysis

Collaborator: Melbourne Genomics Health Alliance

Genomic testing is primarily used to identify/determine a molecular diagnosis for a patient's medical condition, however, it can also be used to identify other health risks, or 'additional findings'. Chatbots have the potential to contribute to additional findings healthcare delivery as they can be easily accessed, collect and provide information, and recognise when to refer to a health professional.

In 2019, we developed a chatbot, Edna, able to explain terms and summarise decision-making factors related to additional findings. In 2020, we trialled Edna with patients who have had genomic counselling, genetic counsellors and students enrolled in related courses. Participants were positive about Edna's role in augmenting genetic counselling. Specifically, participants saw value in Edna's ability to provide credible information which would streamline the counselling process, and for one patient, circumvent it altogether. Edna has potential as a valuable resource for both pre and post genetic counselling for decision making around additional findings analysis.



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

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 2020. 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 (participating remotely).

The course cohort grew from 10 students in 2019 to 30 students in 2020, with student groups building 7 different SMART-on-FHIR apps covering differential diagnosis, mind mapping for clinical reasoning, patient-sourced blood-glucose observations, clinical questionnaires and chronic disease monitoring, in collaboration with clinical stakeholders from the UQ School of Medicine and CSIRO. Professor Braunstein's Health Informatics on FHIR online course was expanded to include videos and exercises covering the Australian digital health landscape. Once again we had an impressive series of guest lectures from local, interstate and international experts, including presenters from AEHRC talking about FHIR, SMART apps, and clinical terminology.

Looking forward, the course has recently been made a permanent part of UQ's computer science, software engineering and information technology curricula, and we expect a further increase in enrolment in the second semester of 2021.

Case Based Learning on FHIR

Collaborator: University of Queensland

The case-based learning tool that CSIRO has produced for use by the University of Queensland (UQ) School of Medicine has seen increased use and an expansion in functionality throughout 2020–21. 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 the use of SMART-on-FHIR apps on the platform.

As part of a UQ Teaching Innovation Grant, the tool has been expanded to support further structured data recording (to encourage better clinical record-keeping), the use of social determinants of health, and cases that involve participants from multiple disciplines. 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 that can support clinical decision making in a particular case. We are currently integrating the use of chatbots into cases to allow for interactions between the medical student and simulated patient (more details below).

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

Collaborator: Nutrition and Health, AMR Mission

The need for integrating data from multiple sources in the healthcare enterprise, and to integrate new technologies such as AI into the clinical workflow, requires a new approach as currently the different domains tend to have data silos and different standards. To overcome this, we have developed a workflow platform, FORTE, based on the FHIR framework. FORTE maps standard operating procedures and clinical workflows into the FHIR framework, and, enables their execution. Each FORTE workflow comprises steps that can be automated or manually executed or performed. Completion of steps is done via interaction with FHIR applications. AI algorithms can then be executed as automated steps and their outputs made available further down the pipeline.

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

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

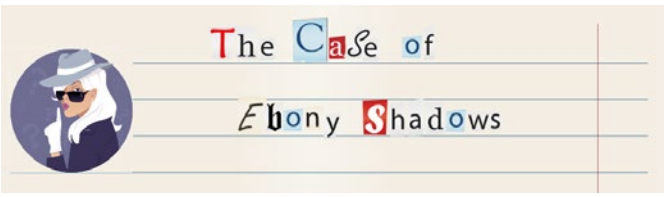
We have extended our collaboration with Pathology Queensland and the University of Queensland to also include Metro North Hospital and Health Services to implement a FHIR-based bioinformatics pipeline. This pipeline provides seamless integration of non-standardised data from the pathology laboratory 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 Queensland One Health AMR Hub platform showcasing antibiotic sensitivity testing apps for the AMR mission.

Pain ROADMAP gamification for children with chronic pain

Collaborators: Metro North Hospital and Health Service

Continuing the success of the Pain ROADMAP platform for chronic pain intervention, we and collaborators from Metro North Hospital and Health Service have been piloting a gamification component of the platform. 'The Case of Ebony Shadows' was designed to increase the compliance of young users of the Pain ROADMAP mobile app. We have had more than 25 children, teenagers and adults find clues and solving puzzles while providing relevant clinical data. The platform has been deployed since July 2020 at multiple pain clinic sites across Australia including the Royal Brisbane and Women's Hospital Queensland, Melbourne Children's Hospital VIC, Support Kids in Pain Queensland, The Therapy Space WA, Pain Specialists Australia VIC and St Vincent's Hospital Queensland.



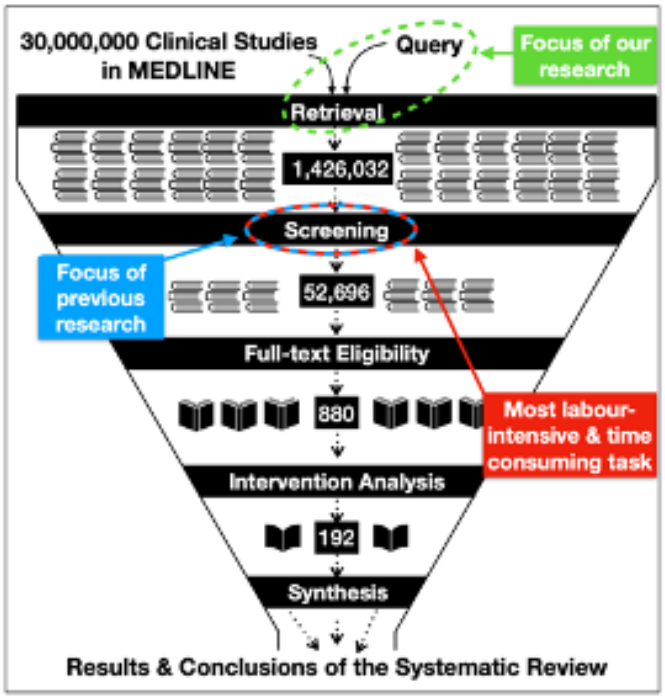
The embedded game 'The Case of Ebony Shadows' was designed to encourage users to participate in the intervention by being entertaining and informative.

Search Engines for Systematic Reviews

Collaborators: Bond University, University of Queensland

This project aims to devise artificial intelligence (AI) based search engine technology that supports the formulation and refinement of effective search queries for literature search in the context of systematic reviews. 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 we have had PhD student Harry Scells complete his thesis titled "Query Automation for Systematic Reviews". We also submitted a Research+ Postdoc application to continue work on this project.

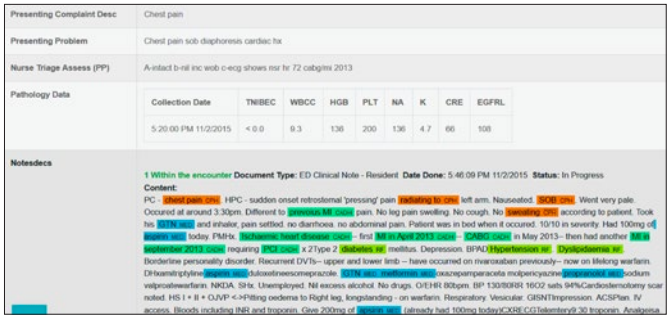


Automating data extraction from electronic health records for a chest pain clinical data registry

Collaborator: Logan Hospital Emergency Department, 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 2017–18 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.



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

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 aims to 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 for these patients. This methodology will be deployed on over 250,000 presentations to the RBWH ETC over the last three years.

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

Interpretable deep learning output from analysis of free-text triage assessments

Dolores the pain chatbot

Collaborator: University of Queensland

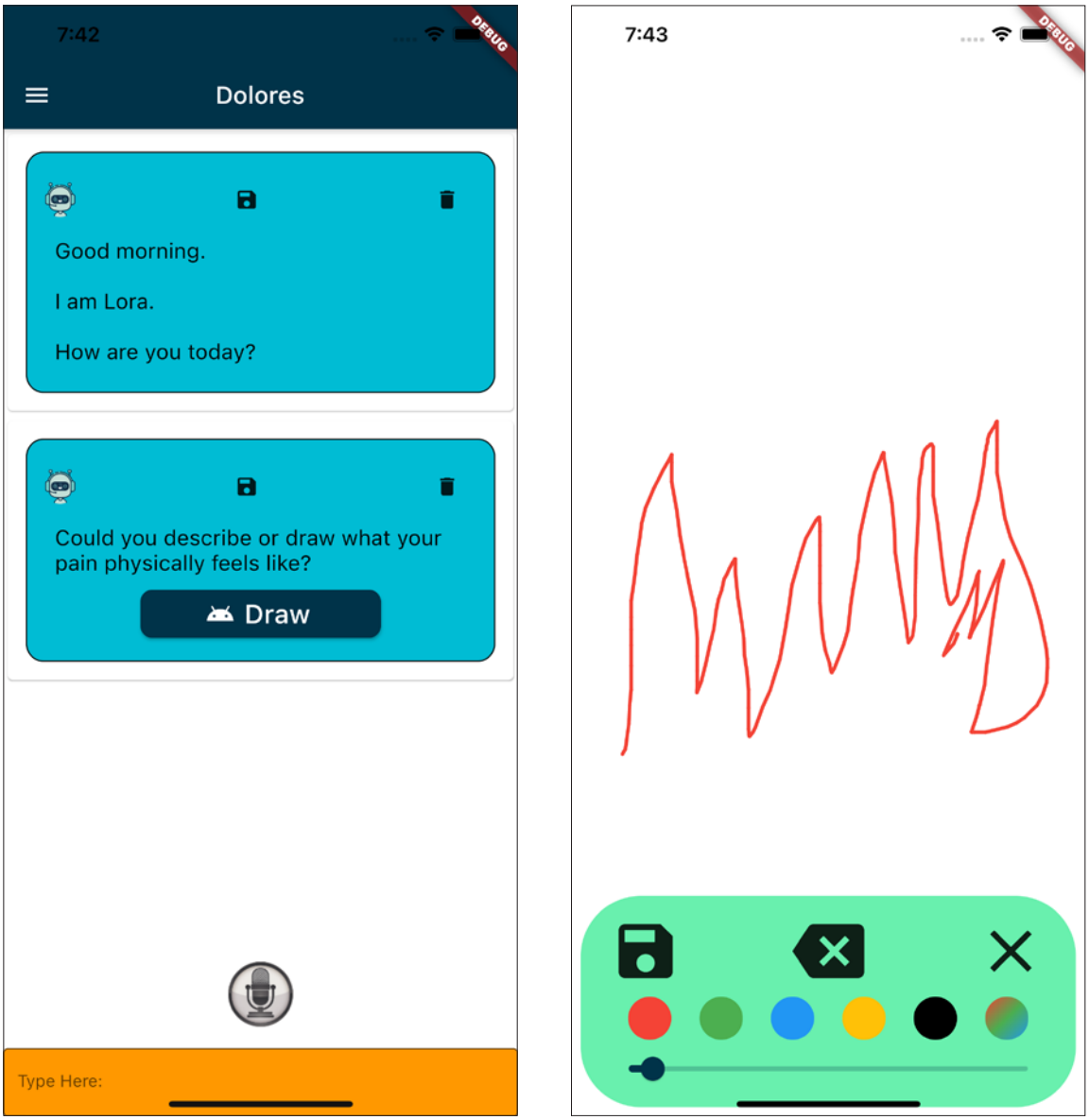
Dolores is a chatbot developed to discuss all things related to chronic pain with language suitable for the age of the user. Topics include pain history, social interactions, medications etc. Dolores 'brain' was developed by clinicians with backgrounds in occupational and speech therapy. Dolores also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

Dolores has been piloted at the Royal Brisbane and Women's Hospital and is expected to be further piloted at other pain clinics including the Melbourne Children's Hospital in mid-2021. The app will be provided to the client in a private section of the waiting room and aims to inform and educate the user and provide pertinent medical history for the clinician.

Sim-Bots: Simulating patient-clinician interactions

Collaborator: University of Queensland

Simulated Patient-Bots (or Sim-Bots) is a SMART On FHIR teaching tool that provides a collection of simulated patients to better train medical students in patient interaction. Each chatbot personality has a medical complaint that the user must investigate by asking pertinent questions. As of mid-2021 more virtual patients with different medical complaints, histories, cultural backgrounds, and personalities are being constructed. It is expected Sim-Bots will be piloted in July 2021 at the University of Queensland with new patients added regularly.



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 Informatics: postdoc and student highlights

Postdoctoral fellow

Thanh Vu, CSIRO Research+ Postdoctoral Fellowship

Clinical information extraction and classification using interpretable deep learning

The majority of health data is recorded in free-text unstructured documents. This data contains information that is valuable for clinical decision making and secondary use. However its clinical importance and large volume hinders manual analysis of such data – 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 have been 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.

PhD students

Liebo Liu, University of New South Wales – 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 will be on developing tools to maximise the utility of the sort of data captured in My Health Record for secondary uses that will reduce waste and duplication in health care, and drive high-value care.

Jinghui Liu, CSIRO R+ Postgraduate Scholarship, Scholarship University of Melbourne

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

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

The Transformational Bioinformatics group

Group Leader: Dr Denis Bauer

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

Transformational Bioinformatics' science and impact highlights for 2020–21

- Expanded out COVID-19 work, with a second publication in TBED (interoperability and COVID-19, Altmetric score 105), CSIRO's collaborative Medal and Regional Grant from the Australian Academy of Science.
- VariantSpark Gigascience publication (August 2020) Altmetric score of 35.
- Successful in several large-scale grants: NHMRC Partnership Grant in Cardiovascular Disease (clinical application of polygenic risk scores), NHMRC Ideas Grant with Childrens Medical Research Institute (better Gene Therapy vectors) and MRFF Frontiers grant (personalised prevention of CAD).
- Denis presented a Plenary at AWS Health and Life Science Day (10,000 attendees).
- The team collaborated on a paper in Nature Biotech (Altmetric score 289).

Genome Insights team

Team Leader: Dr Natalie Twine

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

Digital Genome Engineering

Team Leader: Dr Laurence Wilson

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

Transformational Bioinformatics: platform technologies

VariantSpark

Collaborators: Goldfinch, CAD Mission, Project MinE ALS genomics consortium, Motor Neurone Disease Centre, Macquarie University

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 (PRS) 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) and obtained access to independent validation datasets. This allows us to evaluate the benefit and quantify the power VariantSpark's ability to detect polygenic interacting factors (epigenetic) bring.

We are committed to our ongoing collaboration on Amyotrophic Lateral Sclerosis (ALS, Project MinE), the Alzheimer's Disease Neuroimaging Initiative (Adni) and the Cardiovascular Diseases Mission. We further developed an ecosystem of open source software around VariantSpark to create realistic synthetic datasets (PEPS) and visualise interacting genes from VariantSpark output (BitEpi). Recognition from the Australian Bioinformatics and Computational Biology Society will help VariantSpark grow an Australian community that can facilitate the cloud-based sharing of bioinformatics software.

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

Read more in Transformational Bioinformatics: Project Reports.

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

Serverless Beacon

Collaborators: NSW Pathology, Melbourne Genomics Health Alliance, the Department of Foreign Affairs and Trade, 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 in the haystack efficiently. This is hampered by traditional server and database-based approaches being too expensive and unable to scale with accumulating medical information.

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

GT-Scan Suite

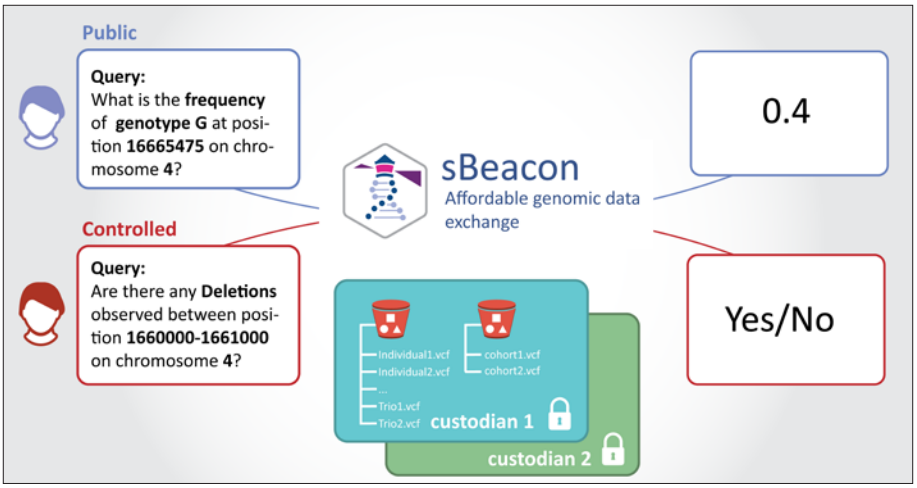
Collaborators: JCSMR, Australian National University, Westmead CMRI (Children's Medical Research Institute) Gene Therapy Research Unit, Westmead CMRI Translational Vectorology Group

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

This is a very expensive task computationally. We reduced the overall runtime for this task from weeks to seconds by massively parallelising the individual search tasks using a revolutionary new compute approach called Functions-as-a-Service or serverless. We also improved accuracy by 30 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 64 times) and has been presented at many international conferences.

Read more in Transformational Bioinformatics: Project Updates.



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

Transformational Bioinformatics: project reports

VariantSpark on Azure

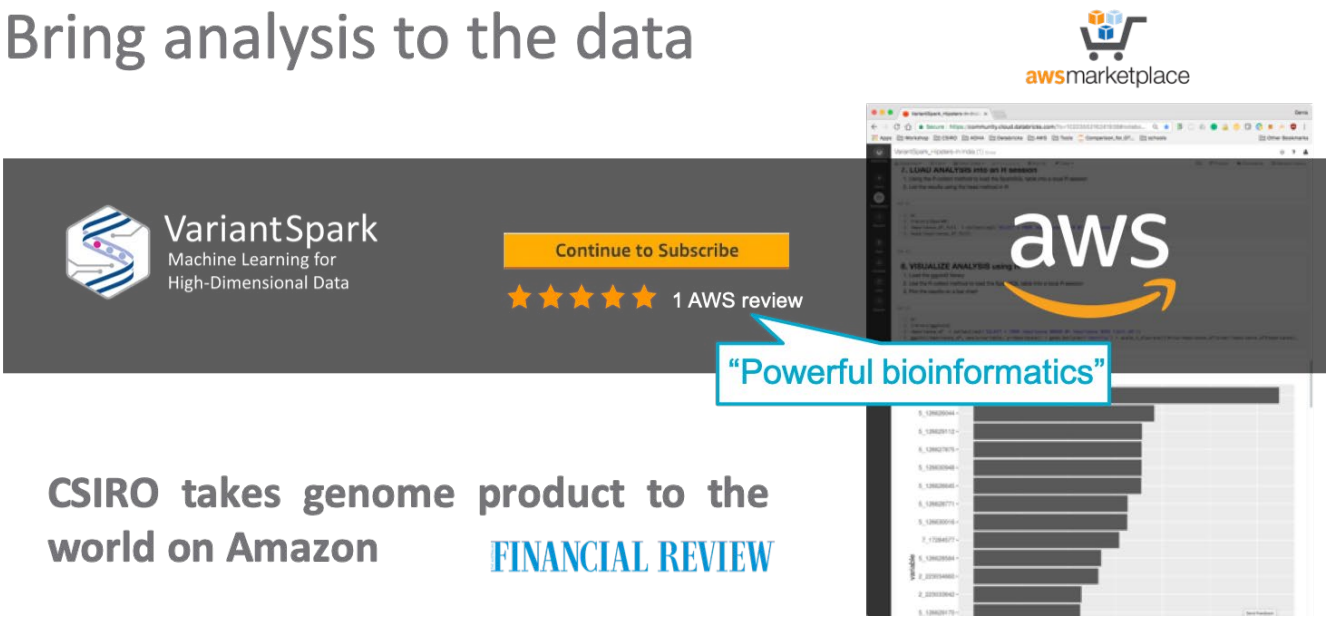
Collaborators: Azure

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

Reducing the barrier to entry, we automated computer cluster configuration by packaging the VariantSpark install as infrastructure-as-code self-deploy package on Azure Marketplace. Users can select specific configuration details like deployed cluster name or set up cluster credentials before spinning up an HDInsight cluster with VariantSpark installed. Scripts like install-variant-spark.sh brings in the version-controlled VariantSpark files and installs all the dependencies along with VariantSpark on the HDInsight cluster. Once the HDInsight cluster is deployed users can explore the example notebook which monitors the VariantSpark run or enables users to start their own analysis. This allows researchers and industry to use VariantSpark on Azure in a version-controlled, fully serviced and automatically deployed infrastructure, bringing "compute to the data".

VariantSpark is also available on Amazon Web Services (AWS), as well as third-party providers such as RONIN (AWS) and BioTerra (GCP, Azure). VariantSpark is also an example notebook on the vendor-agnostic platform DataBricks (AWS, Azure, GCP).

After becoming the first public sector organisation worldwide to publish a health product on the AWS Marketplace in 2019, this year's Azure release is an equal first, opening up new commercially viable deployment avenues on Azure. We have provided video tutorials to assist researchers to deploy these computational environments and compiled notebooks with example workflows for different use cases. We actively maintain online discussion channels like Gitter and GitHub issues to foster input from the bioinformatics and IT community.



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

Identifying viral integration sites in tumour NGS data

Collaborator: Westmead Gene Therapy Research Unit (Children's Medical Research Institute)

Our collaborators at Westmead seek to treat genetic diseases by correcting the mutation that causes the disease, otherwise known as Gene Therapy. A virus shell is often used to deliver the genome editing therapeutics to the right cells. This project develops bioinformatics tools to evaluate the cell toxicity of the used viral vectors, specifically to quantify the frequency with which the viral vector is integrated into the host genome.

This is a problem which must be addressed for any gene therapy, such as those developed by our collaborators at the Gene Therapy Research Unit at the Children's Medical Research Institute in Westmead.

Over the past 12 months, we created isling, a fast and highly sensitive analysis software that can detect viral vector integration. It is also able to benchmark this frequency over natural integration events occurring during infections of the wild-type virus. The software has also been used to identify millions of integration sites in preclinical studies of a vector for a metabolic liver disease which will be assessed in a clinical trial later this year.

This work is an important step towards bringing Gene Therapy into routine clinical practice, by designing viral vectors that are less prone to integration and hence reduce subsequent cancer rates.

PathSBeacon

Collaborators: NSW Health, Australian Academy of Sciences and Indonesian Government

Infectious disease pathogens can mutate, potentially impacting disease progression, vaccine efficacy, or treatment resistance. Being able to identify and compare a pathogen's unique mutation profile amongst international data is hence important. Building on our cloud-native implementation of the genomic data exchange protocol, sBeacon, we built PathSBeacon, which allows the processing of millions of pathogen samples. PathSBeacon allows the tracking of mutations as well as other genomic changes, such as insertions and deletions. It visualises the frequency and occurrence of specific genetic profiles temporal and on a geographical map.

PathSBeacon is currently tested by NSW Health Pathology to improve their abilities to track individual COVID-19 strains. PathSBeacon was also funded by the Australian Academy of Science in their regional development grant to support efforts in India around annotating individual COVID-19 virus mutations and their functional effects. It is also the foundation for the planned COVID-19 genomics response of the Indonesian government.

Linking multiple PathSBeacon around the world in a Network will help improve our readiness to detect and monitor functionally distinct COVID-19 strains, such as vaccine escape mutants, and expand this ability to other infectious diseases, such as antimicrobial resistant bacterial infections.

Transformational Bioinformatics: project updates

Polygenic risk in cardiovascular diseases

Collaborators: Johan Verjans, Gemma Figtree

We analysed the UK Biobank data to identify epigenetic contributors that jointly modulate cardiovascular disease risk. We used our machine learning platform, VariantSpark, to process 51,107 samples with 1,188,280 variants each. We found known and novel variants associated with coronary artery disease (CAD) with VariantSpark replicating most of the traditional logistic regression results. We then ran BitEpi on the top 500 variants as determined by VariantSpark and found a variant (rs12740374) that is involved in multiple higher-order epistatic interactions. This variant is a reported CAD-associated variant, and our findings suggests that it plays a part in more complex biological mechanisms than currently known.

This work has laid the foundation for further polygenic risk analysis by comparing VariantSpark selected markers and interaction terms with the traditional statistical Polygenic Risk Score (PRS) approaches.

Software solution to support a new Prime Editing approach

Collaborator: Paul Thomas (Adelaide Unversity)

We collaborated with the group of Paul Thomas, from the University of Adelaide, to develop PETAL; an online platform for designing Prime-editing applications. The Thomas lab has developed a new method of prime-editing, which enables highly efficient editing of target sequences. PETAL simplifies the design process, allowing users to select the best targets and providing the required oligo-sequences. The flexibility and customisability of PETAL greatly simplifies the design approach, enabling researchers to develop more complex applications.

PETAL is a part of our GT-Scan platform, expanding the AEHRC's genome engineering toolkit.

Detecting foreign DNA using genomic signatures

Collaborators: Maciej Maselko (Macquarie University) and Office of National Intelligence

We developed a universal machine learning method, INSIDER, to identify regions in the genome with different genomic fingerprints. The method works by identifying regions of the genome that "sound" different to their surroundings, thereby pinpointing bits of DNA that do not belong. To identify bits of DNA that do not belong we analysed the frequency of oligonucleotides in a genome. These oligonucleotides represent words within a genome, and every species can have their own genomic vocabulary (i.e, genomic signature). We showed the power of this approach to identify genetic material inserted by genome engineering approaches (e.g., gene drives) and for detecting antimicrobial resistance (AMR) genes. The development of this technology can also be leveraged to create next-generation diagnostics, allowing us to accurately detect pathogens and distinguish between highly related strains.

This work received funding from the Australian Government Office of National Intelligence to distinguish between normal and artificial (CRISPR-Cas) mutations, which Dr. Aidan Tay will be leading.

Cloud native variant effect prediction for Agilent

Collaborator: Agilent

We developed a cloud-native, serverless approach for annotating genomic variants, sVEP. This allows pathology providers to apply a modular and parallel approach for annotating genomic variants to prioritise pathogenic mutations. The modular design of sVEP allows the open-source development of useful plug-ins by the research community that can be effectively incorporated within the current architecture. sVEP is estimated to be 99 percent faster than traditional VEP which will help increase the turnaround time for pathology labs considerably and hence will indirectly improve the diagnostic process.

This work has received interest from Agilent and formed the basis for our engagement with the $2 Million initiative led by Victorian Clinical Genetics Services around automating variant prioritisation.

VariantSpark and GoldFinch

Collaborator: GoldFinch

We currently collaborate with the US Biotech start-up GoldFinch, with its leadership recently recognised as one of the 100 Most Intriguing Entrepreneurs of 2020. GoldFinch uses VariantSpark to identify novel biomarkers for a kidney disease called focal segmental glomerulosclerosis. Their dataset is from an African American population, which is an under-represented group in whole genome sequencing cohorts, hence they have a limited sample size to work with. Their strategy is to explore a machine learning approach to genome wide association (GWAS) using VariantSpark in order to gain additional signal from their dataset, which a traditional GWAS analysis could not offer.

This highlights the gap that VariantSpark can fill for researchers who have utilised traditional approaches with no or limited success. Using VariantSpark they can identify variants that interact to drive the disease process, as well as variants that are independently associated with disease. GoldFinch became aware of VariantSpark through the AWS Marketplace offering, clearly demonstrating the value of offering bioinformatics solutions as services through cloud marketplaces.

Transformational Bioinformatics: postdoc and student highlights

Postdoctoral highlight

Aidan Tay, Postdoctoral Researcher

Aidan has focused on developing computational tools for identifying foreign DNA sequences in the genome for both health and biosecurity applications. He led the development of INSIDER, a tool for identifying regions of the genome that "sound" different to their surroundings. As a result of his research activities, Aidan was awarded a fellowship by the Australian Government Office of National Intelligence to distinguish between normal and artificial (CRISPR-Cas) mutations.

Aidan was also part of the team that was awarded the prestigious CSIRO collaboration medal and played a key role in CSIRO's research response to the COVID-19 pandemic. He developed a platform to analyse SARS-CoV-2 genome sequences to better understand how the virus accumulates mutations over time, which was crucial for the development of the COVID-19 vaccine. Aidan also published a collaborative paper in Nature Biotech on RNA Atlas, which expands the catalogue of human non-coding RNAs.

Masters student highlight

Felix Hartkopf, Masters student

Felix worked on isling, our tool for detecting viruses which have integrated their genome into a host genome. He explored options for running this workflow in the cloud, getting a Kubernetes implementation up and running. Felix then used this to conduct a comparison of isling against other viral integration tools, and developed visualisations of the results, finding that isling was more accurate than the other tested tools.

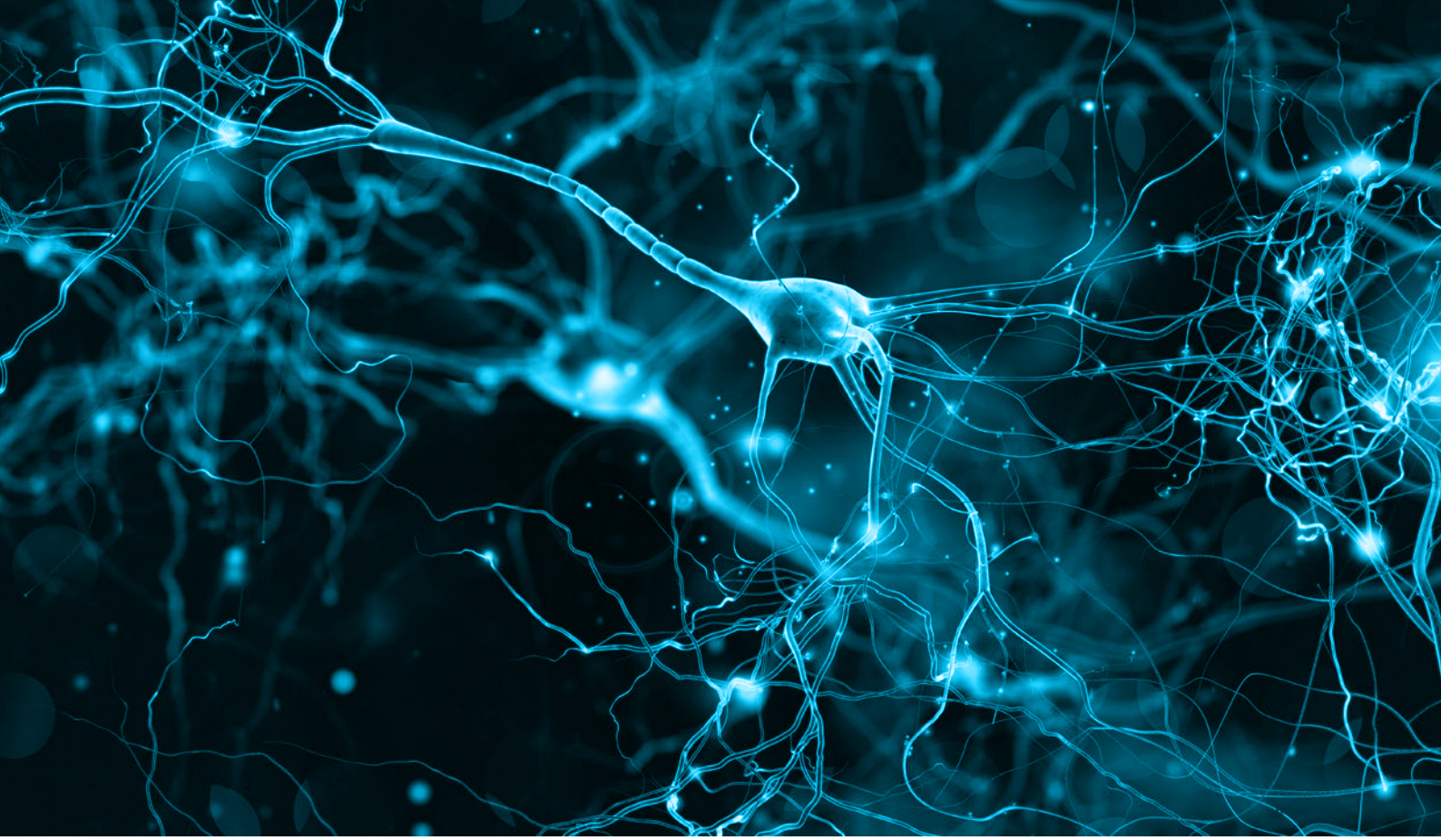
The Biomedical Informatics group

Group Leader: Jurgen Fripp

The Biomedical Informatics group develops and validates novel and advanced Machine Learning (ML) and Artificial Intelligence (AI) methods for use in medical research and clinical translation.

Our particular focus is on using 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 to be used in a wide range of large observational and randomised controlled trials across the human lifespan (from pregnancy to ageing) and across the disease spectrum (including osteoarthritis, cerebral palsy, cancer and dementia).



Biomedical Informatics' science and impact highlights for 2020–21

- Dementia is the second leading cause of death of Australians and is likely to become the leading cause as our society ages. More research and clinical trials of new drugs are required in our search for preventative or curative interventions. As part of our commitment to the Australia Dementia Network (15 institutions nationwide), we have developed a cloud-based data collection platform. This platform follows best practices in governance and standards, and allows for a centralised data collection and curation. The deployed platform is currently used nationwide by six sites (in five different states) and will be expanded when more sites are on-boarded.
  - In large-scale multicenter studies lots of things change. We have published (in Neuroimage) a novel PET harmonisation algorithm that significantly improves the longitudinal consistency of Amyloid biomarkers when camera's and tracers are changed.
  - Using multiple national and international PET datasets, we have developed detailed models of the relationship between changes in Amyloid plaques and tau tangle in the brain. This research provides key indicators for the quantity of amyloid needed to kick-off tau tangles and subsequent cognitive decline in patients.
- Each year in Australia, more than 20,000 infants are born preterm, who face a range of neurodevelopmental outcomes such as cognitive, behavioural, educational and motor deficits including cerebral palsy (CP). In collaboration with the University of Queensland, we are currently following up one of the largest internationally highly characterised cohorts of preterm infants who are now 6 years of age (PREBO-6). We have assessed 46 children at school age of the total 200 infants born preterm, allowing us to track brain development and investigate functional networks. Identifying those infants with greater impairments or difficulties with school readiness earlier in life (in the neonatal period) is critical to provide early and effective interventions.
- In collaboration with GenesisCare, we have helped the development of new cyclic peptide theranostics for difficult to treat cancers.
- $1M partnership with AdvanCell Isotopes for the development of the first scalable solution for medical isotope production.
- In collaboration with AIBL, Biostatistics Team members provided reports and information to Biogen that was used directly to support their recent FDA approval for the first drug to treat Alzheimer's pathology in 20 years.

For more information see Projects.

Biostatistics team

Team Leader: James Doecke

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

Medical Image Analysis team

Team Leader: Jason Dowling

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

Neurodevelopment and Plasticity team

Team Leader: Dana Bradford

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

Neuroimaging team

Team Leader: Vincent Doré

The Neuroimaging team members use their deep knowledge of medical instrumentation, image processing and machine learning algorithms to 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 groups for developing dementia and allowing early interventions (such as improving life-style choice).

The team contributes to image-based biomarker analysis for a number of large studies and supports a range of large Alzheimer's disease trials around Australia, including in the Alzheimer Dementia Network (ADNeT). ADNeT is part of Australia's quest to find cures and prevent and better manage dementia, involving a registry of clinical trial volunteers to fast-track research and translation. We are also partnering with Maxwell Plus in a CRC-P project to translate CSIRO's CapAIBL software in a new platform and to use machine learning methods to increase the throughput of reporting.

Biomedical Informatics: platform technologies

Health research data: CSIRO AWS REDCap

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/managed 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.

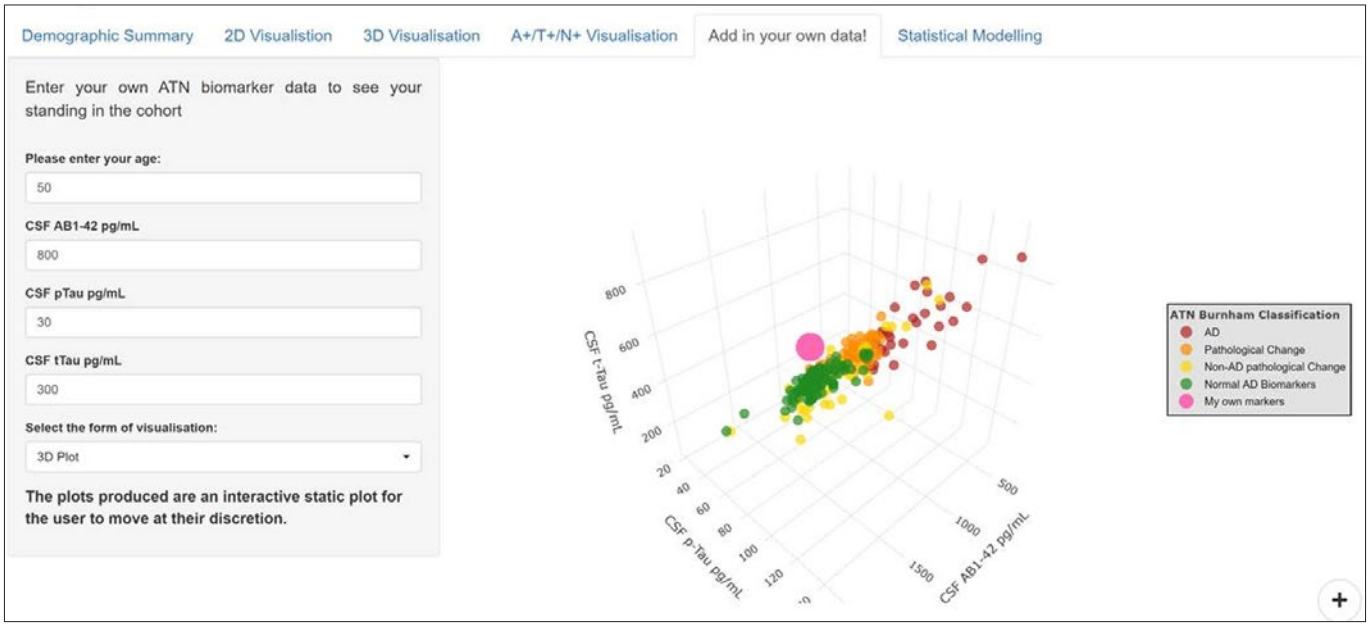
The XNAT platform is used in several large multi-site neuroimaging studies (ADNeT and PISA); read more in Biomedical Informatics: Project Reports and Project Updates.

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 machine learning and artificial intelligence (ML and AI) methods to comb through the data and investigate the collaborator research questions.

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

Shown below is an example of a R Shiny app to visualise data that was presented at the 2021 Australian Dementia Forum by the Biostatistics Team Vacation Student Lucy Nott. The app has multiple pages with graphics to compare biomarkers in a 3D space.



3D visualisation through R Shiny.

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. Several prototypes have now been developed for radiology, and the platform is readily applicable in other domains as well.

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 the medical images (MRI, PET, CT) being uploaded to a cloud-based platform where they are analysed. 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 have allowed the in-vivo examination of brain pathology associated with Alzheimer's disease, such as Aβ plaques, glucose metabolism, cortical atrophy and more recently, tau tangles. PET imaging 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 the 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 cloud-based tool to support the assessment of pediatric brain MRI by providing quantitative information of brain structure (including anatomical volumes and cortical shape) relative to a typically developing cohort. It utilises a range of artificial intelligence and machine learning 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). The tool has been validated on cohorts of children with CP and ABI who were recruited by our collaborators at the Queensland Cerebral Palsy and Rehabilitation Research Centre (QCPRRC). 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.

Currently this software has been used in a number of projects to quantify differences in pediatric brain structure pre- and post-motor rehabilitation intervention as well as find cross-section associations between brain structure and childhood function all in collaboration with 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).

Biomedical Informatics: project reports

Australian Dementia Network (ADNeT)

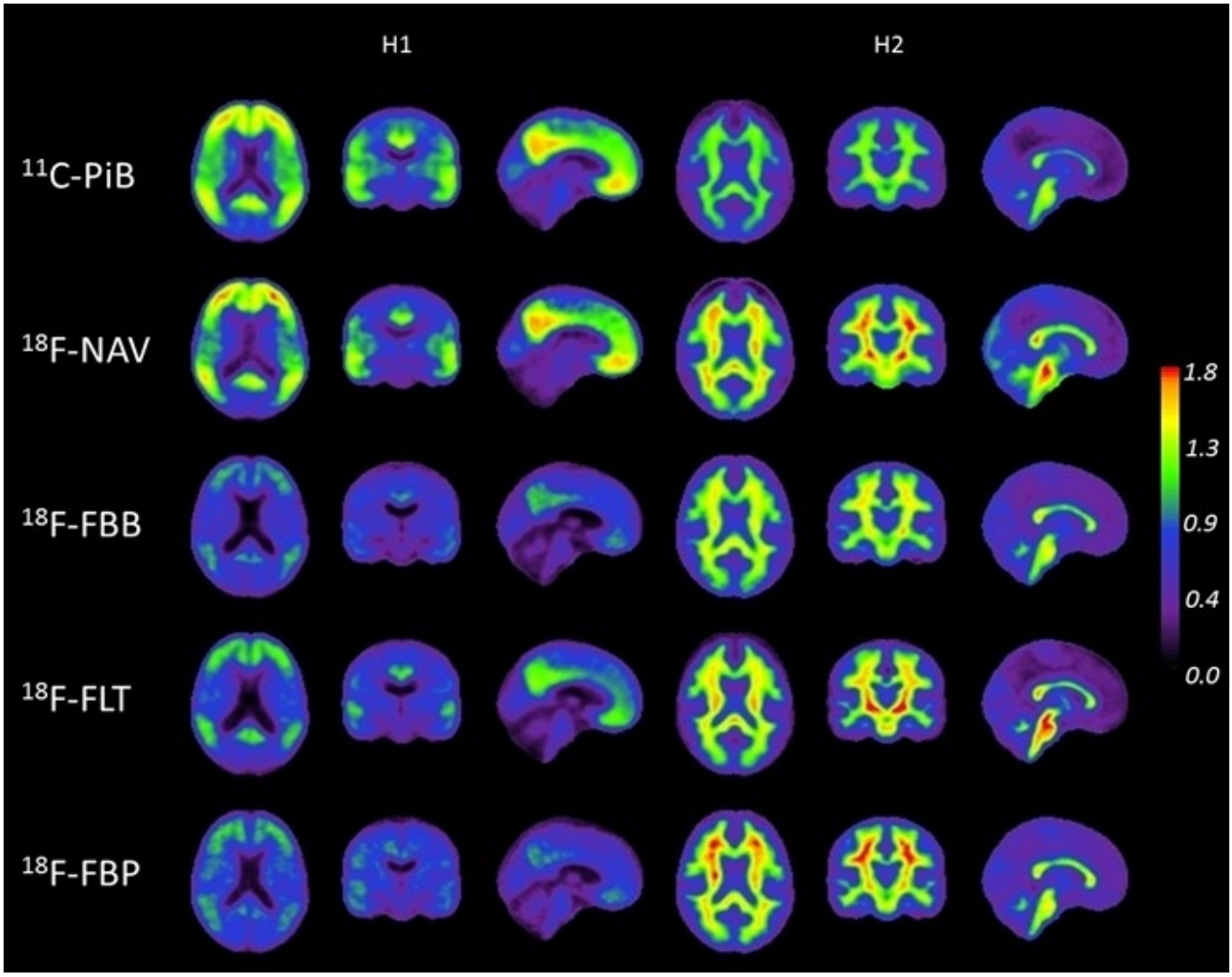
Australian Dementia Network
REGISTRY. CLINICS. TRIALS.

Collaborators: University of Melbourne, University of New South Wales, Monash University, Edith Cowan University, Flinders University, South Australian Health and Medical Research Institute (SAHMRI), University of Sydney, NeuRA, Macquarie University, QIMR Berghofer Medical Research Institute, 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. It's primary aim is to improve quality of care, quality of diagnosis, and accelerate development of new therapies. One of the major outcomes will be to establish an integrated network of dementia researchers, clinicians and health service providers to enable ongoing, high-quality translation of research into clinical care for Australians living with cognitive impairment and dementia. In addition, ADNeT will enable fast recruitment of trial-ready research participants and will support participants through their involvement in clinical trials.

CSIRO is joint technology lead providing the following:

- **Technology support**: Provide secure data collection platform and harmonisation for the ADNeT ecosystem.
- **Image analysis**: Provide the imaging biomarker quantification and clinical translation for the thousands of medical images associated with this novel and far-reaching project.
- **Statistical analysis**: Our Biostatistics team combines data from multiple modalities to answer clinical research questions. This involves using statistical methods to combine data from imaging, genetics, genomics, proteomics, neuropsychology and clinical biomarkers. The team works with national and international collaborators to investigate the destructive pathological processes which occur to cause Alzheimer's disease.
- **Status update**: Over 2,000 subjects have volunteered for recruitment into trials, with 287 enrolled into the well characterised trial ready cohort.



NMF model of the 5 Amyloid tracers

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

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

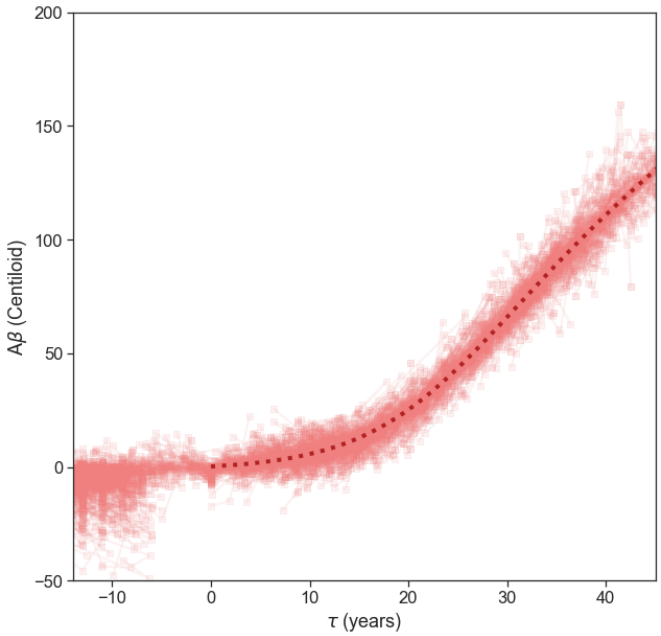
ADOPIC is a NIH-funded (PI Prof Masters, University of Melbourne) study looking at establishing and validating the impact of demographics, genotype and comorbidities on the onset and progression rates of Alzheimer's dementia. This international consortium aims to leverage the power of five leading well 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 1,300 subjects (each assessed three times over a minimum of 4.5 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 that findings are more easily interpreted and transferable to clinical settings.

In the last 12 months, a key development has been 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]). This was employed on the cognitive dataset to impute neuropsychological test scores that were not measured in all studies.
- 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.

CRC-P – Accelerating PET and MR quantification with Deep Learning

Collaborators: Queensland University of Technology, Austin Health, Maxwell Plus, I-MED

Radiologist interpretation of medical images such as PET and MRI is subjective, and variability in skills and experience may result in misdiagnosis, increased cost and potential harm to patients. In collaboration with Queensland University of Technology, we are developing novel artificial intelligence methods for automated radiology reporting. This CRC-P funded project (PI Smith) is led by Maxwell Plus who are licensing the developed technology and will lead regulatory approvals and commercialisation; I-MED, a world leading radiology practice; and Austin Health (Prof Rowe) for validation in a clinical trial.

MR quantification:

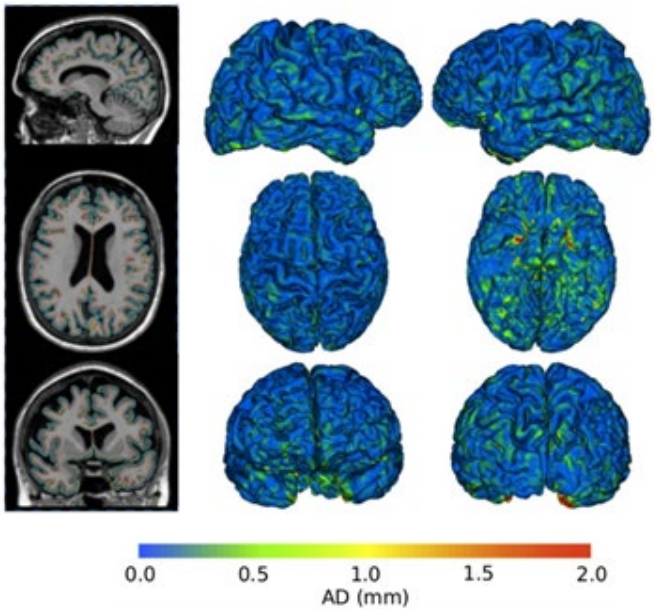
An important step in the quantitative analysis of the human brain structure is the reconstruction of the cerebral cortex from MR images, to compute cortical thickness, which is a marker of brain atrophy. However, existing approaches are time consuming, and prone to errors, limiting their deployment in clinical environments. Aided by recent advances in deep learning, we have developed a fast and accurate cortical reconstruction method, reducing processing time from hours to minutes. The method won the best paper award at the 2021 WACV conference.

PET quantification:

With Amyloid PET imaging now being covered by Medicare, and the recent approval of Aducanumab for anti-Amyloid therapy by the FDA, it is expected that demand for Amyloid PET imaging will increase drastically. This puts our CapAIBL PET quantification software in a favourable position for commercialisation. Over the last 12 months, we have worked with Maxwell Plus to transfer the CapAIBL technology and include the latest methodological developments, and we are now preparing a prospective clinical trial with I-MED and Austin Health to support CE Mark and TGA regulatory approvals.

Post-doctoral highlights:

Dr Santa Cruz and Dr Lebrat proposed the first geometric deep learning model for cortical surface reconstruction that can accurately predict cortical surfaces thirteen times faster than classical methods. They also proposed the state-of-the-art brain morphometry regression network that predicts 165 brain morphometric measures directly from MRI in only a few seconds.



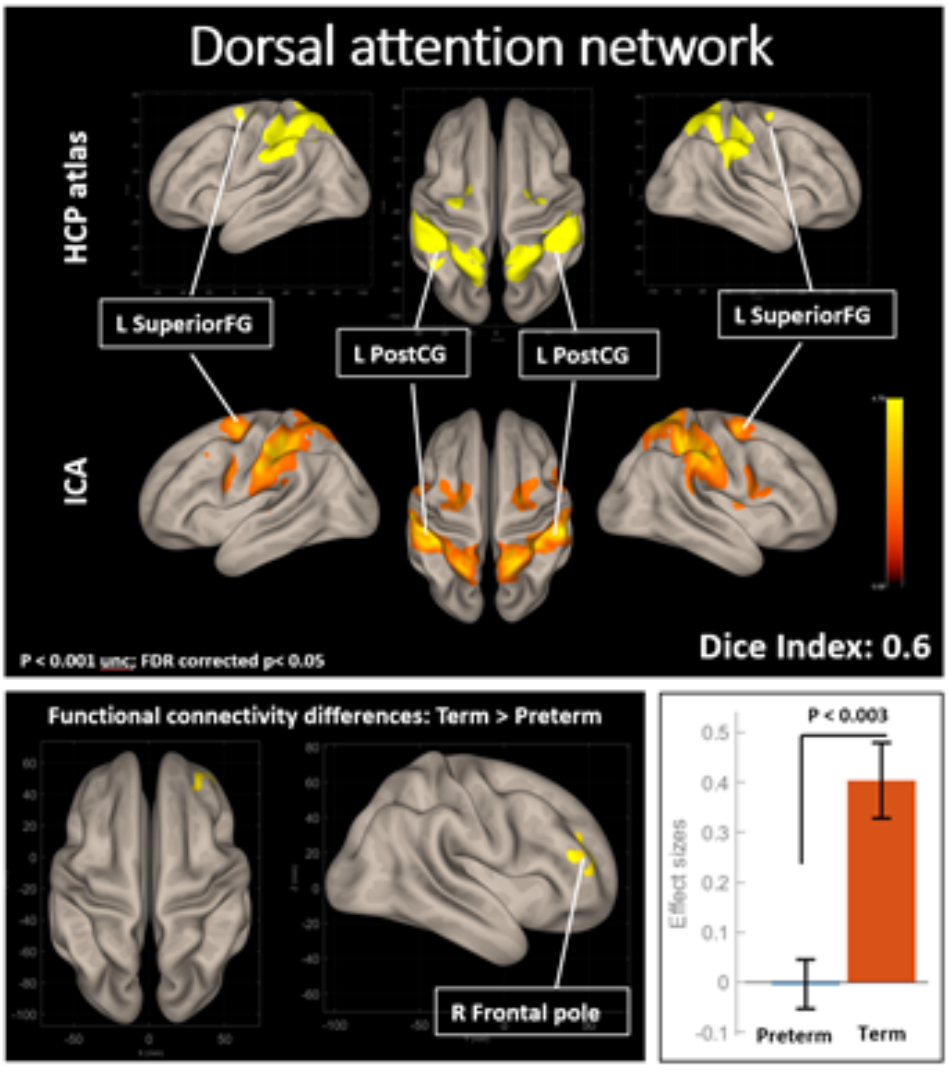
Example of cortical surfaces reconstructed with Deep learning technology. The surfaces are colour coded with the absolute distance to the pseudo ground-truth surface.

Predicting outcomes for babies born pre-term – a six-year follow-up study

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

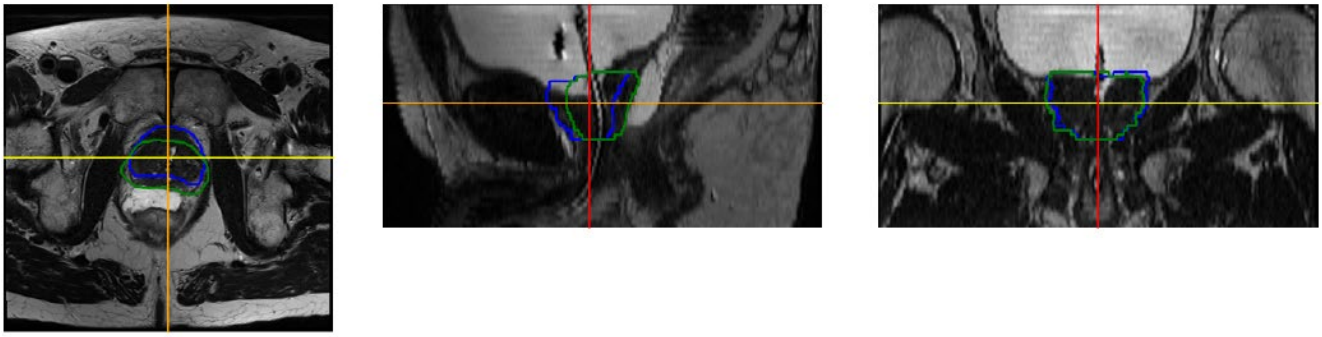
Pre-term infants face a range of adverse neurodevelopmental outcomes, including cognitive, behavioural, educational and motor deficits. In collaboration with the Queensland Cerebral Palsy and Rehabilitation Research Centre, we followed up a landmark preterm cohort (from our PREBO project) at six years to determine if MRI scans of pre-term infants acquired at 29–35 weeks postmenstrual age (PMA) are predictive of academic achievement and health outcomes at school-age. If these early scans are predictive of childhood developmental outcomes, early accurate identification of those at risk could open a new window for therapeutic targeted early interventions and provide family psychological and financial support.

This dataset also contains scans taken at six years, and will be used in a number of analyses, probing the developmental trajectory of brain structure and white matter microstructure and the implications for childhood outcomes. Using functional MRI (fMRI) in the six year old's, we have identified differences in the spontaneous activity of large-scale resting-state networks between those born term and pre-term. We generated population-specific resting-state networks using a data-driven approach called independent component analysis (ICA). Preliminary results have revealed that the connection between a brain network involved in attention and the frontal pole is stronger in children who were born term (See figure). These preliminary findings may help to explain some of the adverse neurodevelopmental outcomes experienced by children born pre-term.

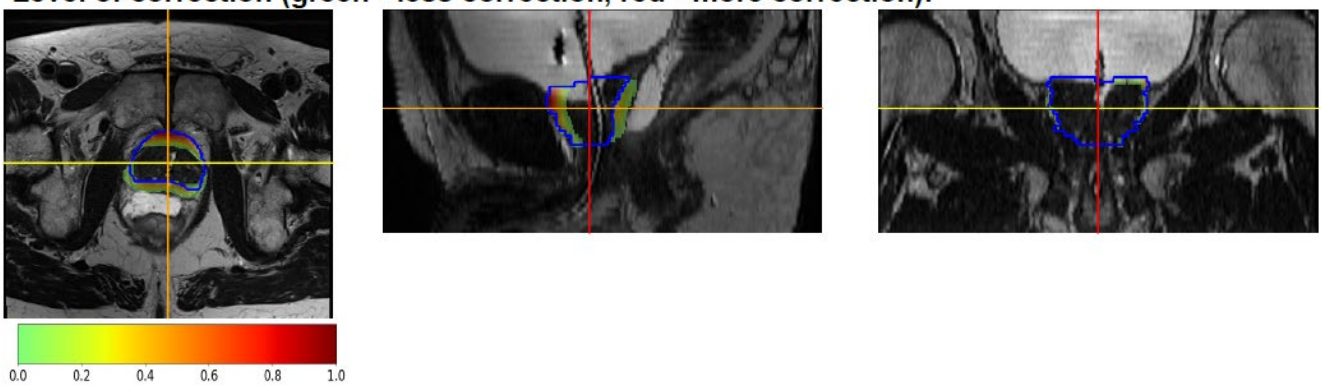


In tasks requiring attention, a number of functionally connected brain regions are active; these regions have been described as the Dorsal attention network. This network also shows some activity while the brain is at rest, which has facilitated the creation of atlases of normal brain functions, such as in the Human Connectome Project, to identify and investigate this network (Top row, yellow). Our functional MRI investigation found that a similar network overlaps this area (second row, orange). When we looked at how other brain regions were connected to this network, we found that an area in the right frontal region (bottom row, left) showed a higher functional connection in children who were born at term than in pre-term born children (bottom row, right).

Case name: PR_PAH24
Manual contour name: PR_PAH24_PROSTATE_fail.nii.gz (labeled in blue)
Benchmark contour name: Avg_msk_PR_PAH24_PROSTATE_fail.nii.gz (labeled in green)
Dice between the manual and benchmark contour: 0.714
95% Hausdorff distance between the manual and benchmark contour: 7.292mm
Category score: 2 Require major correction.
Contour overlay:



Level of correction (green->less correction, red->more correction):



Case report template.

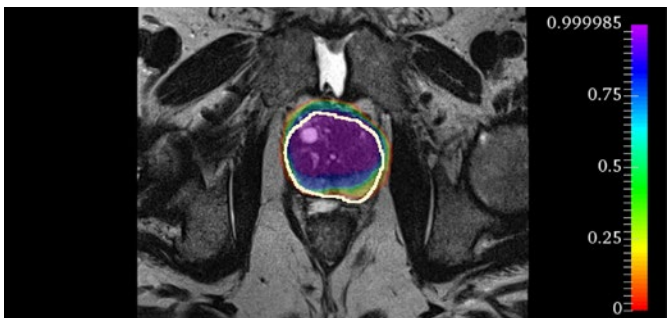
Improving radiotherapy treatment clinical trial quality assurance

Collaborators: Ingham Institute, Liverpool Hospital

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

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

An automatic delineation QA system has been developed 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.

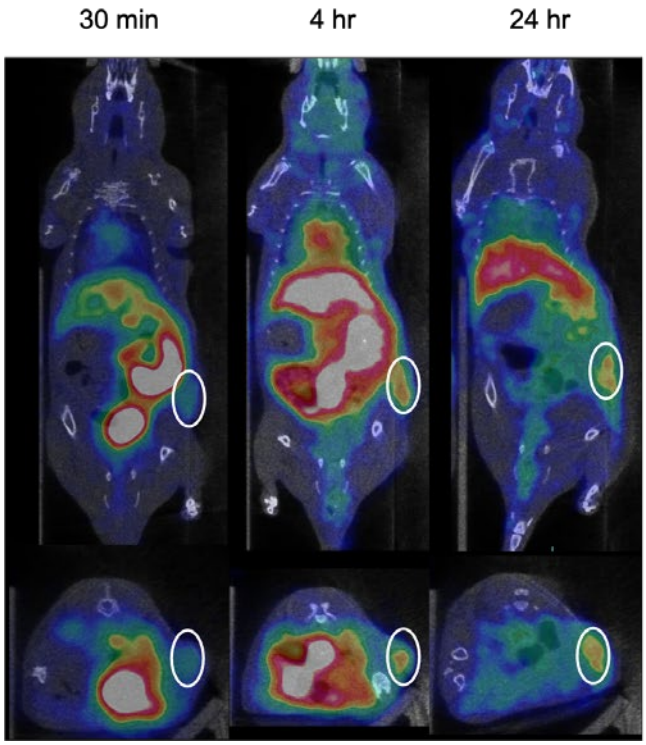


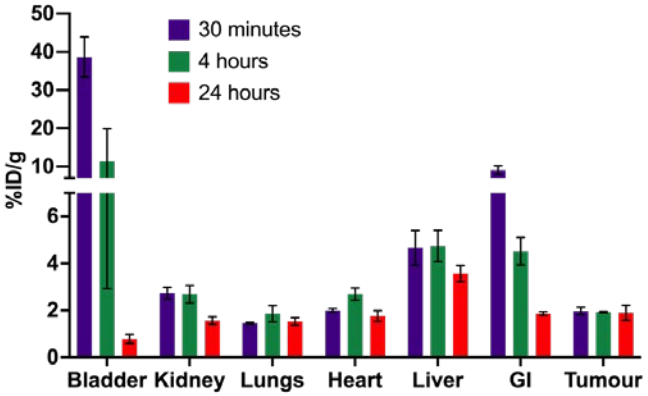
Probabilistic estimate of MRI manual prostate contouring accuracy from the PROMETHEUS trial.

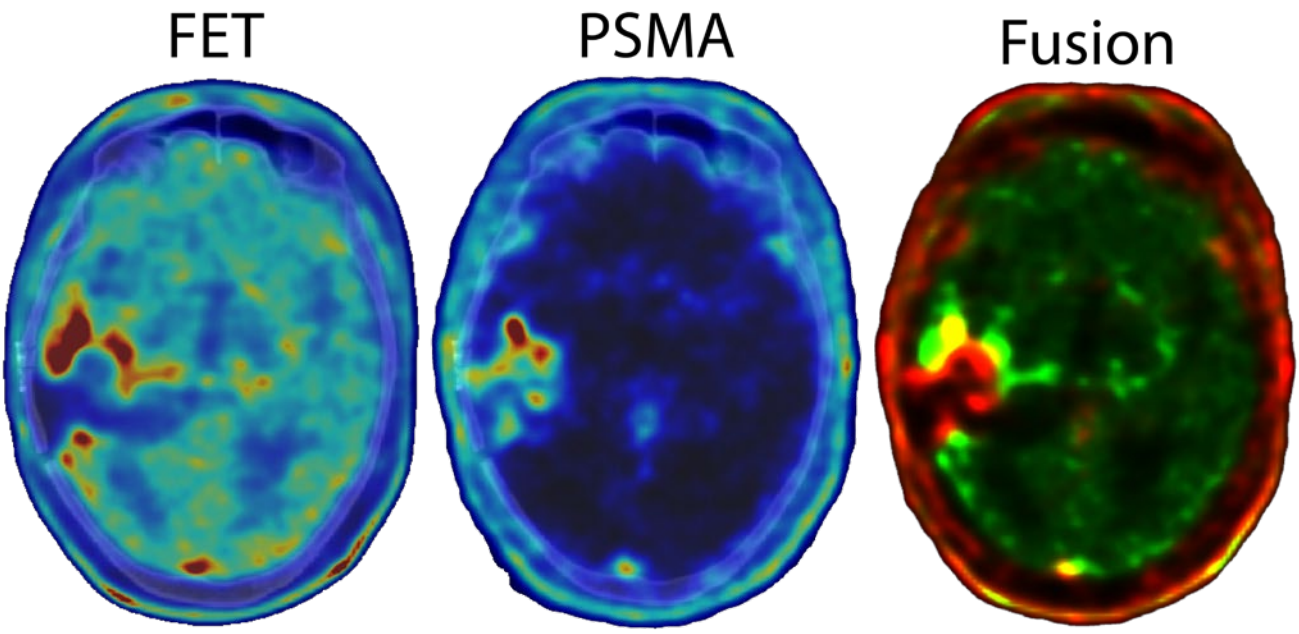
Theranostics: Approach for difficult-to-treat cancers

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

The $5.1M partnership between CSIRO's Probing Biosystems Future Science Platform and cancer care provider GenesisCare continues to develop new cyclic peptide theranostics for difficult to treat cancers. The project has identified nine theranostic targets through bioinformatic screening of full RNA sequencing data from over 28,000 patient biopsies and has validated these targets through immunohistochemical staining of over 300 tumour samples. Further, the project has identified two novel binding ligands for two of these targets and has developed them into early-stage radiopharmaceuticals with preclinical testing currently in progress. The project has gained investment interest from major Australian venture capital funds and a start-up strategy is currently being executed between CSIRO Business Development and Governance and GenesisCare.







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

Scalable 212Pb manufacture for targeted alpha therapy

Collaborators: AdvanCell Isotopes, CSIRO Land and Water, CSIRO Minerals

A new $1M partnership with AdvanCell Isotopes will see the first scalable solution for medical isotope production established at the QCAT site in Pullenvale, Queensland. The project has completed a renovation of one of the Pullenvale laboratories to convert it into a Medium Level Medical Isotope Laboratory that is fully approved by ARPANSA to generate the alpha emitting isotope 212Pb for use in targeted alpha therapies. The project is running in collaboration with two additional CSIRO business units – Land and Water, and Minerals – through a funded Kickstart project to source the parent isotope, 228Th, from waste streams generated by the Australian Rare Earth Element (REE) and Heavy Mineral Sands mining sectors. AdvanCell Isotopes in collaboration with CSIRO will be running a first-in-human imaging trial of its targeted alpha therapy, ADVC001 in Q4 2021.

The AdvanCell Isotopes 212Pb generator to be installed at QCAT, Pullenvale Q3 2021

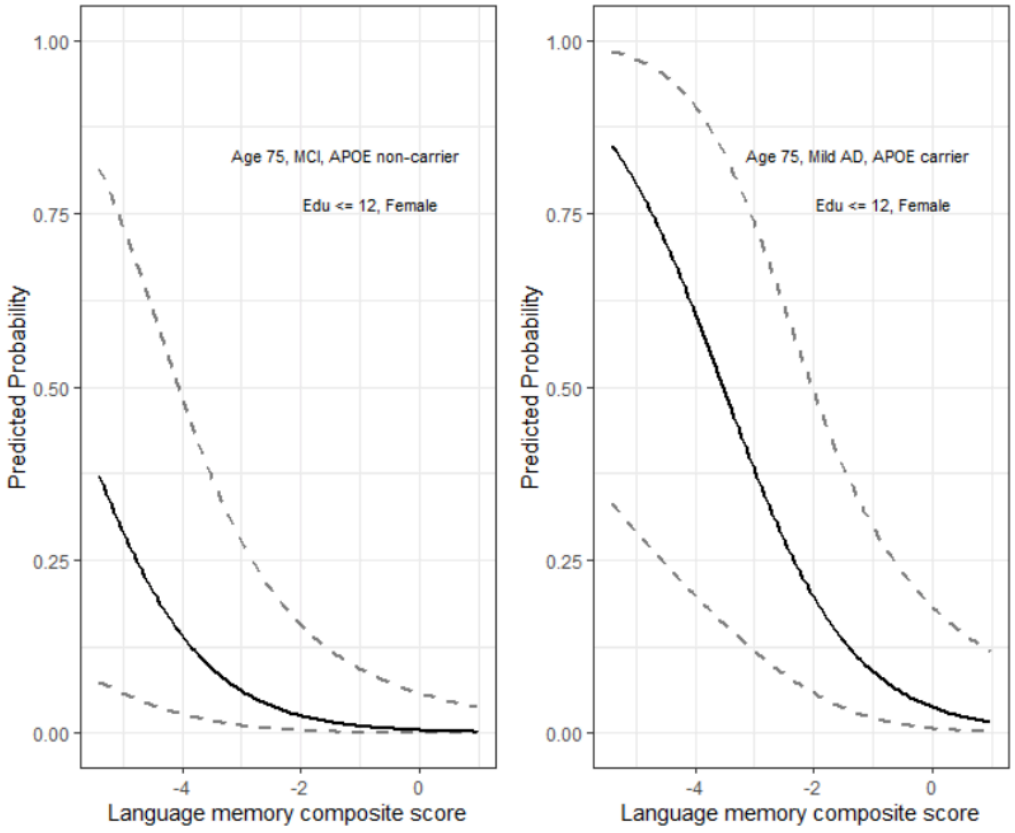
Biostatistics for Alzheimer's disease biomarker identification

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. Work with the Australian Imaging, biomarkers and Lifestyle (AIBL) study of ageing has been focussed upon identifying biomarkers to detect disease pathology prior to the onset of clinical symptoms.

Work with collaborators from Biogen saw Biostatistics team members be part of a five-study international collaboration to understand the underlying disease aetiology for their FDA application for 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 have now been successful in their FDA application.

This is the first drug that has been 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 predicted probabilities on the y-axis and the Language cognitive composite score on the y-axis.



Predicted probabilities of a person having a certain Language Composite score given an average age at 75, average level of education (<= 12 years), and dependent on whether they do or do not have a mutation within the Apolipoprotein gene; (Left) MCI participants who do not have a mutation, and (right)Mild AD participants who do have a mutation. The graphic shows a higher probability of having a lower Language composite score if you have mild AD with a mutation as compared to having MCI with no mutation.

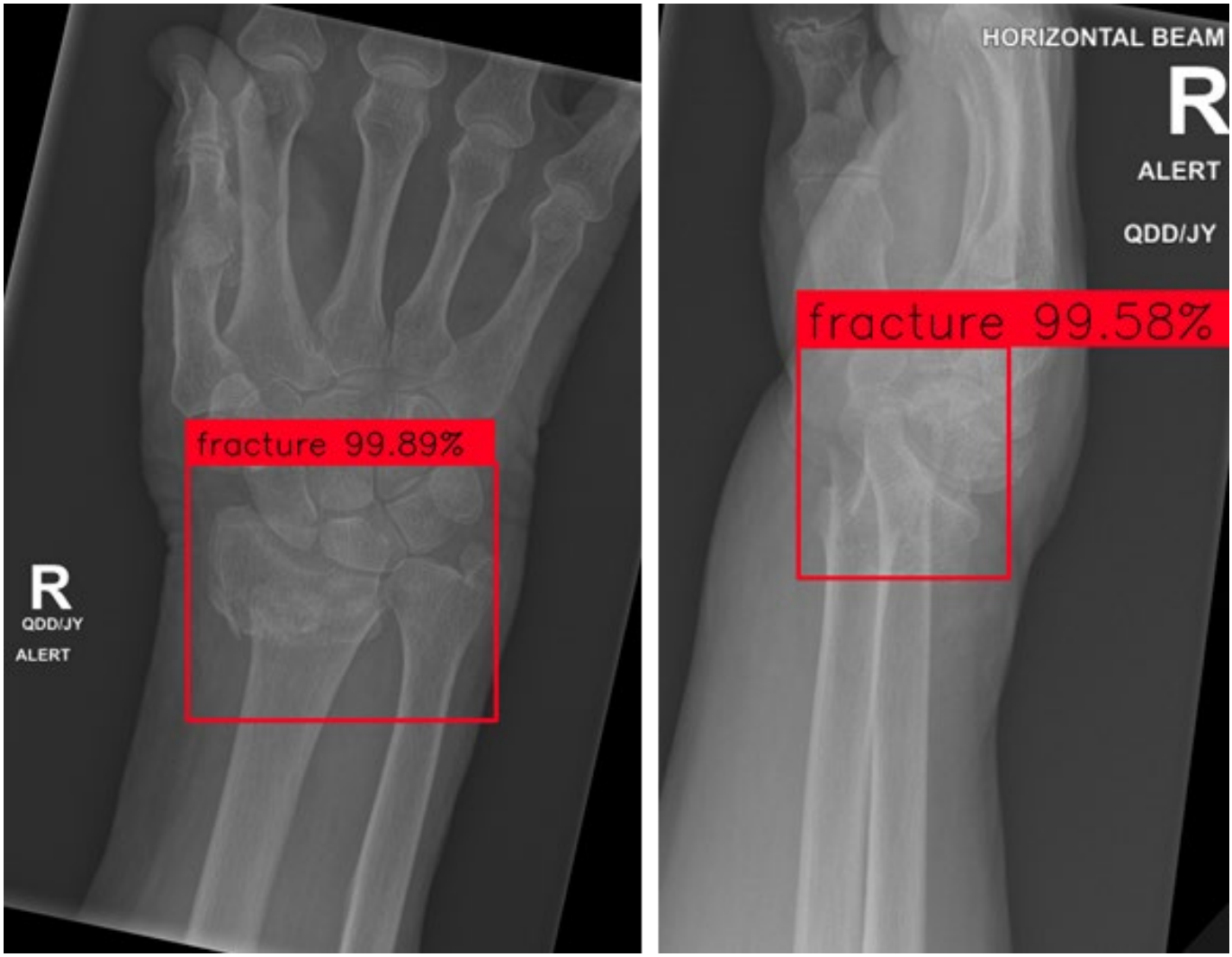
Biomedical Informatics: project updates

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

Collaborators: Jamieson Trauma Institute

Distal radius fracture (DRF) is one of the most common orthopaedic injuries. The DRFs can be classified into three AO classes including extra, partially and complete articular. The complete articular type often requires a CT to better evaluate the fragments.

This project aims to develop an AI screening tool to identify complete articular DRFs on wrist radiographs to advise radiologists whether a CT scan is necessary for the patient. We have applied an object detection network (YOLO) to identify the distal radius region (region of interest) on a wrist or arm x-ray. Currently, the clinical data we received are under manual examination to screen out radiographs of irrelevant anatomical parts.



Application of an object detection network to identify the distal radius region (region of interest) on a wrist or arm x-ray

Musculoskeletal image analysis: ChondralHealth

Collaborators: University of Queensland, Siemens Healthineers

The ChondralHealth project has 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. We have developed algorithms for automated segmentation of joint cartilages from MRI scans and used these to identify morphological and biochemical quantitative descriptors of cartilage health.

Our methods for bone and cartilage segmentation are utilised in the NHMRC Development grant (funded until 2022) "MR Hip Intervention and Planning System" (mrHIPS) project which enables bone lesion and soft tissue visualisation and quantification, and a framework for modelling of hip joint kinematics. These models have been enhanced through image acquisition using the 7T MRI scanner at the University of Queensland. Both projects have been supported by Siemens Healthineers, Germany, who are the commercialisation partner for the technology. An NHMRC Ideas grant has been awarded to extend this work with biomechanical modelling (led by Griffith University).

MRI-based paediatric lung structure and function assessment

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

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

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

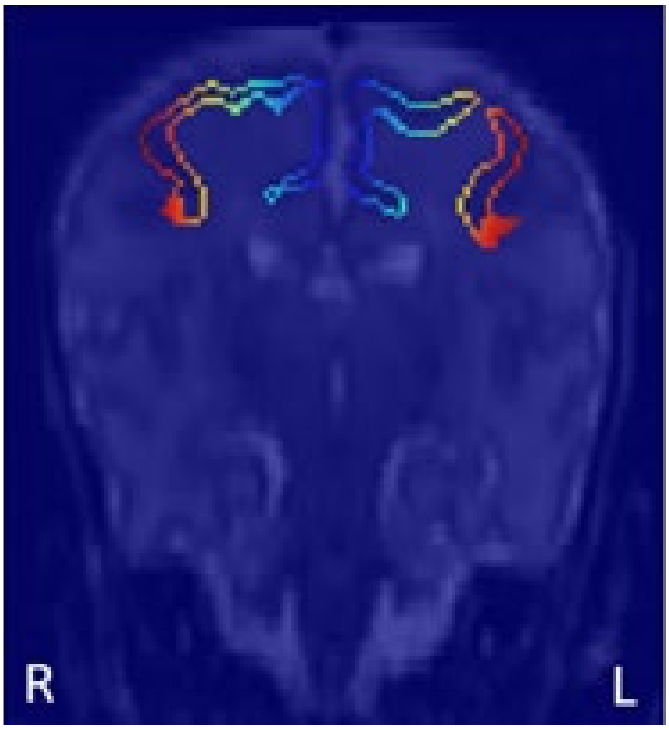
To address this clinical need we are developing image acquisition methods and software to extract quantitative disease status metrics from MRI. This work has been supported by a three-year CSIRO postdoc grant and external funding from the AT Children's Project, the US CF Foundation, and a recent 2020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

Automating MRI scoring to enable more infants to undergo brain assessment at birth

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre (University of Queensland); Centre for Clinical Research (University of Queensland)

Infants born preterm are at high risk of adverse neurodevelopmental outcomes. Early identification of infants at highest risk is crucial to provide the right intervention to the right infants at the right time. Assessment of brain growth and abnormality in the newborn period using MRI shows promise for the early prediction of later neurodevelopmental outcomes but is time consuming and requires a high level of expertise, and is therefore not currently feasible to perform on all infants in clinical practice.

We have developed software to automatically extract a subset of measures of brain growth and abnormality. We validated the automated measures by comparing them to manually obtained measures, showing good agreement. Future research will examine the relationship between these measures and clinical outcomes. This work is a key step toward bringing this important brain assessment to the clinic, augmenting the MRI reporting done clinically.



Automated brain measures can be successfully extracted from MRI scans, reducing the time and expertise required for manual assessments. If these automated measures are found to predict developmental outcomes, they can be applied to large datasets, and more infants will be able to receive brain assessment at birth.

Anatomically-guided nuclear medical imaging reconstruction

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

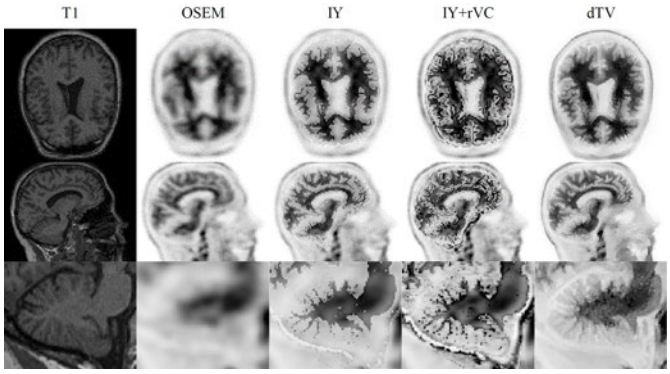
PostDoc Project: Ashley Gillman

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

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

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

This year, an algorithm for post-processing PET data exploiting MRI has been developed and demonstrated on FBB-PET. A protocol for epilepsy acquisition has been developed with Royal Brisbane and Women's Hospital.

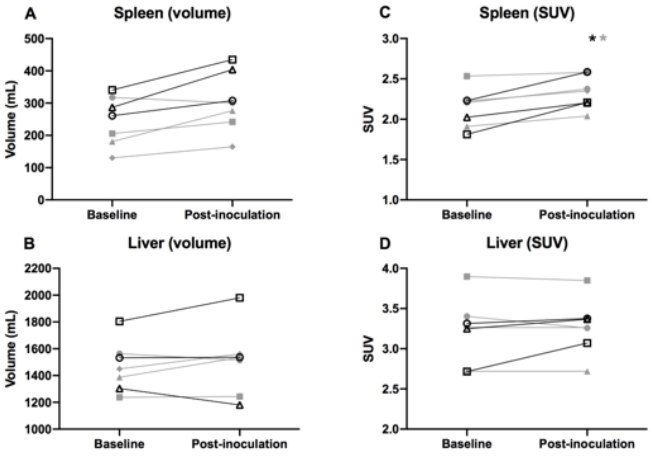


Post-processing of PET images using MRI-guidance via directional total variation (dTV) demonstrates realistic and superior PET recovery compared with segmented Iterative Yang (IY) and reblurred Van-Cittert (rVC) approaches.

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. Medical imaging in malaria is rare, and hence the imaging biomarkers for parasite distribution are not known. In this work, functional FDG-PET, a known biomarker for metabolism and inflammation, as well as volumetric MRI were investigated in abdominal organs and the brain. Imaging and analysis of the abdominal region is complete, with neurological analysis underway. Results indicate that both MRI and FDG-PET are able to elucidate the disease burden. Preliminary results indicate that infestation of the bone marrow may take longer than previously thought.

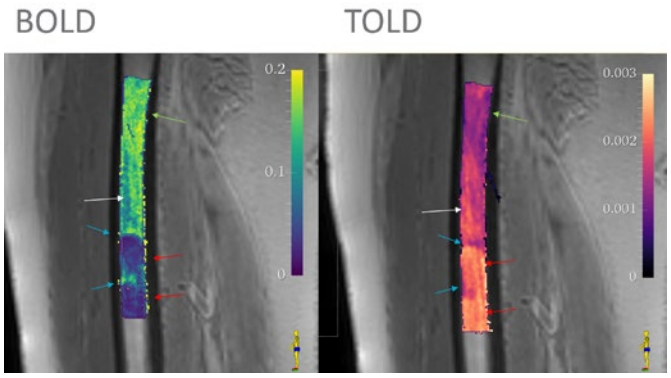


Both MRI-derived splenic volume and FDG-PET standardised uptake value (SUV) significantly increased, whereas hepatic biomarkers did not. Parasites are known to preferentially infest the spleen.

Non-invasive MR oximetry of the marrow

Collaborators: Queensland University of Technology,
Herston Imaging Research Facility,
Dr Michael McAuliffe, CaptixBio

Bone marrow has been identified as a promising site for implantation of cell therapy devices. Such devices have promise, for example, for treatment in Type 1 Diabetes. However, insufficient oxygen supply to therapeutic cells has been described as the most critical impediment to progress. In this work, MRI techniques for identification of sites with adequate oxygen delivery are explored in a pilot trial. To date, 7 of 11 participants have been imaged, and Contrast-Enhanced Perfusion, Dixon Water/Fat Separation, Blood Oxygen Level Dependent and Tissue Oxygen Level Dependent MRI techniques show promise in identifying vasculature, blood supply and oxygenation.



Blood and Tissue Oxygen Level Dependent MRI in the femoral marrow give independent insight into local oxygen partial pressure.

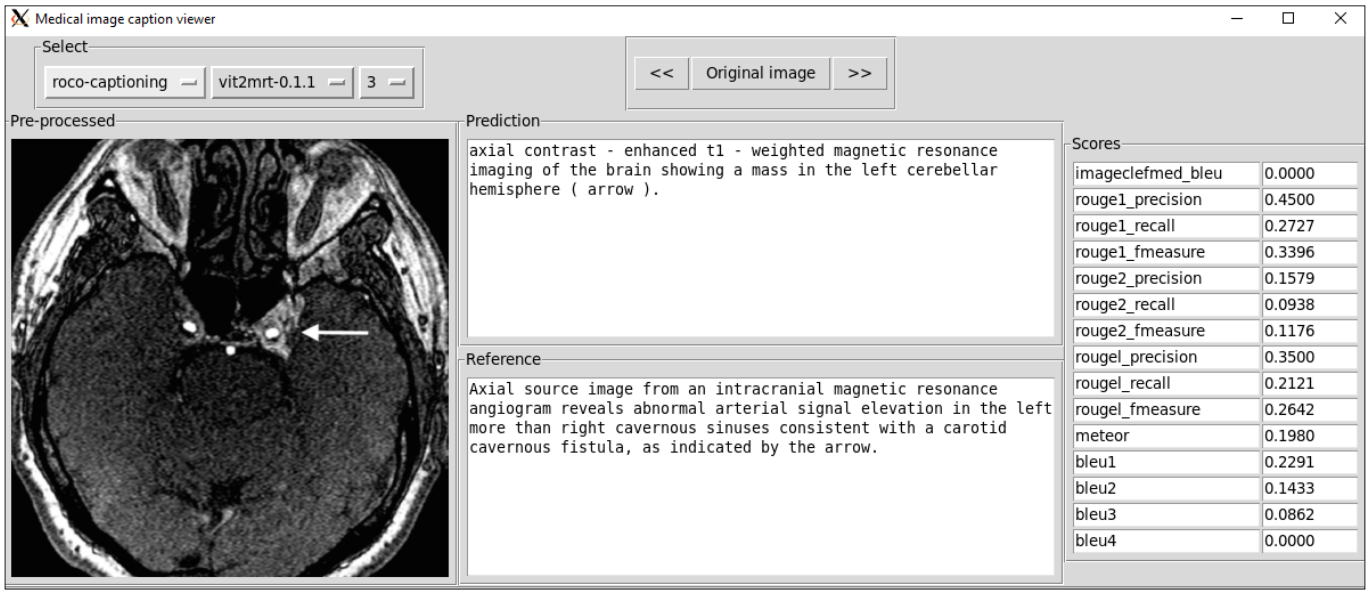
Medical image captioning

Collaborators: MLAI Future Science Platform

PostDoc Project: Aaron Nicolson

For medical tasks such as diagnosis and prognosis, clinicians often use multiple modalities to inform their decision. Examples of such modalities include natural language (e.g. medical reports), images (e.g. radiographs), speech (e.g. emotion monitoring), and video (e.g. stroke detection). However, a common theme in hospitals is a limited and strained supply of skilled clinicians. Moreover, training a clinician requires a significant amount of time and resources. This motivates the development of an automatic system that can accurately perform diagnosis and prognosis from the aforementioned modalities. Such a system should be able to detect medical concepts, produce medical reports, and make treatment decisions. Early versions of such a system can help clinicians to interpret medical data – leading to faster and more accurate decisions. Currently, we are focusing on using both medical reports and medical images–with a task called medical image captioning.

Given a two-dimensional medical image, the aim of medical image captioning is to automatically produce a syntactically and semantically correct medical caption – in essence, a short medical report. The caption should include the modality (e.g. magnetic resonance imaging), a directional reference (e.g. anterior), the plane (e.g. coronal), the location (e.g. brain), any detected anomaly (e.g. hyperintense lesion), the location of the anomaly (e.g. right side of the corpus callosum), and any other relevant information of the image. We currently have a preliminary medical image captioning system working, as shown in the figure below. To evaluate this system, we will participate in the ImageCLEFmed 2021 caption task, which includes examples with captions from clinicians. This will also enable us to compare to other medical image captioning systems.



GUI showing the predicted caption given the medical image. A reference caption given by a radiologist is also shown, along with a series of objective scores for the predicted caption on the right.

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

Collaborators: QIMR Berghofer Medical Research Institute, 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 293 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 designed to target the symptomatic treatment of Alzheimer's disease. The ability to identify patients who will respond to ChEI using biomarkers would significantly impact treatment and policy guidelines for the use of these cognitive enhancing drugs.

In collaboration with Queensland Brain Institute and The Prince Charles Hospital, we are investigating a novel PET tracer for direct imaging of cholinergic neurotransmitter function. The current cohort of 23 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 in which there is underlying cholinergic dysfunction.

ChemoBrain

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

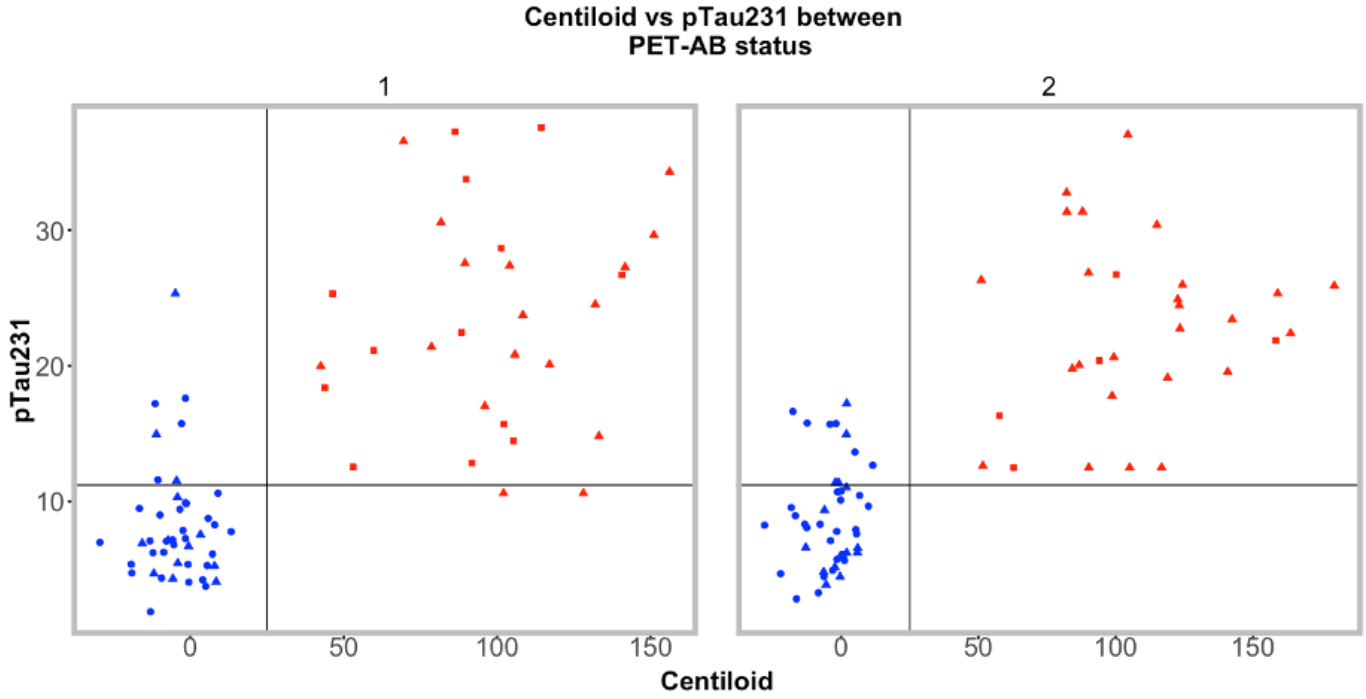
ChemoBrain trial is an MRI-based study aims at identifying if chemotherapy associated neurocognitive Impairment in Acute Myeloid Leukaemia (AML) patients is linked to brain iron overload. It is a prospective observational longitudinal cohort study and patients undergo standard chemotherapy treatment will be eligible for participation in this study.

ChemoBrain aims at recruiting 25 patients who can complete three imaging and neuropsychological assessments. So far 18 patients have been recruited and 11 have completed all three assessments. At this stage, MRI images are analysed to provide advanced imaging reports capturing anatomical and biochemical tissue properties. Trial outcome will provide support for further funding to investigate iron chelation therapy to prevent cognitive decline while going through chemotherapy.

Fluid based biomarkers to predict Alzheimer's disease

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

We have projects with large international pharmaceutical companies Roche, Biogen, Eisai, Janssen, Diadem, Abbvie and others to assess both the early detection of biomarkers predictive of Alzheimer's disease (AD) pathology, and the cognitive trajectory of the disease from its very early stages (prodromal and pre-clinical) through to late-stage clinical AD. Research is focused 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. Shown below is an example of a blood-based biomarker to predict the Alzheimer's disease pathology Amyloid beta as measured via PET imaging.

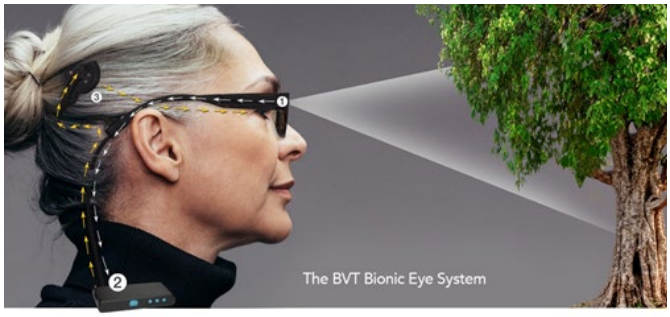


Example blood-based biomarker data to separate PET Amyloid positive participants from PET Amyloid negative participants. (Left) Blood based pTau231 (y-axis) vs Centiloid value (x-axis) at time point 1. Red dots represent those who are Amyloid positive, blue dots represent those who are Amyloid negative. Vertical and horizontal lines represent thresholds for Centiloid (vertical at 25 CL) and pTau231 (horizontal at 12). (Right) Blood based pTau231 (y-axis) vs Centiloid value (x-axis) at time point 2 (validation), Red dots represent those who are Amyloid positive, blue dots represent those who are Amyloid negative. Vertical and horizontal lines represent thresholds for Centiloid (vertical at 25 CL) and pTau231 (horizontal at 12).

Determining the effectiveness of a bionic eye implant for improving performance in tasks of everyday living

Collaborators: Bionic Vision Technologies, Bionics Institute, Centre for Eye Research Australia, College of Engineering and Computer Science, Australian National University, Data61, CSIRO

Retinitis Pigmentosa is the most prevalent cause of inherited blindness. We are working on a bionic eye implant (the Bionic Vision Technologies retinal suprachoroidal prosthesis) that may restore a sense of sight for people with end-stage Retinitis Pigmentosa. We have focused on developing methods to enhance functional vision, e.g., techniques to understand the environment with limited information. Four people have the bionic eye implant and have taken part in studies to determine if the device is effective for helping with tasks important for activities of daily living. These activities include being able to detect and avoid obstacles while walking, as well as detect and touch common tabletop objects. Our findings show that the bionic eye can improve functional vision and shows promise of potential improvement in sense of sight and tasks of everyday living for individuals with profound vision loss.



The Bionic Vision Technologies Gen 2 device. 1. Camera captures images in real time. 2. Image sent to processing device and sent to interface. 3. Data sent to implant, then to brain for user navigation. Image courtesy of Bionic Vision Technologies (bionicvis.com/products-technology).

Collaborators: Pfizer, CSIRO Nutrition and Health

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

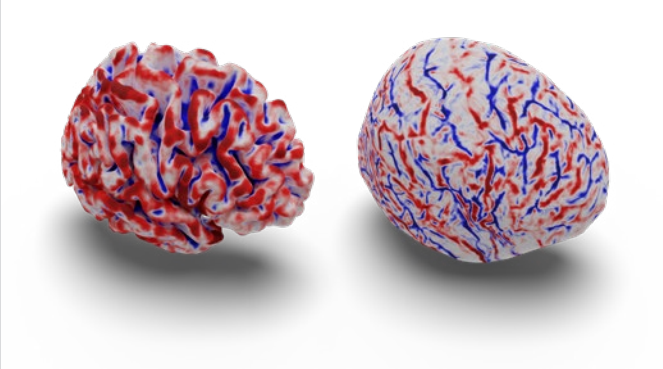
Biomedical Informatics: postdoc and student highlights

Rodrigo Santa Cruz and Leo Lebrat

Geometric Deep Learning For Cortical Reconstruction and Morphometry

Collaborators: Queensland University of Technology, Maxwell Plus, I-Med, Austin health.

Brain morphometry from MRI is a useful biomarker for the quantification of neurodegeneration in Alzheimer's and other neurodegenerative diseases. However, the limitations of existing toolboxes (long run time, inconsistencies, and inaccuracies) have curtailed their use in clinical settings. Rodrigo and Leo are developing a new set of robust tools for brain morphometry. This includes a state-of-the-art brain morphometry regression network that can predict the regional brain volume and thickness directly from a raw MRI in only a few seconds and the first geometric deep learning model for cortical surface reconstruction that can predict cortical surfaces thirteen times faster than well-established methods.



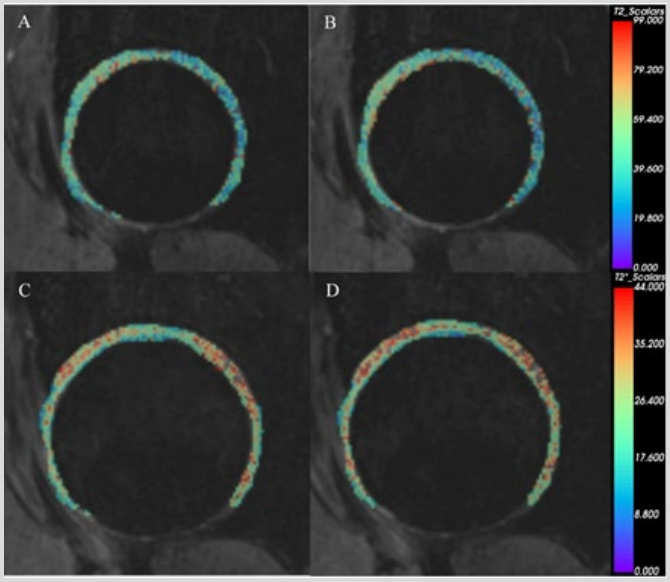
Brain morphometry analysis

Jessica Bugeja

Automated analysis of immediate reliability of T2 and T2* relaxation times of hip joint cartilage from 3T MR examinations

Collaborators: The University of Queensland (School of Information Technology and Electrical Engineering; School of Human Movement Studies) and The Imaging Research Department, Steadman Philippon Research Institute, USA.

Magnetic resonance (MR) T2 and T2* mapping sequences allow in vivo quantification of biochemical characteristics within joint cartilage of relevance to clinical assessment of conditions such as hip osteoarthritis (OA). This study aims to evaluate an automated immediate reliability analysis of T2 and T2* mapping from MR examinations of hip joint cartilage using a bone and cartilage segmentation pipeline based around focused shape modelling.

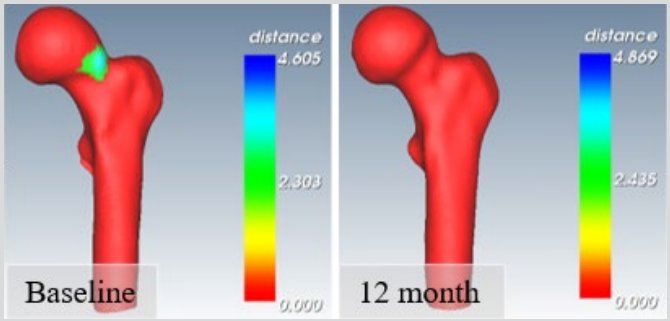


Top: Heat Map representation of the T2 map from repetition 1 (a) and 2 (b) overlayed onto the registered 3D-trueFISP image for case 3. Bottom: Heat Map representation of the T2* map from repetition 1 (c) and 2 (d) overlayed onto the registered 3D-trueFISP image for case 3. The colour map used was the rainbow colour map shown to the right of Fig. b (T2 colour map) and Fig. d (T2* colour map). These images show the good reliability of relaxation times between repetition 1 and 2 of the T2 and T2* cartilage mapping values.

Automated volumetric and statistical shape assessment of cam-type deformities of the femoral head-neck region from 3D magnetic resonance images

Collaborators: The University of Queensland (School of Information Technology and Electrical Engineering; School of Human Movement Studies); University of Sydney (Institute of Bone and Joint Research); John Hunter Hospital (Department of Orthopaedic Surgery); Royal North Shore Hospital (Department of Rheumatology); and University of Melbourne (Department of Physiotherapy).

This work introduces a fully automated three-dimensional cam-deformity assessment method using magnetic resonance images, which quantifies the femoral head and cam morphology via measures of surface area, maximum height, and volume. This fully automated approach combines the benefits of 3D U-net proximal femoral bone segmentation, patient-specific anatomical information from statistical shape modelling, the ability to focus on the head and neck region using focused shape modelling and pathological region constraints learnt from arthroscopic procedures completed by orthopaedic surgeons.



Left: Femoral bone model showing the identification of the cam lesion morphology in the antero-superior femoral head-neck region. Right: Post femoral ostectomy femoral bone model showing the cam morphology algorithm accurately identifying no cam morphology. The scalar bar to the right of the images is the distance between a generated healthy bone model and the original cam lesion model. As a result, it signifies the cam morphology height.

Febrio Lunardo

Motion Prediction in Magnetic Resonance Imaging guided Radiation Therapy (MRIgRT)

Collaborators: James Cook University, Townsville Hospital and Health Services

Magnetic Resonance Imaging guided Radiation Therapy (MRIgRT) hardware integrates the superior soft tissue contrast that MRI provides into a therapy. The efficacy of a treatment is limited due to intrafraction motion of internal organs. However, the introduction of MRI into RT hardware enables motion tracking and management in the treatment. This project aims at improving the accuracy and latency of motion estimation during treatment via the application of a Deep Learning (DL) algorithm. It is envisaged that the algorithm will be capable of compensating for latency in the MRIgRT system for responding to measured motion. This project will use data from the Townsville Hospital and Health Services' recently installed state-of-the-art MRIgRT hardware, the Elekta Unity.

The Health Services group

Group Leader: Mohan Karunanithi

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

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

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

Health Services' science and impact highlights for 2020–21

- An implementation trial of the M♡THer platform commenced in the Brisbane Metro South region for up to 2,000 pregnant women with gestational diabetes, to improve communication with their clinicians, enable self-management and timely intervention.
- The Smarter Safer Homes (SSH) platform completed a 12-months randomised control trial among 200 older people, to improve their quality of life and care through self-management and support from their aged care providers. A follow-up study using SSH assessing the needs of government-funded aged care home service packages, among 30 older people also finished. Both aged care trials implemented revised procedures to continue during the COVID-19 lockdown.
- The BabyCam trial to enable parents to monitor their pre-term infants was awarded the outstanding achievement at the Queensland Health Excellence Awards.
- A retinal imaging study investigating novel markers of hypertension (n=300) was completed. Preliminary analysis of correlation between fine vessel loss and hypertension mediated damage on kidney and large blood vessel, providing a capacity of non-invasive retinal imaging for cardiovascular risk.
- We completed the Activate TKR trial of mobile health for total knee replacement. The trial showed increased patient engagement with technology intervention when technology introduced in advance of surgical intervention.
- We added a COVID-19 screener to the CALD Assist app – with endorsement and considerable usage across NSW Health.
- The Health Services group had 36 publications, including in Nature Scientific Reports on the automated detection of age-related macular degeneration, and a journal paper on the outcomes of an innovative telemonitoring enhanced care program trial for chronic heart failure.

Artificial Intelligence in Tele-Health team

Team Leader: Shaun Frost

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

Health Internet of Things team

Team Leader: Qing Zhang

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

Mobile Health Systems team

Team Leader: Marlien Varnfield

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

Tele-Health Solutions team

Team Leader: Janardhan Vignarajan

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

Health Services: platform technologies

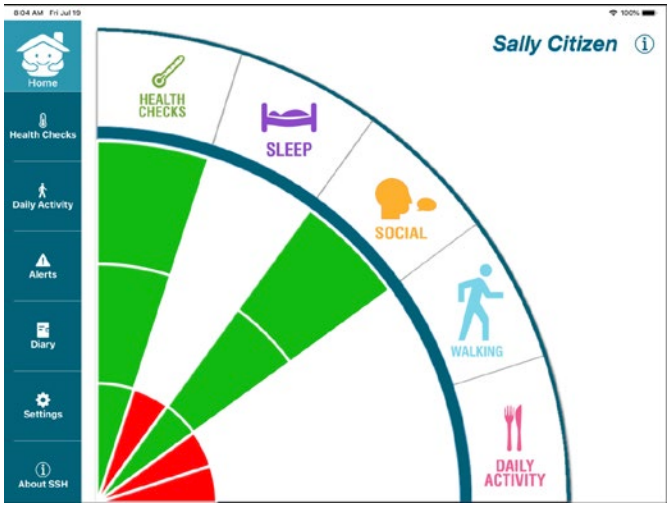
Smarter Safer Homes platform

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

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

The platform has been through several pilot studies since 2013, and has recently undergone 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 was effective at improving the quality of life of older residents, improvement of care by the service providers and 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.

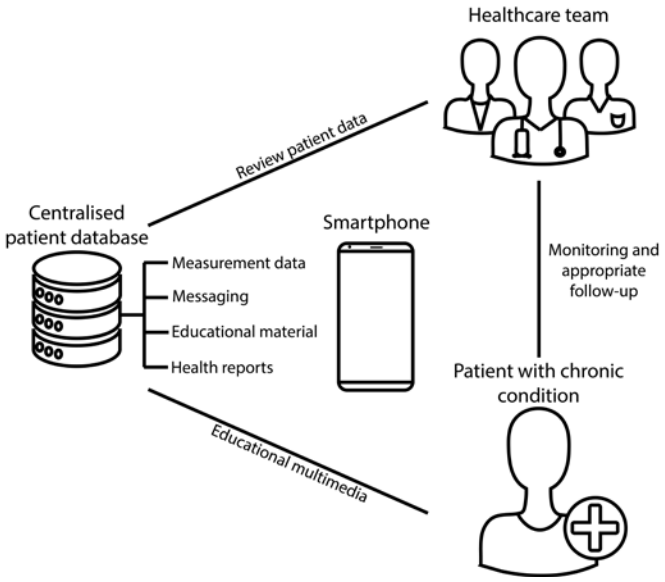


The SSH mobile application enables residents to view data derived from the sensors and medical devices.

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, has been 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 currently being evaluated in collaboration with our health service and industry partners. In addition to utilising the platform for self-management of existing health conditions, we have also developed a preventive smartphone application risk profiling matrix for chronic diseases.

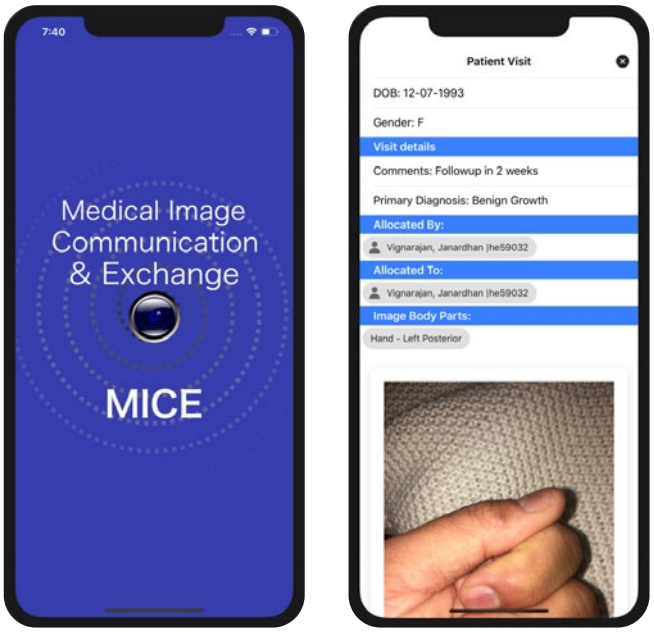


Components of the mHealth platform and data communication.

Medical Image Communication and 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 we are working with partners to deploy the technology in different clinical settings, such as burns ward rounds, plastics, emergency cases, radiology consent forms and home-based patient visits by nurses.



The MICE app image review.

Remote-I: store and forward telehealth platform

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

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

Health Services: project reports

M♡THer Studies

Collaborators: Metro South Hospital and Health Service (MSHHS), Mater Mothers' Hospital, Queensland Aboriginal and Islander Health Council (QAIHC), Western Queensland Hospital and Health Service in Cairns, and Mulungu in Mareeba.

Gestational Diabetes Mellitus (GDM) is a common complication during pregnancy. Increasing risk factors in the population and changes in diagnostic criteria are leading to increased prevalence of GDM in Australia. Antenatal clinics are under growing pressure to deliver 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. To date >1,500 women with GDM have used the app and clinicians and women indicated satisfaction and ease of use of the mHealth platform. Logan and Royal Brisbane and Women's Hospitals are soon to commence their participation in the implementation trial, expected to conclude at the end of June 2022.

We have also commenced a feasibility study to investigate how the solution can add value to wellbeing outcomes of Aboriginal and Torres Strait Islander peoples in Mount Isa, and 11 women with diabetes during pregnancy have been recruited to the study that aims to recruit 40 women. See Postdoc fellow project updates.

Future studies will see M♡THer being trailed for the management of hypertension during pregnancy in a randomised controlled trial at three South Western Sydney Local Health District hospitals in New South Wales. This also includes a PhD project that aims to assess the appropriateness, feasibility and effect of a Smartphone and Internet based system for the management of high blood pressure at two ATSICCHOs, Wuchopperen in Cairns and Mulungu in Mareeba. See PhD student updates.

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

Smart footwear for diabetes monitoring

Collaborators: e-Health Queensland and Mt Isa Hospital

An estimated 1.2 million (6 percent) of Australian adults are living with diabetes. One severe chronic complication associated with poor diabetic management is diabetic foot, where peripheral arterial disease (PAD) and reduced sensation from neuropathy can lead to infection, ulcers, and ultimately, amputation. Specialist foot clinics provide care for diabetic patients to intervene and treat any pathologies that arise as a secondary complication of diabetes. Management in foot clinics includes patient education, inspection, identification of infections, and wound care treatment as needed. Prior research has shown that infection and skin breakdown is preceded by increased local skin temperature and changes in pressure distribution, which may not be noticed by the patient due to neuropathy and inability or unwillingness to inspect.

Our Diabetic Foot Sensing System (DFSS) is a novel extra-clinical foot monitoring solution designed to non-invasively and continuously monitor physiological signals indicative of overall foot health during normal daily activities. The DFSS measures dorsal skin temperature on both feet using a medical-grade integrated circuit, and then transmits the sensor data wirelessly via Bluetooth to the user's mobile device. Importantly, the DFSS can be flexibly integrated into several different ergonomic configurations, such as a custom sock or sandal footwear, to accommodate individual user preferences and increase comfort and compliance. Along with activity data, the foot temperature data can be reviewed by either the patient or their treating clinician and changes to temperature or activity indicative of a possible ulcer formation can be flagged for follow-up or further inspection.

The DFSS was tested in a preliminary study at Mount Isa Base Hospital in May 2021. The study recruited five participants to use the DFSS in their preferred sensing configuration during a short, supervised instrumentation trial. The DFSS was well received by the participants, who indicated their interest in using such a device to increase their ability to self-manage their own foot health. Data collected during the trial was evaluated with clinical research staff to further refine the workflow and evidence towards future integration into standard care.

Activate TKR: Mobile health for total knee replacement

Collaborators: Johnson and Johnson Medical Devices

The Activate TKR project, sponsored by Johnson and Johnson Medical Devices, wrapped up this year. The project analyses and documents the effects of introducing a platform technology comprising of a patient focused mobile technology and wearable activity tracker to engage Total Knee Replacement (TKR) patients with their surgical journey and a clinical portal to provide remote monitoring functionality for clinicians. Patients (n=133) undergoing total knee replacement surgery using the ATTUNE® prosthetic were selected from nominated hospital lists. The impact of the use of the platform was analysed using a wide range of health and wellbeing outcomes. Data was also recorded from the platform used in the trial, and questionnaires and interviews were conducted.

The platform deployed in this study was designed in conjunction with Australian TKR patients and clinicians to enhance two-way communication between them, to inform and support patients in their TKR journey and to support self-monitoring and participation in health outcomes. A minimal viable product (MVP) was developed by a Sydney based software development company. A three and a half year, multi-state trial was conducted.

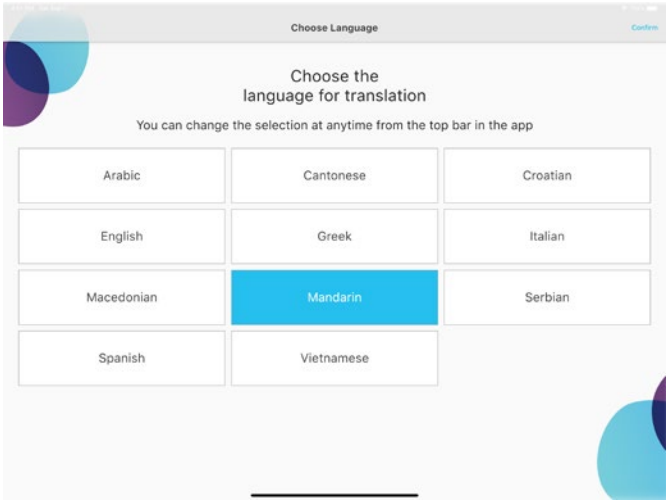
The platform was shown to be successful in increasing patient engagement with at home physiotherapy in comparison to the control group, with the highest impact achieved with the app was provided to patients in the weeks prior to surgery. Similarly, a significant difference in empowerment and general health perception between the groups in favour of the intervention group were recorded when the app was provided to patients in advance of surgery. Empowerment is acknowledged as a critical component in engaging individuals with their health and their participation in healthcare decisions.

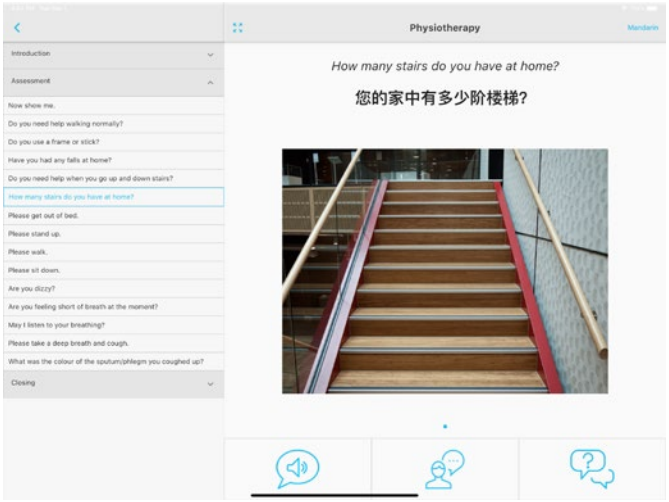
CALD Assist

Collaborators: Western Health

The CALD Assist communication app was developed in partnership with Western Health and designed for use with patients from culturally and linguistically diverse (CALD) backgrounds when interpreters are not available. The free app, endorsed by NSW Health, ensures all clinical staff can deliver safe, high-quality care to a potentially at-risk and vulnerable population, reducing inequity in healthcare delivery.

The development of the app (for both Android and iOS) involved a range of clinicians and professional interpreters from across the required languages and health domains. The inclusion of clinical staff and medically accredited interpreters ensured the app addressed inter-cultural communication sensitivities that are critically absent in automatic web-based text translations. The languages included in the app are largely reflective of the common languages identified in the Australian Census (2011) as well as the specific needs of the hospitals where it's been trialled: Mandarin, Cantonese, Vietnamese, Italian, Greek, Macedonian, Serbian, Croatian, Arabic and Spanish.





In the last 12 months, the app was enhanced with a COVID-19 screener ensuring health authorities could ascertain critical information from people from non-English speaking backgrounds, and deliver key health messaging about recommended behaviours, restricted movement and testing to ensure CALD groups receive appropriate messaging and instructions to keep their communities safe. CALD Assist received public praise from Victorian Minister for Health Martin Foley who congratulated Western Health and CSIRO for innovating through the pandemic and finding new ways to support culturally and linguistically diverse patients. The updated CALD Assist app was then released nationally and in English-speaking regions and has had over 4,400 individual downloads in the last 12 months.

Research has shown that the app effectively improves staff communication with patients from non-English speaking backgrounds and in April 2021 CALD Assist was endorsed by the NSW Ministry of Health and NSW Multicultural Health Communication Services to be used across NSW Health to support patient-staff communication, particularly with COVID-19, allied health clinicians and nursing staff. Early reports from NSW Health suggests that CALD Assist is creating a more inclusive environment, where communications with CALD patients improves, reducing stress and frustration in both staff and patients.

Smarter Safer Homes: DACS Trial

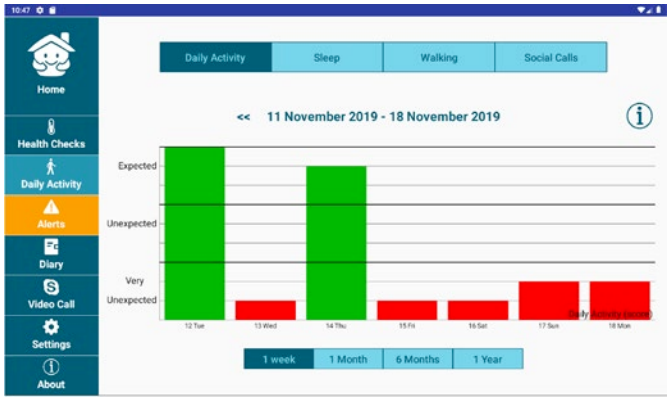
Collaborators: Anglicare Southern Queensland, integratedliving Australia, All About Living

This trial was a single-blind, stratified, randomised controlled trial. The trial was conducted in two geographical areas, one metropolitan and one regional. The setting was home-based, with participants living in their home, in the community. The trial involved partnership with three Aged Care Service Providers (ACSP), listed above, that delivered aged care services to metropolitan and regional areas around Brisbane.

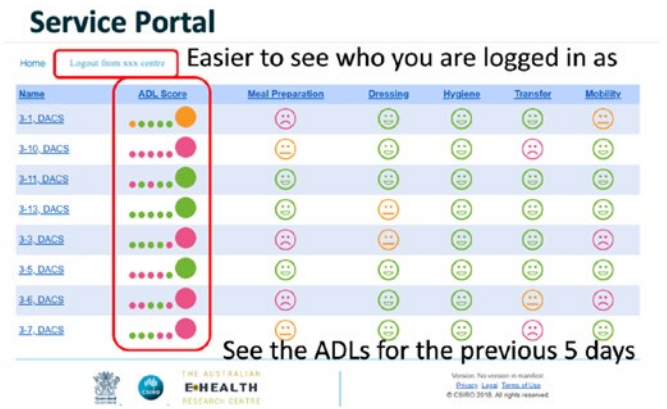
The key research question of this trial was whether implementing smart home technology-enabled self-management and care delivery could maintain or improve the impact of care provided by the ACSPs to older persons living independently in their own homes.

Selection of trial participants included 200 individuals, aged 65 years and older, recruited through the ACSP partners. Participants were then randomly allocated into the control group or the intervention group. The intervention was using the Smarter Safer Homes (SSH) platform to assist the ACSPs to monitor and provide timely support to their clients in the community for a period of one year. The trial outcomes were evaluated by Impacts of Community Care for Older People (ACCOM measure), Quality of life (EQ5D 5-L survey), Activities of Daily Living (Katz ADL), Instrumental activities of daily living (Lawton iADL), Depression (Geriatric Depression Scale), care giver burden (Zarit ZBI-12), and health service utilisation (PBS, MBS data, Queensland Health Linkage Data and ED data sources).

The trial recruited its first participant in April 2019, and finished its data collection of the last participant, in November 2020. The trial received participants' clinical service data from government data resources in June 2021. Survey data was collected from participants at the beginning of the trial, as baseline data and subsequently at two follow-up time periods. Those were mid-trial (at six month) and end-trial survey (at 12 month). Sensor data was transferred to the in-home Internet of Things (IoT) router and then collected directly to CSIRO's secured sever. Data on the burden experienced by carers of the persons participating in the trial were collected at the end of the trial during semi-structure interviews. Health service utilisation data was collected from the Department of Health and QUEENSLAND Hospital services.



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



The SSH service portal, showing how timely interventions can be initiated when a participant's ADL score does not meet expectations.

Smarter Safer Homes: CHSP Trial

Collaborator: Anglicare Southern Queensland, integratedliving Australia

This was an observational cohort study with a novel Commonwealth Home Support Program (CHSP) model being piloted and evaluated among older aged participants. CHSP funding provides entry level, community based, aged care services to support continued independence for people aged 65 and over living at home. The study was conducted in partnership with two Aged Care Service Providers (ACSP). This project aimed to develop a novel consumer-centred and on-demand aged care service delivery model of CHSP. This project used the Smarter Safer Homes (SSH) platform to gain an understanding of whether the most suitable CHSP services had been allocated to the recipients.

Selection of study participants included 30 to 50 individuals, aged 65 years and older, living in metropolitan areas of Queensland, Australia. Implementation of the SSH Kit (tablet, hub, sensors) was coordinated by a CSIRO project officer. The system works by gathering 14 days of baseline data after being installed in the home. After the baseline had been gathered, the system remained running in the participant's home for a further 1.5 month period. Changes in quantity and type of services provided were estimated based on a review and comparison of the goals of care, as per the participant's Care Plan at baseline and upon completion of the study.

A digital profile was obtained after the 14 day baseline period, at which time the goals of care were compared to the observations of the SSH portal data. Opportunities to change the goals of care were identified at this time, in discussion between the participant and their ACSP. At the end of the trial, a comparison of care plan changes and digital profile changes was made. The user interviews also sought to understand the outcome of changes to plans.

At the end of the trial, results demonstrated that both participants and service providers saw benefits of the consumer-centred model and associated CHSP plan review based on their digital profiles. ACSP used the daily objective ADL scores to provide on-demand services to older people. This not only helped participants, but also provided valuable feedback to ACSPs about changes of participants' health and welling status and their needs.

Finally, in this study, we tested the feasibility of self-installation of the SSH platform. We evaluated the sensor hardware errors and sensor data quality after self-installation. Compared against data acquired from previous similar trials where the SSH platforms were installed by CSIRO Project Officers, we found insignificant difference between the number of hardware issues and the percentage of incorrect sensor firings. This demonstrated that self-installation of the SSH platform is feasible by older people and/or their family members and can thus be easily deployed in Australian families.

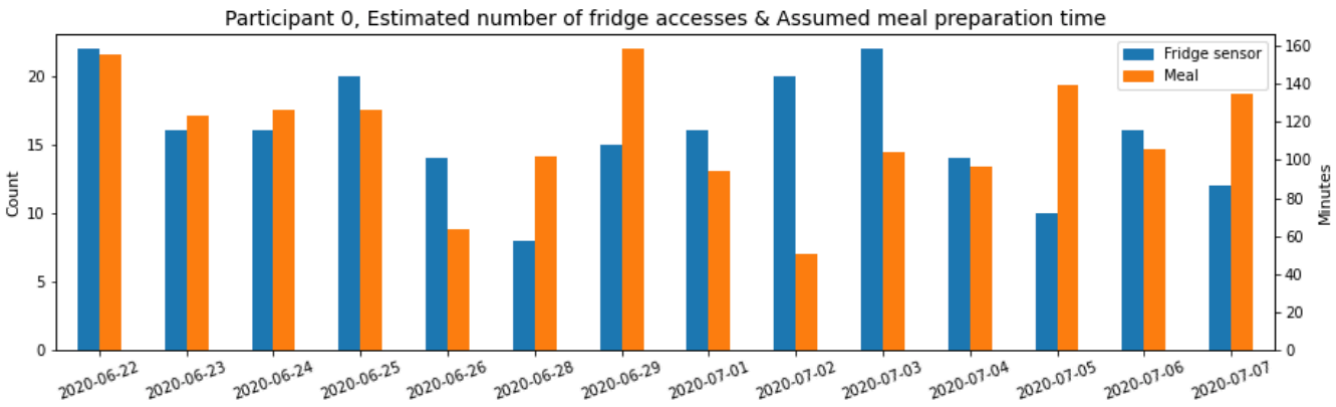
Retinal imaging in hypertension

Collaborators: Royal Perth Hospital, Doheny Hypertension Centre

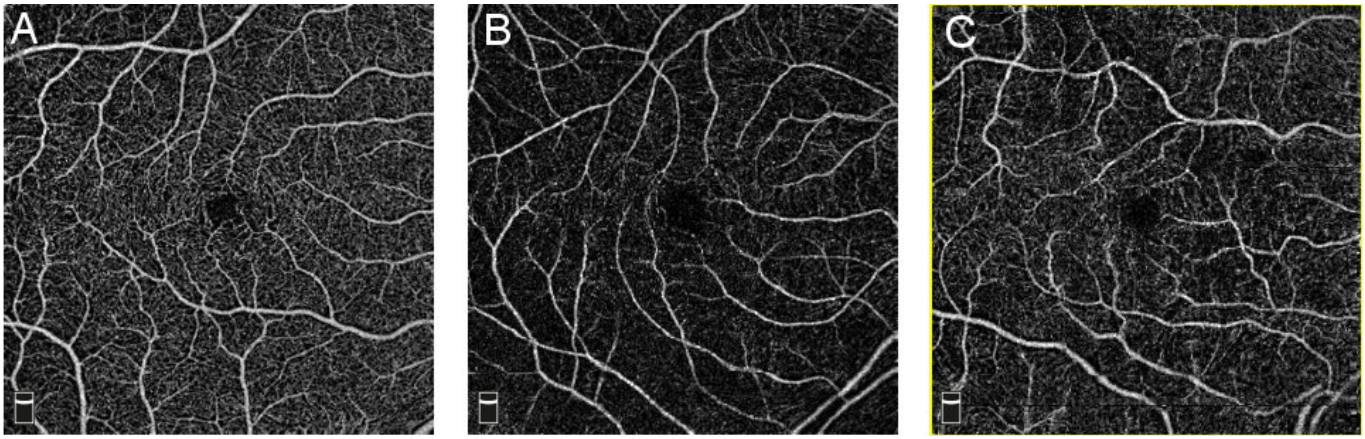
Funding: Department of Health WA

Hypertension (high blood pressure) is a risk factor for many disorders and increases the risk of heart attack and stroke. Through its effects on the vasculature it damages many organs, including the heart, kidneys and the retina at the back of the eye. Early detection and monitoring of these changes are critical to the management and treatment of hypertensive patients.

Physicians have already used hypertensive retinopathy (signs of damage to the retina due to hypertension) to predict risk of stroke, cardiovascular disease, and even mortality. As a result, the assessment of hypertensive retinopathy appears in clinical guidelines for the management of patients with hypertension.



Meal preparation time and fridge access times in the resident's digital profile, observed by the SSH platform



Superficial macular OCT-A image samples demonstrating differences in capillary density.

Mild hypertensive retinopathy signs, such as generalised and focal retinal arteriolar narrowing and arteriovenous nicking, are weakly associated with systemic vascular diseases. On the other hand, moderate hypertensive retinopathy signs, such as isolated microaneurysms, haemorrhages and cotton-wool spots, are strongly associated with subclinical cerebrovascular disease and predict incident clinical stroke, congestive heart failure and cardiovascular mortality. These data support the concept that an assessment of retinal vascular changes may provide further information for vascular risk stratification in persons with hypertension.

However, retinopathy occurs after substantial hypertensive damage has already occurred. Recently developed retinal imaging technology allows us to now image the finest retinal vessels, providing an opportunity to detect signs of organ damage much earlier. Recently developed optical coherence tomography angiography (OCT-A) now allows investigation of the fine retinal capillaries, which may provide a superior marker of overall vascular damage due to hypertension.

We recruited 300 hypertension patients from Royal Perth Hospital for OCT-A and colour retinal photography. The study discovered associations between loss of fine vessels in the retina and hypertension mediated damage to the kidney and large blood vessels of the body.

Non-invasive retinal imaging may provide a measure of the integrated blood pressure burden a patient has been exposed to at any given time and provide a simple, inexpensive test for accurate prediction of cardiovascular risk. Longitudinal assessment and the corresponding changes in retinal markers may also serve as an indicator of adequate or inadequate anti-hypertensive treatment. We hypothesise that inclusion of retinal imaging will add substantially to risk stratification of hypertensive patients, better management resulting in improved outcomes and may be useful to assess therapeutic efficacy with serial imaging over time.

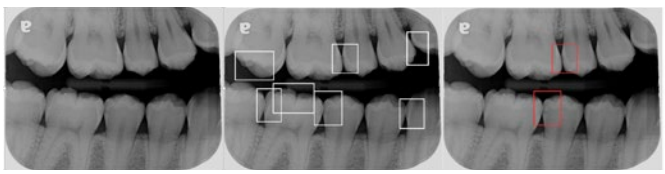
Artificial intelligence analysis of dental images and radiographs

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

Early detection and accurate diagnosis of tooth decay are essential for timely treatment decisions and improved oral health outcomes. Detection of tooth decay in the early stages is challenging as it may not be visible during a dental examination and can be difficult to detect by trained human eyes in radiographs. Radiography is a vital adjunct for diagnosing tooth decay, but digital radiography is no more accurate than traditional radiographic methods. In recent years, artificial intelligence (AI) methods such as deep learning have demonstrated a great promise to detect, segment, and classify lesions on medical images. We worked with partner clinicians at the Royal Perth Hospital to develop and train convolutional neural networks (CNNs) for tooth numbering and decay detection in a set of panoramic and bitewing radiographs.

The study's findings demonstrated that the tooth detection module had achieved a recall, precision and F1 score of 0.98 for tooth numbering on panoramic images. The caries classification module achieved a sensitivity, precision, and F1-score of 89 percent, 86 percent and 87 percent, respectively, in detecting dental caries on bitewing images.

The proposed automated system can be deployable at oral health facilities to enable early detection of tooth decay, support the clinical decision of dentists, and reduce the time associated with reading oral radiographs and completing dental charts manually. Also, this will contribute to improved workflow and clinical service efficiency.



The image on the left-hand side represents sample input to the CNN. The image in the middle demonstrates region of interests produced by the Faster R-CNN. The image on the right-hand side represents the final output generated by the caries classification system based on the Inception-V2 network.

Automated detection and classification of early age-related macular degeneration biomarkers

Collaborator: Doheny Eye Institute, University of California, Los Angeles, USA

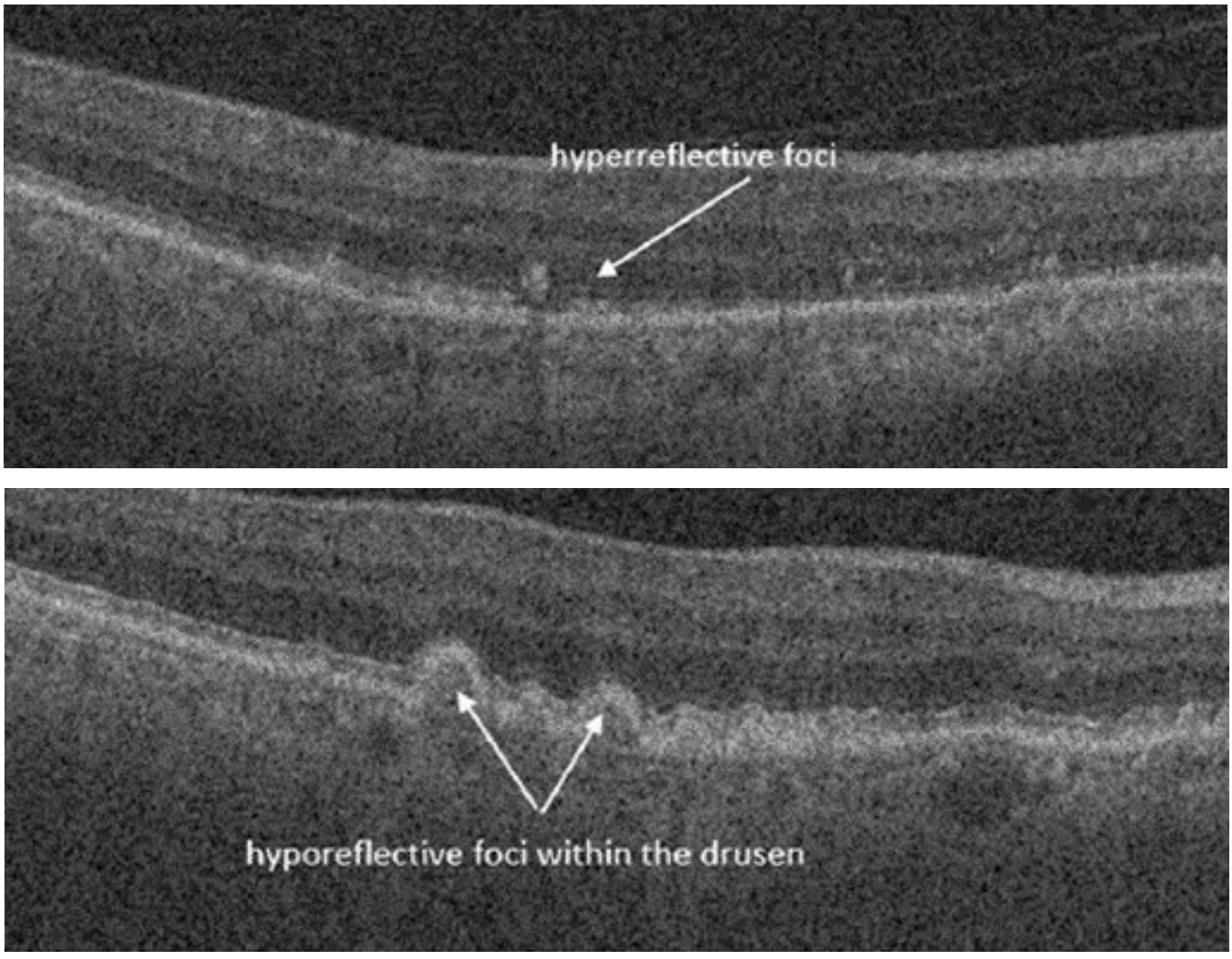
Age-related macular degeneration (AMD) affects millions of people and is a leading cause of blindness throughout the world. Ideally, affected individuals would be identified at an early stage before further progression leads to irreversible loss of vision. However, accurate and precise staging of AMD, particularly using newer optical coherence tomography (OCT)-based biomarkers is time-intensive and requires expert training, which is not feasible in many circumstances including in screening settings.

CSIRO together with Doheny Eye Institute have developed a method for the automated detection and classification of an early AMD OCT biomarker.

Deep learning models (convolutional neural networks, CNN), were trained for automated detection and classification of hyperreflective foci (see Figure below), hyporeflective foci within the drusen, and subretinal drusenoid deposits from OCT B-scans.

For each of the pathology types we trained a different CNN, namely Inception-v3, ResNet50, and InceptionresNet50. Pre-segmentation of the retinal layers was performed using the ReLayNet CNN and then 11 different CNN training approaches were tested, each fine-tuning different proportions of the CNN layers. A total of 19,584 Spectral domain (SD)-OCT B-scans of 153 patients, who were diagnosed with early or intermediate AMD in at least one eye, were used for training and testing the CNNs (random 10 percen selected for testing).

An overall accuracy of 87 percent for identifying the presence of early AMD biomarkers was achieved. Given the increasing burden of AMD on the healthcare system, the proposed automated system is highly likely to perform a vital role in decision support systems for patient management and primary care-based screening approaches for AMD.



Examples of hyperreflective foci (A) and hyporeflective foci in drusen (B), from optical coherence tomography imaging.

Wrist fracture detection in radiographs

Collaborator: Fiona Stanley Hospital

Emergency Departments (EDs) are consistently inundated by a plethora of medical conditions, and with a limited number of medical resources available at any given time, many conditions are left un/mis-diagnosed. Musculoskeletal bone fractures are one of the most poorly diagnosed conditions in EDs, due to a variety of factors such as the chaotic ED environment, lack of specialist orthopaedics and/or radiologists on-hand, poor diagnostic equipment, inexperienced junior doctors, as well as the complex nature of interpreting patient radiographs with hairline fractures. Practitioner fatigue due to long and/or odd hours and a surplus of patients resulting in shorter analysis times have also been postulated as major contributors. In particular, wrist fracture symptoms being presented to EDs are an extremely common occurrence.

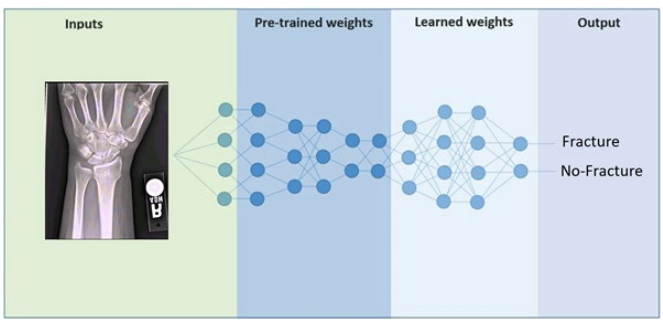
With the recent emergence of highly accurate artificial intelligence (AI) algorithms, especially convolutional neural network (CNN), automated image analysis has been proposed as a possible solution to aid in the computational diagnosis of musculoskeletal bone abnormalities, including fractures in wrist radiographs.

In this we performed feasibility study of CNN-based wrist fracture detection using radiographs at the Emergency Department. In this project we trained and validated different state-of-the-art CNNs in the context and critically analysed their respective performance.

Transfer learning approach to detect wrist fracture.

In this pilot study we did experiments involving two different datasets and three different state-of-the-art CNNs to analyse the feasibility of CNN-based wrist fracture detection at the emergency department. For each CNN in consideration we experimented on 11 different setups and identified the best setup in the context. Transfer learning was used to train the CNNs.

On the FSH dataset we achieved an accuracy between 82~85 percent by the three different CNNs when cropped images were used. Accuracy decreased by 8~12 percent when original FSH images (without cropping) were used. On the MURA dataset we achieved accuracy of 84~85 percent. Though, all of the three CNNs produced similar results, Inception and ResNet were found to be more consistent in comparison to DenseNet.



These findings are in line and comparable with the findings in the literature. In future we would like to experiment on more data. We would also like to critically analyse the heatmaps produced by the CNNs and compare that with the bounding box provided by the experts.

A roadmap to inform a digital robotics strategy for Queensland Health

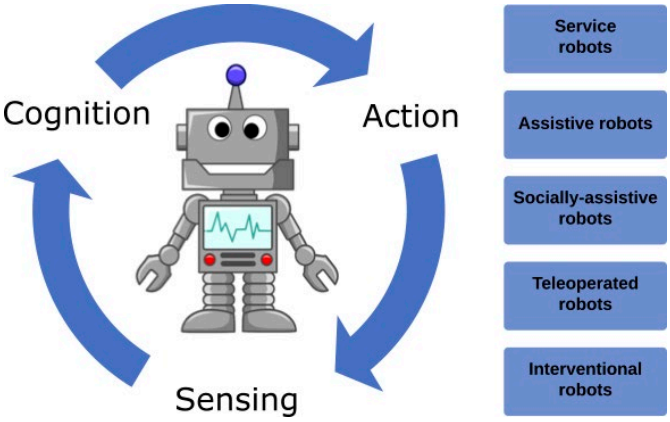
Collaborator: eHealth Queensland

Global trends indicate that patients are getting older and sicker. With increase demand healthcare workers face increasingly hazardous work environments and are themselves at greater risk of debilitating injury and disability. Robotics technologies in healthcare have the potential to enable high levels of patient care, clinical productivity and a safety for both patients and healthcare workers. This presents new opportunities to develop a strategic approach to the roll-out of robots in the Australian health system.

This project's main objective was to chart key opportunities and considerations for the implementation and long-term adoption of robots in healthcare, to inform the development of a new digital robotics strategy for Queensland Health. This study was conducted via semi-structured interviews with staff members from Queensland Health.

In the final report, applications of robotics were grouped into the five main areas of application: service, assistive, socially-assistive, teleoperated and interventional robots. Participants were particularly interested in systems that support clinicians rather than exclude or replace them, and that can provide quick and tangible benefits. Short-term opportunities were identified in service, socially-assistive and telepresence robots.

Since the overall sector of robotics in healthcare is still an emerging area, it is difficult to make a final conclusion about the future trajectory. Nonetheless, this report identifies the main drivers, challenges, applications and key recommendations to the implementation of robots in healthcare to maximise quality, acceptability and safety of the technology.



Robotics in Healthcare.

Health Services: project updates

Health-e Minds

Collaborator: Sunshine Coast Hospital and Health Service

We developed and evaluated a digital technology platform designed to support patients with serious mental illness (SMI), and to enhance multidisciplinary care provided by their treating clinicians. Novel to the platform is a farm game component that rewards patients, using their measured activities (as measured by the app) against goals set in consultation with their clinician through the clinical portal.

Recruitment of patients aged 18 years and older, with confirmed SMI, commenced in October 2019 and follow-up of the 17 participants recruited concluded in early 2020. Due to the small sample size, no significant changes in health-related quality of life and wellbeing could be reported. However, user satisfaction and acceptance were high. This supports the evidence that mHealth platforms are well accepted and feasible to use by people with a diagnosed mental illness. Greater understanding is needed to address the barriers in recruitment and uptake within the health system.

Stroke rehab

Collaborator: Monash University

Few individuals who experience a stroke or Transient Ischemic Attack (TIA) attend a secondary prevention or rehabilitation program. Novel strategies to facilitate secondary prevention which meets the needs of clinicians and patients are needed. We collected feedback from clinicians and patients on their experience, interest and perceived benefits in using digital technology for secondary prevention of stroke.

Overall, 110 consumers and 78 clinicians completed a survey (18 nurses, 17 doctors, 16 physiotherapists, 12 occupational therapists and 15 other professionals). Most clinicians indicated the importance of monitoring health and lifestyle measures more frequently than what currently occurs in practice, particularly physical activity, weight and sleep. Most consumers and clinicians agreed that monitoring lifestyle and health measures and providing automatic alerts about potential deterioration in the individual's condition were the preferred functions for a digital program.

m-Health program for chronic obstructive pulmonary disease (COPD)

Collaborator: The Prince Charles Hospital

Chronic Obstructive Pulmonary Disease (COPD) affects one in seven Australians over the age of 40 years. The management of COPD relies on patients self-managing their conditions based on a COPD action plan outlined by the national guidelines and prescribed by COPD clinicians. Patients adherence to self-management has been shown to be sub-optimal. Also, clinicians adherence to the national action plan has also been limited. To address this, the AEHRC and the Prince Charles Hospital (TPCH) developed a mHealth solution that integrates the COPD action plan to support clinician delivery of COPD management and enable patients adherence to their self-management. The mHealth COPD platform features a smartphone app for patients at home to review educational videos, monitor COPD symptoms and risk factors.

To evaluate the effectiveness of mHealth COPD intervention to support the management of COPD according to the action plan guidelines, TPCH and AEHRC undertook a randomised control trial in late 2019. The patient recruitment was halted in 2020 due to COVID-19 but resumed in 2021 and is expected to complete by July 2022.

Rehabilitation for pulmonary disease (m-PR)

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

m-PR is a Mobile Pulmonary Rehabilitation digital solution being tested to determine, in people with COPD, if the remote program results in equivalent outcomes as face-to-face programs. The outcomes under investigation are improvements in quality of life, symptoms, psychological status, daily physical activity levels, and uptake and completion of a pulmonary rehabilitation program. The m-PR platform has been finalised and has now entered the research phase with three research projects:

i) Evaluation of text messages to support improved COPD self-management. Seventy-five people with COPD have provided feedback on text messages with data currently being analysed.

ii) Patient and clinician user testing of m-PR. There have been 12 participants with COPD and five clinicians recruited through five sites with the aim to recruit 30 participants.

iii) Results from ii) will inform a clinical trial (n=100) to evaluate effectiveness of m-PR compared to centre-based pulmonary rehabilitation, to commence early 2022.

Child health: post-concussion management

Collaborator: University of Queensland

Thirty-six to 63 percent of patients and families with paediatric concussion do not receive information upon discharge from emergency departments and even if they do, the discharge information may omit key facts, be out-of-date, or have scant information about post-concussive symptoms (PCS). This represents a significant exclusion of patients without adequate knowledge of PCS given that up to 25 percent of paediatric cases have PCS for more than a month following injury.

In partnership with the University of Queensland (UQ) Acquired Brain Injury in Children (AbiC) program, we developed a technology-assisted clinical care program for post-concussive symptoms following a concussion injury. To date there were 37 enrolments for the app (four children and the rest parents). Preliminary data shows that users are not using the app for the whole intervention period of 12 weeks and the team is investigating ways of improving adherence. Responses to a Satisfaction with Care survey might provide direction for future adherence improvement.

Wearable sensors for early detection of cerebral palsy

Collaborators: Queensland Cerebral Palsy and Rehabilitation Research Centre

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

We have developed a suite of small wearable sensors to measure infant movements and track their longitudinal progression. In the past year, we completed an initial study with infants recruited from the Queensland Children's Hospital and Royal Brisbane and Women's Hospital to track movement development from 12–18 weeks corrected age. With some COVID-19 delays, we are looking to recruit additional infants at high-risk of Cerebral Palsy from sites across Southeast Queensland to investigate the feasibility of in-home wearable sensor assessments.

HAPPI MIND

Collaborator: Monash University

Dementia is a major cause of morbidity and mortality globally. The progressive nature of dementia means people have an increasing reliance on health and aged care services including doctor and allied healthcare visits, hospital admissions, and use of residential care facilities. There is currently no disease-modifying treatment for dementia, but appropriate prevention, intervention and care is essential to help minimise the current and future emotional, physical and financial burden of dementia.

Primary care is an ideal setting for the implementation of dementia prevention programs in Australia. In this setting, middle-aged adults with high risk of developing dementia (e.g. those with cardiovascular risk factors, diabetes, depression, obesity) can be identified early, and targeted education, management and referrals can be organised. This study aims to evaluate the effectiveness of a multi-domain intervention (HAPPI MIND) for assessing dementia risk and reducing dementia risk factors in middle-aged adults in the primary care setting.

Climate safe rooms

Collaborator: Geelong Sustainability Group

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

The pilot finished installation of Climate Safe Rooms for 14 residents in the City of Greater Geelong region by June 2021. By the end of 2022, we will have collected sensor data from these 14 homes through the SSH platform, trialled a variety of delivery methods and captured key learnings to prove that Climate Safe Room concept is effective. This will enable the scoping pathways for future project delivery at scale.

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

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

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

EMFIT Quantified Sleep (QS) sensor.

In accordance with the above study, a pilot study was completed at the Prince Charles Hospital (TPCH) Sleep Sciences Lab to validate the EMFIT sleep measurements against polysomnography (PSG). Analysing data collected from 33 sleep lab patients showed that a consensus between PSG and EMFIT QS was found in sleep onset latency and average heart rate. There was significant discrepancy and lack of consensus in other sleep outcome measures.

My Garden: a gamification app to engage smart home residents in ground-truth data acquisition

Collaborator: CSIRO Data61 and Queensland University of Technology

The Smarter Safer Home (SSH) platform, developed and tested by CSIRO, is a promising approach that could help support independent living of older adults. However, the data collected through this platform could be noisy and not reliable. Older adults can help this technology to perform more effectively and efficiently by self-reporting their activities of daily living. We developed "My Garden", as a solution to facilitate ground truth data acquisition in the SSH platform.

This project evaluated My Garden through a user experience study and investigated how older adults interact and engage with My Garden. Data was collected from 10 participants (65–85 years old, seven females) across Australia through a hybrid qualitative-quantitative approach. Overall, most participants were able to adequately carry out My Garden tasks, and many reported being motivated by the study's aims to continue using the game.

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

Collaborator: CSIRO Mineral Resources, University of Queensland

Falls and falls-related hospitalisation remain particularly common among seniors aged 65 years and above. A pressing need exists for techniques that can help reducing harms from falls through automatically monitoring, alerting professionals, carers and family members to get timely interventions. In this study, we propose the use of the Ultra-Wide Band (UWB) Sensor to address this issue. The sensor prototype used in this study was developed by CSIRO Mineral Resources research team.

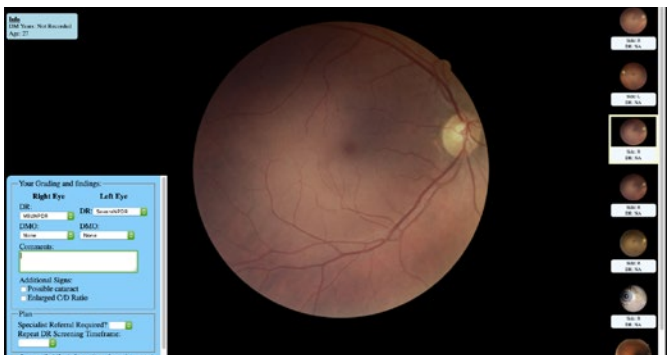
The success of this case study will encourage future commercial development of fall detection sensors to be used in aged care facilities, hospital wards, and home environment. In the past 12 months, we finalised the trial protocol, obtained ethics approval, and conducted data collection trial from simulated falls. In total, 1,200 equal samples of fall and ADL events were collected from 10 participants. Application of three deep learning models demonstrated an accuracy of over 90 percent in classification of falls and non-fall events.

Remote eye care delivery in northern Australia

Collaborator: Queensland Health, Laynhapuy Homelands Aboriginal Corporation and Marthakal Homeland and Resource Centre Aboriginal Corporation

The project is funded by CSIRO and Cooperative Research Centre for developing Northern Australia and additional in-kind contributions from project partners. The primary project objective is to identify factors around the successful implementation of service delivery for diabetic retinopathy management in remote communities in northern Australia using telehealth technologies. This service delivery involves connecting metropolitan-based ophthalmologists with remote health clinics via telehealth to prevent the leading cause of preventable blindness in working-aged people.

In 2020–21 we successfully developed and deployed the screening technology in the cloud and as of June 2021, 163 clinical exams have been diagnosed by ophthalmologists from seven community sites. The telemedicine platform (Specialist review screen is shown) has gone through rigorous cybersecurity hardening processes to mitigate security and privacy risks. The platform provides seamless integration of retinal cameras into the clinical workflow.



Retinal image reconstruction in optical coherence tomography

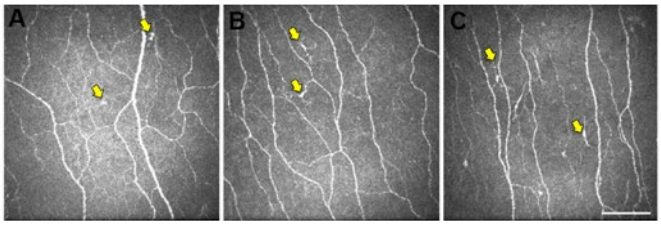
Collaborator: Queensland University of Technology (QUT), QUT Contact Lens and Visual Optics Laboratory (CLVOL)

Speckle noise is an inherent limitation of optical coherence tomography (OCT) images that makes clinical interpretation challenging. The recent emergence of deep learning techniques could offer a reliable method to reduce noise in OCT images. In this project, we investigate the application of OCT image reconstruction/denoising employing deep learning techniques. We sought to investigate the use of deep features (VGG) to limit the effect of blurriness, increase perceptual sharpness and evaluate its impact on the performance of OCT image denoising (DnCNN). Currently, we are investigating the use of deep neural networks to denoise Imperceptible OCT images for results to be comparable with 'gold standard' averaged OCT images. The network training and results are completed and we are in the process of publishing the work and getting expert feedback from our collaborators.

Ocular biomarkers for Alzheimer's disease

Collaborator: University of Melbourne

There has been increasing interest in identifying non-invasive imaging biomarkers for neurodegenerative disorders. The aim of this proof-of-concept study was to investigate whether corneal sensory nerve and dendritic cell (DC) parameters, captured using in vivo confocal microscopy (IVCM), are altered in individuals with mild cognitive impairment (MCI) and Alzheimer's disease (AD). Corneal DC field area and perimeter were greater in individuals with MCI, relative to CN controls, in both the central and inferior whorl regions ($p < 0.05$ for all comparisons). In addition, corneal DCs in the whorl region of MCI eyes had lower circularity and roundness indices and a higher aspect ratio relative to CNs ($p < 0.05$ for all comparisons). There was a trend toward lower quantitative parameters for corneal nerve architecture in the AD and MCI groups compared with CN participants. This study is the first to report morphological differences in corneal DCs in humans with MCI.



Representative central corneal IVCM images. Images of the central corneal sub-basal nerve plexus from participants in the CN (A), MCI (B), and AD (C) groups. The epithelial DCs (yellow arrows) are smaller and less stratified in CN eyes (A) relative to the larger more stratified morphology of DCs in MCI and AD eyes. Scale bar: 100 um, applied to all images.

Whole slide image showing different region of interest.

Artificial intelligence for diagnosis of prostate cancer in whole slide imaging

Collaborator: Ai4Path

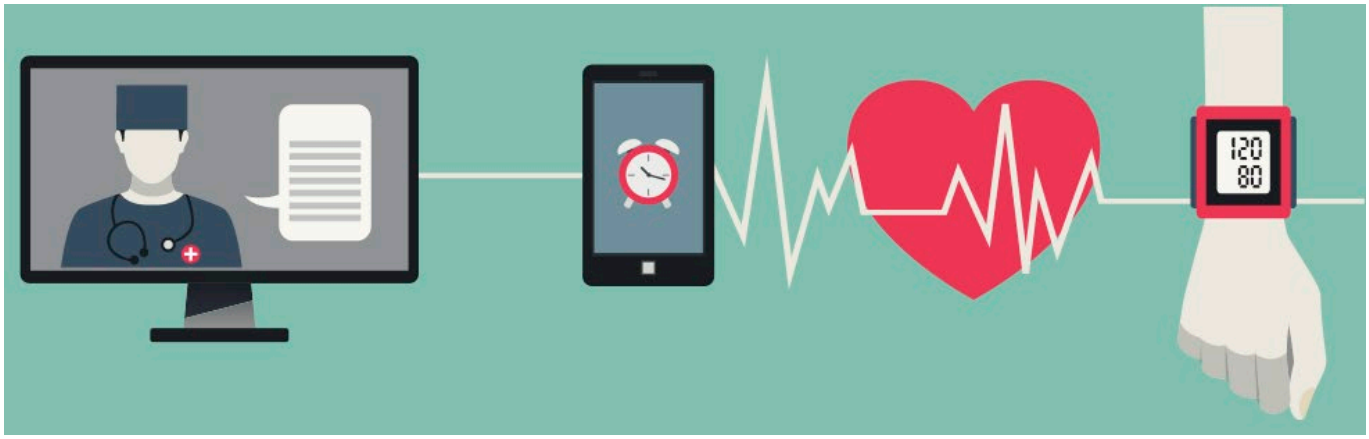
The project aims to develop an AI-based system for automated diagnosis of prostate cancer. Deep learning model will be trained to classify the whole slide imaging (WSI) slices into 'cancer' and 'normal' categories. Transfer learning will be used to train the deep learning model. A heat map that shows the cancerous regions in the slice will be produced. The outputs produced by the AI system will be critically analysed with respect to human experts' diagnosis.

Primary endpoints: Development and performance analysis of CNN-based method for diagnosis of prostate cancer in whole slide imaging. In this work we aim to achieve sensitivity and specificity of more than 90 percent.

Convolution neural network (CNN)-based approach for segmentation of diabetic foot and wound

Collaborator: CSIRO Chile

The project aims to develop an CNN-based system for automated segmentation of diabetic foot and wounds. Transfer learning will be used to train the deep learning models. The output of the system will be binary masks representing respectively the foot region and wound regions in the image. Bounding boxes containing the regions of interest (i.e. foot and wounds) will also be shown.



Digital platform to support secondary prevention of stroke

Digital care assessment and support platform for people after stroke or transient ischaemic attack

Collaborator: Monash University

This project aims to develop a novel digital support platform to address secondary prevention of stroke and heart disease for individuals returning to the community after stroke or transient ischaemic attack (see image above). As part of this project, we collected feedback via surveys, focus groups and interviews from 78 clinicians and 110 patients on their experience, interest and perceived benefits in using digital technology for secondary prevention of stroke. Most clinicians (94 percent) indicated the importance of monitoring health and lifestyle measures more frequently than current practice. Consumers and clinicians also agreed that monitoring lifestyle and health measures, and providing alerts about potential deterioration in the individual's condition were the preferred functions for a digital program. The digital platform will be completed in the coming year.

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

Collaborators: Queensland University of Technology, Autism Hub

The aim of this project is to evaluate the effects of humanoid robot-assisted interventions on the story retelling skills of school-age children on the autism spectrum. This project is funded by the Autism CRC. The expected outcomes include a guide for teachers and schools planning to implement robot-assisted interventions for supporting story retelling learning activities with children on the autism spectrum. This project is conducted through a mixed-method design, using a humanoid NAO robot (Fig 1). Over the past 12 months, we completed recruitment, data collection and analysis. The final report will be completed in the coming year.

SoftBank Robotics' Humanoid robot NAO.

Robotics in aged care

Collaborator: Healthovation Pty Ltd

The potential of autonomous and semi-autonomous robots in aged and residential care is vast. Robots can provide physical support, information, entertainment and interaction opportunities. They can assist with daily activities, reminders and navigation, helping people to remain independent for longer, reducing the need for hospitalisation and care homes, with benefits to both patients and healthcare workers.

The aim of this project is to assess the current standing and expectations of robotics in the Australian residential care sector, as well as the gaps and opportunities where robots could be incorporated. Priority areas for the introduction of robots in residential care will be identified.

Interchange determination of behaviour health framework

Collaborator: CSIRO Data61 and Nutrition

The management of many chronic diseases and age-related conditions rely on self-management and adherence to lifestyle changes and medical interventions. In most cases, there is a lack of uptake and adherence to self-managed interventions. This is, in part, due to interventions being a one-fits-all approach. The aim of this project is to enable a more individualised model of care via personalised interventions. To do this, we conducted a study to identify the correspondence of personality traits and behavioural change techniques (BCTs) commonly used in behaviour change interventions. Outcomes from this study will inform a future study to investigate the efficacy of personalised behaviour change interventions in promoting physical activity in healthy adults.

Health Services: postdoc and student highlights

Postdoctoral fellows

Dr Mohamed Estai, AEHRC

Development and validation of deep learning system for oral imaging diagnostics

Detection of tooth decay in the early stages may not be visible during dental exams and difficult to detect on oral radiographs. We proposed to develop and validate convolutional neural networks (CNNs) for tooth numbering and decay detection in a large set of panoramic and bitewing radiographs. The proposed automated method can support the clinical decision making to detect tooth decay, and reduce the time for reading oral radiographs and completing dental charts manually.

Artificial intelligence for automated detection of tooth decay on colour dental photos

Reaching out to all children to carry out regular dental check-ups is challenging and costly. We proposed developing a deep learning model to enable automated detection of tooth decay on colour dental photos. If artificial intelligence is combined with a smartphone camera, then this can play a vital role in expediting remote dental screening and early detection of tooth decay in children, even during times of dental services disruption or shutdown, such as with COVID-19.

Read more in Health Services: Project Reports.

Dr Mahnoosh Kholghi

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

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

My Garden: a gamification app to engage smart home residents in ground-truth data acquisition

To explore an engaging way of involving older adults in processing of data collected in smart homes, we developed "My Garden", a gamified prototype, to facilitate interactive self-reporting of daily activities. This project aims to evaluate My Garden and gain design insights that fosters long-term use of self-reporting applications. We expect the data collected through My Garden could lead to significant improvement of Smart Homes technology and support the independent living of older adults.

Read more in Health Services: Project Updates.

Dr Wei Lu

Health evaluation in smart home

The development of assistive technologies has the potential to realise savings in health expenditure and satisfy older people's desire to maintain independent living. In collaboration with FSP MLAI, Wei is developing a health evaluation system based on deep learning models to provide an objective and personalised measure of health and wellbeing status through non-intrusive ambient sensors in a smart home environment.

Read more in Health Services: Project Updates.

Dr Angelina Duan

Ocular imaging biomarkers for Alzheimer's disease and mild cognitive impairment

Angelina is investigating structural and functional retinal biomarkers of Alzheimer's and dementia. One approach is to provide repeatable flickering light stimulation to the eye, which is known to increase the energy demands of the retina. The resulting changes in blood supply can be explored using fundus cameras and optical coherence tomography angiography (OCT-A). Additionally, non-invasive recording of electrical signals from the human eye following flickering light stimulation can provide an indicator of neural health.

Read more in Health Services: Project Updates.

PhD students

Janis Nolde, University of Western Australia

Artificial Intelligence based cardiovascular risk stratification

Janis is investigating machine learning approaches to the management of hypertension. Efficient prediction methods for patient outcome 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.

Read more in Health Services: Project Reports

Vera Buss, University of New South Wales

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

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

Ahmed Hassan Alkenani, Queensland University of Technology

Textual Data Analysis of Early Symptoms of Dementia through Daily Conversations

Alzheimer's disease (AD) along with other related neurodegenerative pathologies are considered to be one of the most common persistent issues facing an ageing population due to their nature of being incurable. This research project aims to develop a fully automatic diagnostic system for early Alzheimer's and other related dementias via conversational analysis. Specifically, it explores the potential of using linguistic patterns and deficits fusion with a conversational agent in detecting these neurodegenerative pathologies on a daily basis.

Yashodhya Vachila Vijesinghe, Queensland University of Technology

Automatic prediction of fall and frailty of seniors using clinical data

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

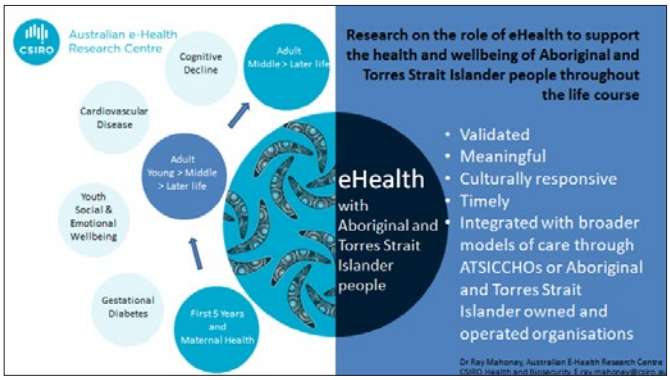
The AEHRC and Indigenous Health

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

The Australian e-Health Research Centre is committed to increasing its contribution to addressing the health disparities between Indigenous and non-Indigenous people in Australia.

We are partnering with Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHO) to co-design and co-develop potential e-Health solutions to complement existing successful models of care for some of the most significant health issues in their communities.

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



(L–R) Louisa Warren, Executive Manager, Office of Indigenous Engagement; Andrew Goodman, PhD Candidate, Australian e-Health Research Centre (AEHRC); Jed Fraser, PhD Candidate, AEHRC; David Hansen, CEO, AEHRC; Georgina Chelberg, PhD Candidate, AEHRC; Kaley Butten, Postdoctoral Fellow, Queensland Aboriginal and Islander Health Council and AEHRC; Ray Mahoney, Senior Research Scientist, AEHRC

The AEHRC and Indigenous Health: project updates

Hypertension scoping study: mobile health platform

Collaborators: Queensland Aboriginal and Islander Health Council (QAIHC), Wuchopperen Health Service and Mulungu Aboriginal Corporation Primary Health Care Service.

AEHRC has partnered with the Queensland Aboriginal and Islander Health Council (QAIHC) to investigate if mHealth (mobile health) is an appropriate, feasible and effective health resource to address hypertension within an Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHO) setting.

A scoping study was undertaken in 2019 to determine whether further consideration of hypertension mHealth is a relevant priority with the Indigenous Health Sector and to provide valuable insights about the needs, preferences and priorities of how Indigenous people may wish to engage with mHealth for hypertension management.

The AEHRC and QAIHC presented findings back to the initial engaged ATSICCHO sites as apart of in person follow up visits. Dr Ray Mahoney and Mr Andrew Goodman (PhD Candidate) presented findings to the broader ATSICCHO sector at the QAIHC 2020 members conference in October 2020. Following this presentation, Wuchopperen and Mulungu ATSICCHOs, based in North Queensland, requested to continue their participation as feasibility trial sites. Both ATSICCHOs approved the research study and provided support letters. Ethics approval has been gained from Far North Queensland HREC (FNQHREC/HREC/2021/QCH/61500 – 1511), reciprocal ethics approval has been granted by CSIRO and the University of Queensland. Community consultation and planning is underway for the commencement of data collection.

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

The Hypertension (HTN) mHealth platform uses a smartphone App, clinician portal, measurement devices and multimedia content to support patients with hypertension throughout the diagnosis and management journey. This research project aims to assess the appropriateness, feasibility and effect of an mHealth platform specifically tailored for the clinical management of hypertension for patients accessing care at two (2) ATSICCHOs Wuchopperen and Mulungu in Cairns and Mareeba.

Alice Springs residential thermal comfort monitoring trial

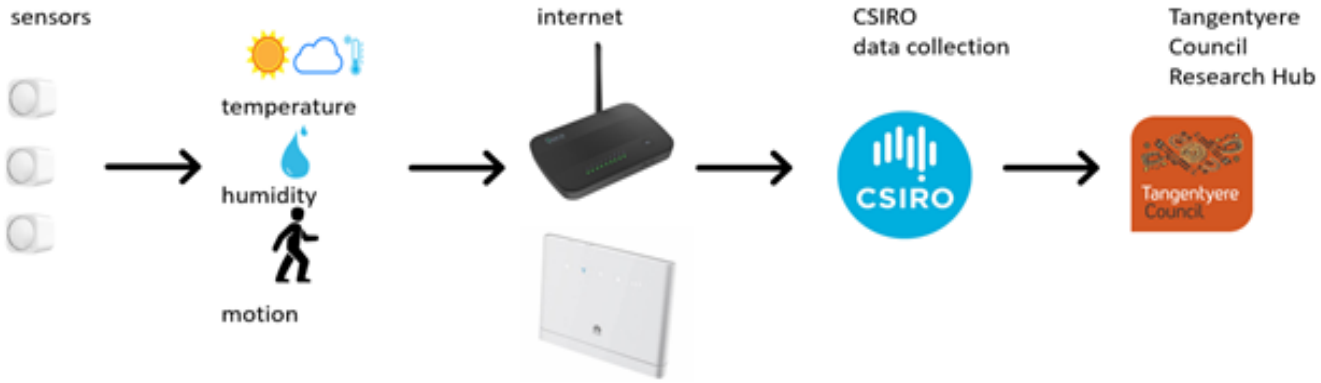
Collaborators: Tangentyere Council Aboriginal Corporation (TCAC)

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 Aboriginal Corporation (TCAC) in Alice Springs.

A successful scoping phase in 2020 deployed the AEHRC Safer Smarter Homes (SSH) platform in three Town Camps and established the feasibility of data upload to cloud storage using local satellite internet or 4G. Access to real-time sensor data on temperature, humidity and power usage was confirmed, and led the way for a larger trial.

Full ethics approval with CHMHREC (2020_058_HREC) for data collection of temperature, humidity and power usage over 12 months was achieved in November 2020. Installation of SSH sensors in up to 20 residential houses across Town Camps by Tangentyere Senior Research Staff commenced in May 2021. This deployment follows an AEHRC site visit to Tangentyere Council in May 2021 for research planning, training of staff on SSH installation, trial installations and troubleshooting, focus group discussions and strategic meetings with local health and aged care service delivery providers.

Vanessa Davis (TCAC), Michael Klerck (TCAC), Vanessa Smallbon (AEHRC) and Georgina Chelberg (AEHRC)



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)

There are no national standards for the collection of health data for Indigenous people in Primary Care settings. The Primary Care Data Quality Foundations Project (see Health Informatics section) is a community-driven consensus programme to standardise primary care data using a standard data model (FHIR) and a terminology (SNOMED CT) to improve data quality, interoperability and population health data use.

AEHRC has been funded by the Department of Health to lead a project with the RACGP and NACCHO to commence developing an interoperable Medicare Benefits Schedule (MBS) item 715 form (SMART MBS715), for potential deployment initially in Aboriginal and Torres Strait Islander Community Controlled Health Organisations (ATSICCHOs) and ultimately the wider Primary Care service settings across Australia.

It is proposed that this SMART MBS715 will encompass features that have already been identified through the PCDQP as well as additional features to support a holistic and comprehensive clinical workflow aimed at achieving resource efficiencies and enhanced patient care.

The central vision of this project is to expand the health check from just a clinical data collection tool, to include other aspects, such as SEWB, chronic disease management and the role of social determinants of health in preventive health care for Aboriginal and Torres Strait Islander people and communities.

We aim to develop the following:

- Scoping, co-designing and developing with industry and Aboriginal and Torres Strait Islander community-controlled health sector partners, a prototype SMART Health Check forms server which can integrate with primary care software.
- Prototyping and evaluating the SMART Health Check forms server in a select number of ATSICCHOs in Queensland ahead of initial implementation.
- Developing a strategy for deploying the SMART Health Check form across Primary Care service settings nationally.

The AEHRC is recruiting an ResearchPlus (R+) CSIRO Early Research Career (CERC) Postdoctoral Fellowship position to join the team to lead research and the mixed methods evaluation on the integration of the SMART Health Check form into primary health care service delivery, and how data can be re-used to identify early warning signs and opportunities to intervene.

e-Health Research Collaboration for Aboriginal and Torres Strait Islander Health

In 2019, the AEHRC established a collaborative group: The e-Health Research Collaboration for Aboriginal and Torres Strait Islander Health (The Collaboration). Membership includes Queensland Aboriginal and Islander Health Council, The University of Queensland's Centre for Online Health, and School of Public Health, the Queensland University of Technology Australian Centre for Health Services Innovation and Queensland Health's eHealth Queensland. The group is focused on establishing an evidence base for technology in health care specific to the interests and needs of Aboriginal and Torres Strait Islander people.

The Collaboration was awarded funding from the Queensland Cardiovascular Research Network to support the development and preparation of a grant application for the MRFF Cardiovascular Mission in 2020. The Collaboration is supporting a project to co-design a best practice framework (BPF) that will guide and inform the culturally safe implementation and evaluation of electronic health (eHealth/mHealth/telehealth) interventions within existing models of care for Aboriginal and Torres Strait Islander peoples.

The AEHRC and Indigenous Health: postdoc and student highlights

Postdoctoral fellow

Dr Kaley Butten, AEHRC-Queensland Aboriginal and Islander Health Council (QAIHC)

Project title: M♡THer in regional Queensland

Kaley is a Postdoctoral Fellow collocated between the QAIHC and AEHRC. Kaley has Bachelor of Public Health and PhD in Health Research with Queensland University of Technology with a focus on Aboriginal and Torres Strait Islander Health.

Kaley is currently focused on understanding if mobile health platforms are effective and acceptable to Aboriginal and Torres Strait Islander women with a diagnosis of gestational diabetes, with a specific focus in understanding the needs and challenges of regional and remote areas with respect to mobile health (mHealth).

The first regional setting for the project is in Mt Isa in Central West Queensland and after consultation with the local Aboriginal and Torres Strait Islander Community Controlled Health Organisation, Gidgee Healing, recruitment at the Mt Isa Base Hospital commenced in May 2021. Kaley and the team will be engaging with participants and clinician users to explore their experiences of the mHealth platform across the hospital and ATSICCHO sector.

Read more in Health Services: Project Reports.

PhD Students

Andrew Goodman, PhD candidate (The University of Queensland/CSIRO)

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

Andrew Goodman is a PhD candidate with the School of Public Health, University of Queensland co-hosted with the AEHRC. Andrew's PhD research project aims to 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.

Andrew is leading our collaboration with Wuchopperen in Cairns and Mulungu in Mareeba.

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

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

Georgina Chelberg, The University of Queensland

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

Georgina's research has reviewed the use and effectiveness of digital health platforms with First Nations, including Aboriginal and Torres Strait Islander people. The current research activities of the project are to explore the perspectives of key stakeholders within Aboriginal and Torres Strait Islander communities regarding the use and adoption of digital health platforms. A review and evaluation of mobile apps for dementia awareness and support in Australia has also been conducted. Outcomes of the research will inform the development of 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.

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

Jed Fraser, The University of Queensland

Co-creating an Aboriginal and Torres Strait Islander youth health assessment

The aim of the research is to understand what Aboriginal and Torres Strait Islander youth health priorities are to co-create a youth specific health assessment to meet Aboriginal and Torres Strait Islander youth health needs when accessing primary health care. Youth are the experts in their own health, however are rarely at the table when it comes to health care. Jed's research has a focus on valuing Aboriginal and Torres Strait Islander youth voices to co-create a health assessment that is designed by youth, for youth.

Jed is a PhD Candidate with The University of Queensland, a recipient of the CSIRO Indigenous Postgraduate Top Up Scholarship.

The Health System Analytics group

Group Leader: Dr Rajiv Jayasena

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

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

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

Health System Analytics' science and impact highlights for 2020–21

- Delivery of explainable machine learning models for real-time identification of patients at high risk of re-hospitalisation across all major public hospitals in Queensland.
- Delivery of explainable machine learning models for real-time identification of patients at risk of deterioration using integrated electronic medical record (ieMR) data from a major Queensland Hospital.
- Delivery of models to improve the prediction of demand for ED and inpatient services and support better capacity management for the Queensland Patient Access Coordination Hub (Q-PACH).
- Delivery of a suite of analytics solutions and prototypes developed to inform decision making during the COVID-19 crisis for Queensland Health.
- Delivery of syndromic surveillance plans for the major Queensland and South Australian public hospitals which show disease outbreaks coinciding with the COVID-19 outbreak and other infectious disease outbreaks since 2017.
- Delivery of a simulation platform to quantify performance impacts of operational changes to hospital operating theatres for WA Health.
- We finalised the evaluation of the Victorian Department of Health HealthLinks Chronic Care program. The project showed that intervention patients were better streamed into non-admitted specialist care services and highlighted the need for change management in managing chronic disease and complex patients in acute settings for intervention models like HealthLinks to succeed.
- Delivered several reports as part of the Advanced Statistical and Analytics Capability Uplift agreement with the Victorian Agency for Health Information (VAHI).

Health Implementation Science team

Team Leader: Mr Norm Good

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

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

Health Intelligence team

Team Leader: Dr Sankalp Khanna

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

Health System Analytics: platform technologies

Algorithms for predicting demand for health services

Predicting demand is one component of improving efficiency and access performance of health services – vitally important as the population ages and health budgets get squeezed. The need to ensure 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 the efforts of 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 2020–21, the team developed new models to generate forecasts of ED presentations, inpatient admissions and separations for the 27 major public hospitals in Queensland. An ensemble approach combining predictions from a Negative Binomial Regression model and a Moving Average model gave best performance. Models that use less data from previous years (e.g. a rolling Moving Average model based on the last six weeks) performed well in 2020 which experienced different flow patterns from previous years due to the pandemic.

Algorithms for syndromic surveillance and aberrance 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 2020–21, the team applied anomaly detection processes to flag when one of Queensland or South Australia's major public hospitals may need to introduce extra staff because the ED is under workload stress due to the rate of patient presentations. The Time Between Event approach was also used to detect outbreaks of influenza-like illness using ED presentations and social media (tweets) as signals to monitor. An outbreak is flagged as this time gets significantly smaller, and each event offers a decision point on whether an outbreak has occurred.

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

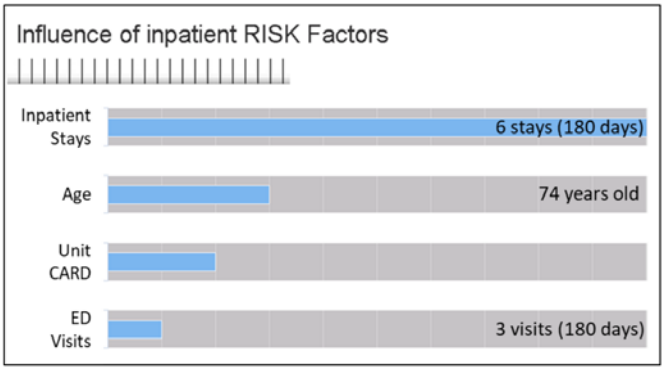
REPORT: Machine Learning driven real time clinical decision support tools

With the increasing implementation of electronic medical records (EMRs) in hospitals, there is growing potential to use the data to inform operational and clinical decision making in real time. The AEHRC Real-time Explainable Prediction of Risk Tool (REPORT) set of algorithms uses the data captured in electronic medical records and administrative systems to identify patient cohorts of interest for clinical streaming/intervention.

We have developed a number of REPORT tools that have been deployed or trialled :

- For the Australian Government Health Care Homes integrated care trial, we developed a tool to identify patients who were at high risk of being hospitalised over the next 12 months. The tool was deployed at more than 150 general practice clinics across Australia to identify chronic disease patients for the trial.
- In the acute care setting, we have developed explainable algorithms that use inpatient, emergency, pathology and medications data to predict a patient's likelihood of rehospitalisation in real time. These algorithms have been trialled for two years at a major Queensland Hospital and recently been validated on statewide data for deployment across Queensland.
- Working with another major Queensland Hospital, we have also recently developed algorithms that employ patient demographic, clinical and physiological data collected at the bedside in the Integrated Electronic Medical Record system to predict a patient's risk of deterioration in real time

We are now working with a number of hospitals to undertake a trial of these tools in in a clinical setting and identifying other use cases for real-time explainable risk prediction.



Employing explainability helps deliver machine learning tools that clinicians can trust and use to guide decision making

Simulation based operational scenario modelling and optimisation

The ability to create realistic digital representations of physical systems (or "Digital Twin") 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 a number of 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 the flow of patients through a process accurately. The team have demonstrated with a number of models 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 patients being discharged from hospital.

In 2020–21, the team built simulation models to run what-if scenarios on different operating theatre configurations to assess impacts on hospital KPIs. Scenarios explored reallocation of emergency/elective cases between two theatres, reallocation of specialties between two theatres, reducing the amount of turnaround time between operations and changing the opening and closing times of theatres. Simulation models were packaged as web applications for our collaborators to allow theatre planning and other staff to define and run their own scenarios and assess their impact on utilisation (idle capacity), pre-operative length-of-stay, reclaimed surgery time and patient waiting time.

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

Health System Analytics: project reports

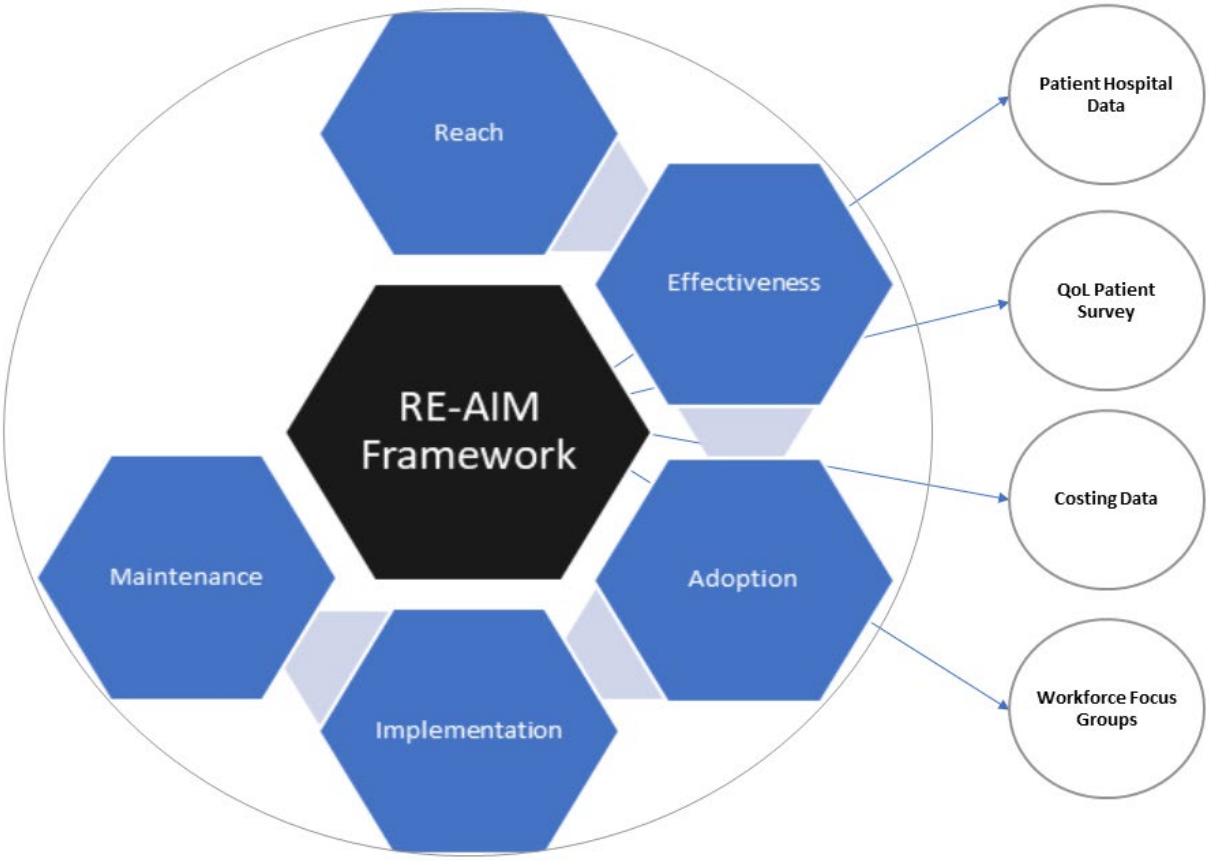
HealthLinks: Chronic Care Evaluation

Collaborator: Department of Health Victoria

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

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 is planned for August 2021 to disseminate results to a wider audience.

Approximately 50, 000 patient 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 to play 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.

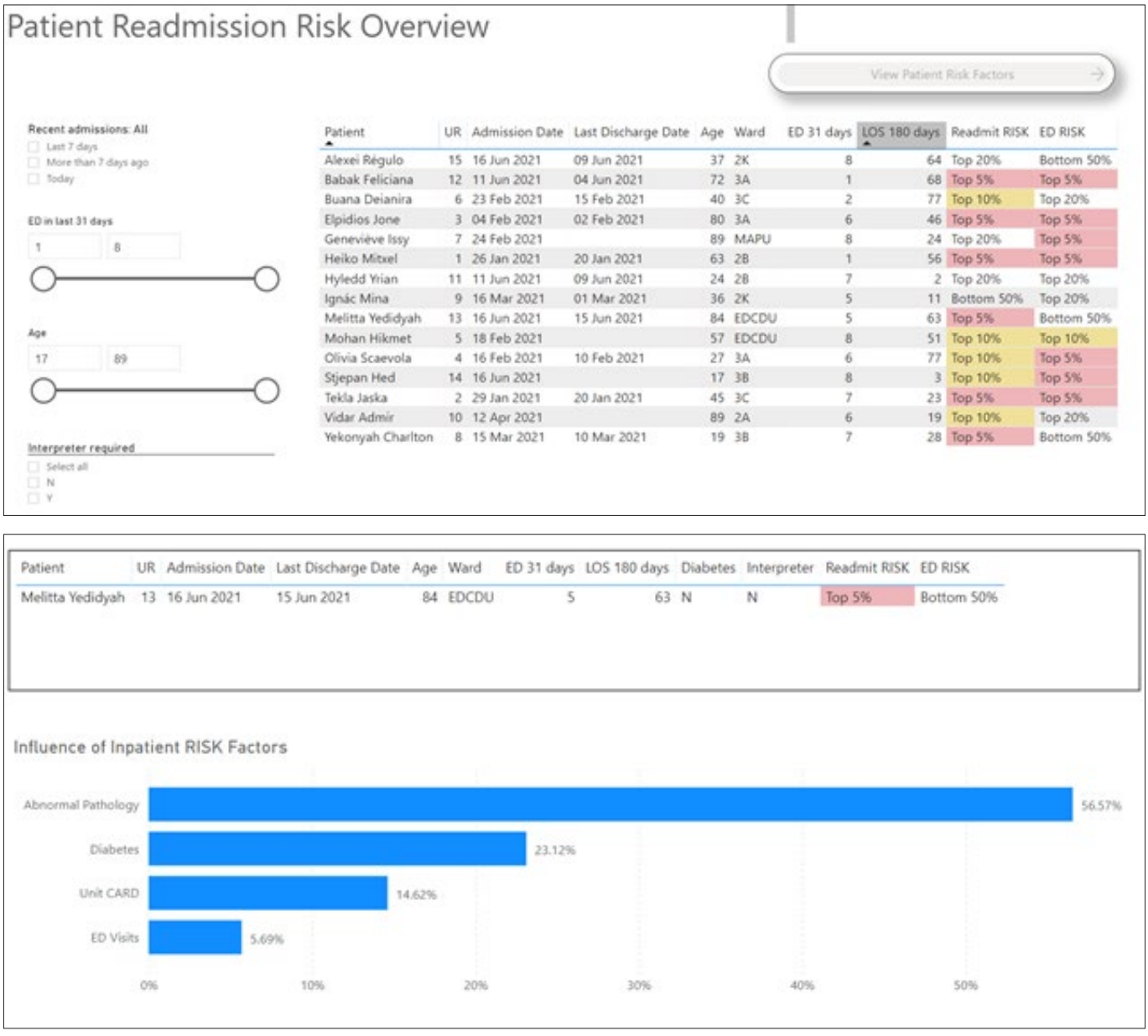
Decision support algorithms to reduce unplanned chronic disease hospitalisations

Collaborator: Clinical Excellence Queensland, Queensland Health

Following a trial at Logan Hospital, the AEHRC was asked to develop and validate a web-based application that uses routinely collected hospital data to identify patients at high risk of re-hospitalisation for all major public hospitals in Queensland. This risk tool can help manage and reduce unplanned readmissions for chronic disease patients.

Several predictive modelling techniques were explored (namely logistic regression, random forests and gradient boosting) and validated across five years of project data. The models use a range of predictor variables sourced from state-wide ED, inpatient, medications and pathology databases. Predictive performance of the models was evaluated using the Area Under the Receiver Operating Characteristic curve (AUC), Brier score, the Calibration curve, and the Precision-Recall curve. Predictive performance of the models is approximately 70 percent area under the Receiver Operating Characteristic curve (AUC ranging between 64 percent and 85 percent depending on the cohort) with at most three percent difference between modelling approaches for a given patient cohort. This performance is comparable with other global attempts at developing models to predict and stratify patients according to their risk of hospitalisation. Calibration of the models was excellent and the importance of individual features contributing to patient risk was explored using Shapley values to assist with interpreting predicted patient risk.

Final models were shared with Queensland Health along with mock-ups for design interfaces that can be integrated into a Power BI dashboard or other software solutions.



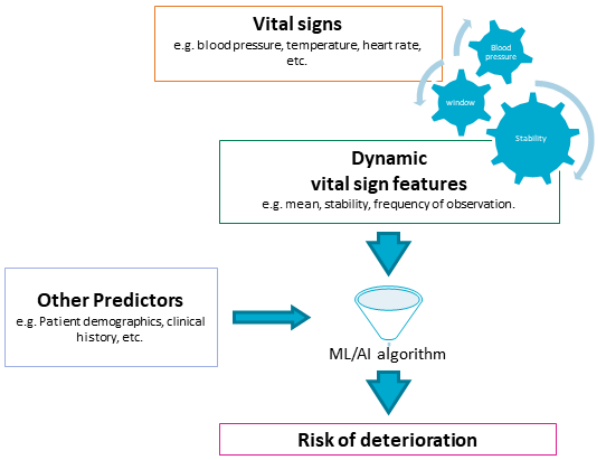
Modelling individual risk of hospitalisation

Predicting patient deterioration

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

CSIRO worked with integrated electronic medical record (ieMR) data from Princess Alexandra Hospital to improve detection of deteriorating patients. The study aimed to reduce the likelihood of triggering a deteriorating alert flag for a patient in a general ward. This included introducing customised vital signs thresholds programmed into a digital hospital's electronic medical record to suit individual patients using historic data, and predicting the likelihood of a patient deteriorating significantly before they become a candidate for critical or intensive care using a range of data sources.

The final report was delivered to Queensland Health in June 2021 and discussions are underway with clinicians from a major Queensland hospital to develop a real-time risk prediction dashboard for trial in the next year.



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

Deteriorating patient risk profile dashboard.

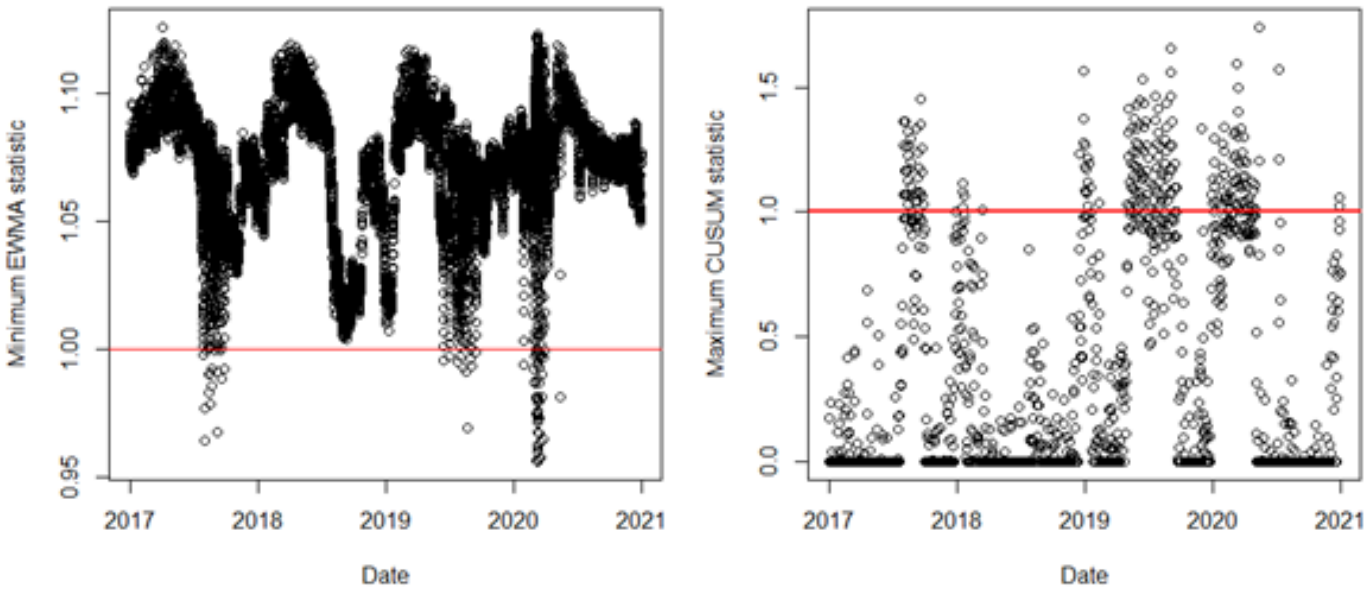
ieMR based data from 2016–18 inclusive were used to train models and data from January to September of 2019 was use for testing model performance. Logistic regression and two tree-based models, random forests and decision tree ensembles, were investigated for predicting the triggering of a red alert: indicating a patient deterioration. Tree-based methods vastly outperformed logistic regression models according to all evaluation metrics. The Area Under the Receiver Operating Curve for a 4hr red alert was 0.90 with an F1-score of 0.62.

COVID-19 Analytics

Collaborator: Clinical Excellence Queensland, Queensland Health

As the COVID-19 crisis unfolded, CSIRO worked in collaboration with Queensland Health on two key activities to develop analytics solutions to inform decision making through the crisis:

- **COVID-19 Barometer:** The COVID-19 Barometer is an innovation that was designed to 1) bring together data from disparate sources, including economic activity, travel and mobility change, and health service capacity, to create a holistic picture, and 2) employ advanced analytics to help monitor various channels of activity, pinpoint vulnerabilities, and predict transmission spread from regional outbreaks. Currently developed as a prototype, the COVID-19 Barometer is designed to provide a better understanding of how each region in the state is responding to the COVID-19 cases in the community, to the restrictions as they were imposed, and to the easing and then lifting of restrictions. It provides new knowledge to inform our decision making, in the event that we have an increase in cases. As Australia's first dynamic monitoring tool, it is changing the way we think and respond to a health crisis moving forward, and also to societal behavioural patterns in general.
- **Patient Journey:** The Patient Journey project developed a novel set of tools to obtain a comprehensive view of care provided to patients across the health system. Initially focussed on COVID-19 patients, it allows for the identification of "typical" and "atypical" longitudinal patient profiles and characteristics of COVID-19 cases. Tools like Theographs for understanding the historic and post recovery healthcare utilisation of COVID-19 patients, and Parallel Coordinate plots for analysing the patterns in multivariate longitudinal data, deliver additional insights to help inform care delivery and care planning. The scope was also extended to explore the impact of COVID-19 infection on changes in healthcare utilisation patterns in COVID-19 patients post-recovery. This provided a proxy for better understanding long term complications and related demands on the health system due to the COVID-19 infection.



Monitoring disease outbreaks; Left – Novel Time Between Event approach where an outbreak is flagged when the surveillance statistic drops below the red threshold. Right – Traditional CUSUM approach where an outbreak is flagged when the surveillance statistic exceeds the red threshold

Syndromic Surveillance and Analytics to inform the health system during pandemics and other disasters

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

In 2020–21, the team carried out analytical projects in the area of statistical process control to inform operational decision making and response planning in the areas of syndromic surveillance and outbreak detection. Influenza like illness cases were analysed and used to develop outbreak detection models for application to syndromic surveillance. Models were constructed based on the time between an event of interest using ED presentations and social media (tweets) as signals to monitor. An outbreak is flagged as this time gets significantly smaller, and each event offers a decision point on whether an outbreak has occurred.

Monitoring plans were developed for the 27 major Queensland public hospitals and 14 major South Australian hospitals and show outbreaks for individual hospitals coinciding with the first wave of the COVID-19 outbreak and other times since 2017. Anomaly detection processes were also applied to flag when an ED at a particular hospital may need to introduce extra staff because the ED is under workload stress due to the rate of patient presentations. A dashboard has been made available to Queensland Health and SA Health displaying real-time output of monitored keyword mentions within Twitter which are first put through a personal health classifier to improve data quality.

The work supports our state health partners in improving syndromic surveillance capability and assisting hospitals in planning and responding to variations in hospital demand. In relation to the current COVID-19 pandemic, an implemented syndromic surveillance approach can pick up future aberrances and geographic outbreaks quickly so they can be contained. Such capability can help with surveillance related to the current and potential future pandemics.

Extract from Theatre Simulation Dashboard to assess impact of operational changes on theatre performance

Operating Theatre Efficiency Modelling

Collaborator: Fiona Stanley Hospital, WA Health

In 2020–21, the team built on their previous work with the Fiona Stanley Hospital which focused on predicting patient arrivals to theatre and theatre over-runs to set the foundations for creating a digital twin of operating theatre flows at the hospital. Digital twins are realistic digital representations of physical systems that can support improved decision making by providing answers to several what-if scenarios and generating insights from the data on how these potential changes impact the real system.

Operating theatre efficiency was explored using a Discrete Event Simulation model for patients admitted to inpatient beds and sent for surgery, where the team assessed how changing the configuration of surgery affects Key Performance Indicators relating to efficiency. A dashboard was built to run scenarios of interest where KPIs were plotted and displayed against baseline values to assess the scale of the impacts. This tool can provide quick insights into the effects of a potential change for more informed strategic planning.

A web application comprising the simulation tool and other novel data interrogation and visualisation dashboards was developed and made accessible to theatre management staff which provides a valuable project outcome for the theatre management team and hospital executives. A particular benefit of the theatre simulation dashboard is it allows running what-if scenarios on different theatre configurations to assess impacts on hospital KPIs. Another use of the dashboards is to allow easy identification of surgery cases which started within a time interval chosen by a user. To control the efficiency of surgery, it is ideal to have actual start times of surgery coincide with planned start time and this web app allows characteristics of such cases to be readily identified. The exact times in a day where starting time differences are the largest can be pinpointed to assist with continuous quality improvement.

VAHI Advanced Statistics and Analytic Capability Uplift

Collaborator: Department of Health Victoria

The Victorian Agency for Health Information (VAHI) engaged the CSIRO to undertake a series of statistical activities to inform various initiatives within VAHI aimed at informing and improving reporting practices. These included:

Hospital standardised mortality ratio (HSMR): An in-depth review of the use of HSMR and other summary mortality indicators in Australia and internationally to inform the usability of, and make recommendations related to the use of, such measures within the Victorian health service setting.

Unplanned readmission indicators: Readmission indicators are used in Australia and internationally as an assessment of health service safety and quality with rising readmission rates serving as a trigger for health services to consider opportunities for improvement. The objective of this project was to inform the development of risk-adjusted measures for unplanned readmission for total knee replacement, total hip replacement, heart failure and acute myocardial infarction.

Statistical Process Control chart methodology: Statistical wProcess Control (SPC) is a quality control method to observe a process and monitor its progress over time using a control chart. There has been increased uptake of SPC charts as an instrument for patient safety and quality performance monitoring and highlighting areas for improvement in hospitals. The objective of this project was to conduct a literature review on the use of control chart methodology within Australia and internationally to identify options and make methodological recommendations for the use of SPC charts for patient safety and quality monitoring and reporting within the Victorian health service setting.

Risk adjustment model for emergency laparotomy mortality: The objective of this project was to develop and validate risk-adjusted statistical models to predict mortality following emergency laparotomy (EL) in Victorian hospitals. Working closely with VAHI and clinical experts, the team has delivered models for predicting in-hospital mortality following an EL procedure.

CSIRO also conducted a series of masterclasses for VAHI staff as part of this engagement.

Health System Analytics: project updates

Predictive analytics for statewide patient access coordination

Collaborator: Clinical Excellence Queensland, Queensland Health

The project focussed on developing predictive models to inform daily situational intelligence relating to forecasted demand monitoring of inpatient capacity risk to support Queensland Health's new South East Queensland (SEQ) Patient Access Coordination Hub (PACH) initiative.

Predictive models employing ED and inpatient data were developed for 27 major QUEENSLAND public hospitals with a view to improving the current demand predictions embedded within the SEQ PACH dashboards. Models to generate forecasts of ED presentations and inpatient admissions and separations were also developed. A novel ensemble approach combining predictions from two distinct models provided superior predictive performance. Models that performed well during 2020 when flow patterns differed due to the COVID-19 pandemic were also identified.

Differences between daily predicted inpatient admissions and separations were used to generate retrospective surveillance plans for monitoring capacity risk for a given hospital.

Evaluation of a falls prevention strategy implemented in hospitals using Responder-5 system

Collaborators: 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 the 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 evaluation will also study the implementation process on key enablers and barriers to workflow implementation and suggestions for future modifications and the implementation efforts.

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.

The 1) Next Available Appointment Scheduling Tool enhancement and 2) Template Planning Tool have both been developed, and a comprehensive report describing the results of the modelling and validation have been delivered to the client. The next stage of the project is for Austin Health to implement the Next Available Appointment Scheduling Tool in their business-as-usual system while the CSIRO team implements the Template Planning Tool followed by an evaluation.

Health System Analytics: postdoc and student highlights

Postdoctoral fellows

Dr Kay Mann

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

Dr Vahid Riahi

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

PhD students

James Kemp, Centre for Big Data Research in Health, Faculty of Medicine, University of New South Wales

AEHRC Industry PhD, scholarship UNSW. Fraudulent or inappropriate claims from healthcare providers can be costly for government health programs. With increasing numbers of claims, data analysis becomes a bottleneck in the process of detecting abnormal claims. Improving analysis methods could lower the cost of detection as well as increase detection rates. 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 is currently working on his first methods paper using association rule mining techniques.

Kristin Edwards, James Cook University

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

Marko Simunovic, Queensland University of Technology

Marko is a PhD student jointly supervised by Queensland University of Technology, LaTrobe University and CSIRO. His project has investigated spatiotemporal trends in asthma hospitalisations across Queensland and associations with grass pollen exposure, and to investigate whether temperate areas of South East Queensland are at increased risk of epidemic thunderstorm asthma compared to subtropical areas of Queensland. This research has generated new knowledge to better understand epidemic asthma risks and the outcomes will help inform public health strategy for mitigating risks of pollen-induced allergic respiratory disease in South East Queensland and the Darling Downs.

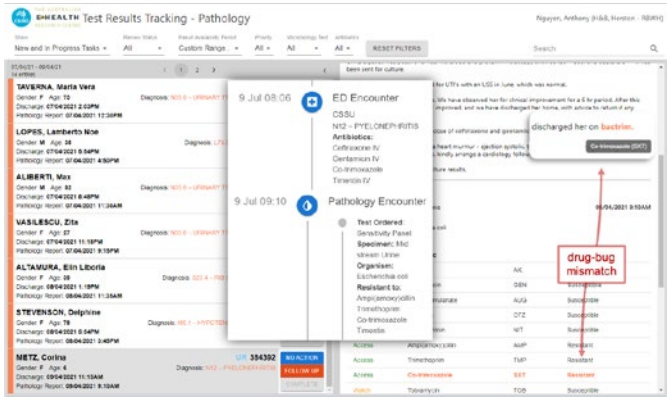
Vacation student projects

Project: Tackling superbugs in EDs with FHIR: A SMART approach

Student: Leonie Dickson, University of New South Wales

Supervisor: Anthony Nguyen

The pathology test result review process used in emergency departments (EDs) is a time-consuming and unprioritised process, compromising patient safety and decreasing efficiency in the hospital. A proof of concept ED Test Result Review application, based on the SMART on FHIR health care interoperability standard, has been developed to streamline this process by providing a list of patients prioritised based on reconciling antibiotic prescriptions identified from ED discharge letters and microbiology test results. The application also allows clinicians to mark patients for follow up, make comments, and filter patients by a range of criteria.



Microbiology test result review decision support app, based on the SMART on FHIR health care interoperability standard, identifying untreated pathogens and drug-bug mismatches for Emergency Department patient follow-up.

Project: Implementing cloudless IoT for aged care facilities without internet access

Student: Saurav Kumar, University of Queensland

Supervisor: Qing Zhang

The functional ability for independent living among the elderly is currently performed through a cloud based Internet Of Things (IOT) network of sensors. Many facilities in rural Australia do not have stable internet making the implementation of the networks difficult. This project involves the use of OpenHAB to develop a cloudless alternative that is cheap, scalable, flexible and customisable. OpenHAB allowed the construction of an internet independent IOT network that can communicate with Z-Wave, ZigBee and Bluetooth devices.

Project: Mining Wikipedia to generate a geographic location ontology

Student: Chanon Kachornvuthidej, University of Queensland

Supervisor: Alejandro Metke

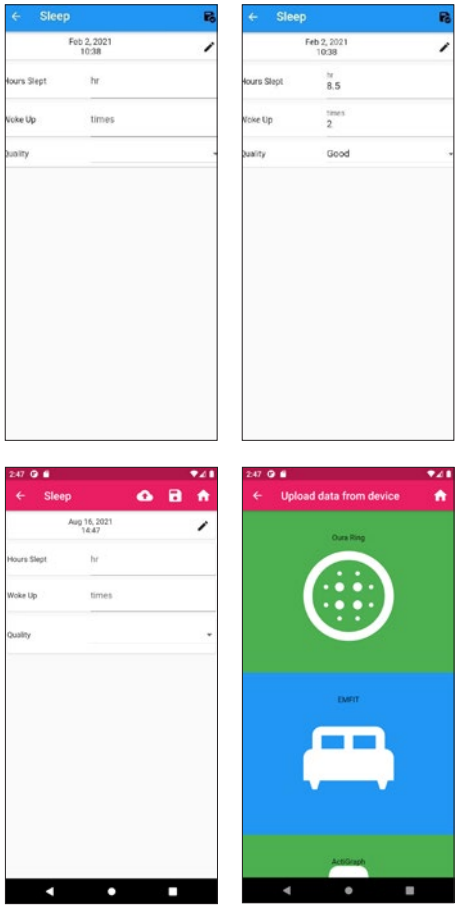
The project aim was to produce a generic framework to standardise the process of creating coded geographical location data in a format suitable for sharing within clinical settings. An example utilising data from Wikipedia and transforming it into FHIR CodeSystem format was demonstrated. The CodeSystem was uploaded to Ontoserver to simulate data sharing to other clinical software applications. The OntoServer accepted the CodeSystem produced following the proposed four-stages framework: location data extraction, knowledge graph database, mining Wikipedia, and FHIR CodeSystem generation.

Project: Postnatal follow-up for women with diabetes during pregnancy

Student: Harry Huang, University of Queensland

Supervisor: Marlien Varnfield

With the M♡THer app already existing as part of the MoTER platform for self-management of Gestational Diabetes (GDM); it was decided that the Sleep section of the app should be improved for future use. Currently, all sleep tracking in M♡THer is done manually by the user. This means the user must remember the details of their sleep, which is not only inaccurate, but stressful for post-partum mothers managing GDM. Hence, the aim of this project was to compare commercially available sleep tracking devices to see which are most acceptable to be used for future trials to remove the hassle of manual sleep tracking. After completing an observational study comparing three commercial sleep tracking devices (Oura Ring, EMFIT, ActiGraph); it was found that the Oura Ring had the best acceptability due to its apparent data accuracy and slick design (as indicated by the participants). Furthermore, an initial integration of the three devices used in the study was completed in M♡THer as a starting point, with other devices to be added in future applications.



Sleep data recording interface of the existing M♡THer app (a,b manual sleep data entry) and of the new interface (c,d automatic upload from sleep tracking device)

Project: Chest pain risk stratification: A deep learning approach

Student: Robert Murray, University of Queensland

Supervisor: Hamed Hassanzadeh

Chest pain is among the top 10 reasons for patients' presentation to Emergency Departments (EDs). Stratifying risk of an adverse cardiovascular event for each patient with chest pain is a critical task by ED clinicians. This project focused on developing a machine learning-based automatic risk stratification algorithm using various sources of patients' electronic health records such as demographic data, pathology results, and unstructured free-text data. Natural Language Processing (NLP) techniques was employed to extract important information from unstructured data.

Project: De-binarising the ATN framework: Continuous modelling of Alzheimer's Disease biomarkers in 3D

Student: Lucy Nott, Queensland University of Technology

Supervisor: Marcela Cespedes

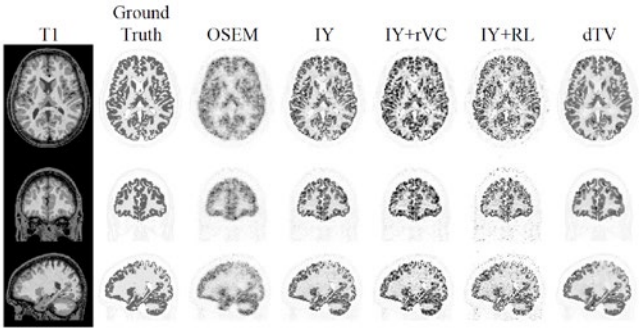
The descriptive amyloid (A), tau (T) and neurodegeneration (N) classification scheme is a well-accepted framework to categorise the pathophysiology of Alzheimer's disease (AD). However, this framework does not provide information on the interplay of the biomarkers in their continuous form. Additionally, information on individuals with borderline biomarker values are lost when they are treated trichotomously into A/T/N groups. In this project, the aim was to investigate the joint associations of amyloid, tau and neurodegeneration over the AD domain through an interactive web application that effectively visualises the interplay of key AD biomarkers.

Project: Better PET images the easy way: Partial volume correction of PET images from MRI in image-space

Student: Min Han Quah, University of Wollongong

Supervisor: Ashley Gillman

PET imaging remains a popular functional imaging technique for detecting early onset of various diseases. However, PET images are of relatively low resolution compared to anatomical imaging techniques such as Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scan. Typically, a MR or CT guided PET reconstruction will be done to increase the resolution. However, the usage of raw data to process it makes it a cumbersome practice, and other image-based techniques require segmentation which is prone to inaccuracies. Instead, a Partial Volume Correction (PVC) utilising iterative deconvolution, regularised by minimising shared directional total variation (dTV) with an anatomical prior image is done using STIR and CIL libraries. Grey matter-white matter contrast increased using dTV compared with baseline, however, where an accurate segmentation is available, traditional PVC techniques are superior. With appropriate hyper-parameter selection, dTV deconvolution can preserve PET-unique features.



Using MRI (T1) images to estimate underlying positron emission tomography (PET) images (Ground Truth) by deblurring measured images (OSEM). Traditional approaches, iterative-Yang (IT) with and without reblurred Van-Cittert (rVC) or Richardson Lucy (RL) deconvolution produce noisy results. The proposed directional total variation (dTV) produces more accurate estimates.

Project: Talking about pain: An age-appropriate chat-bot for individuals with chronic pain

Student: Pranavie Vijayakumar, University of Melbourne

Supervisor: David Ireland

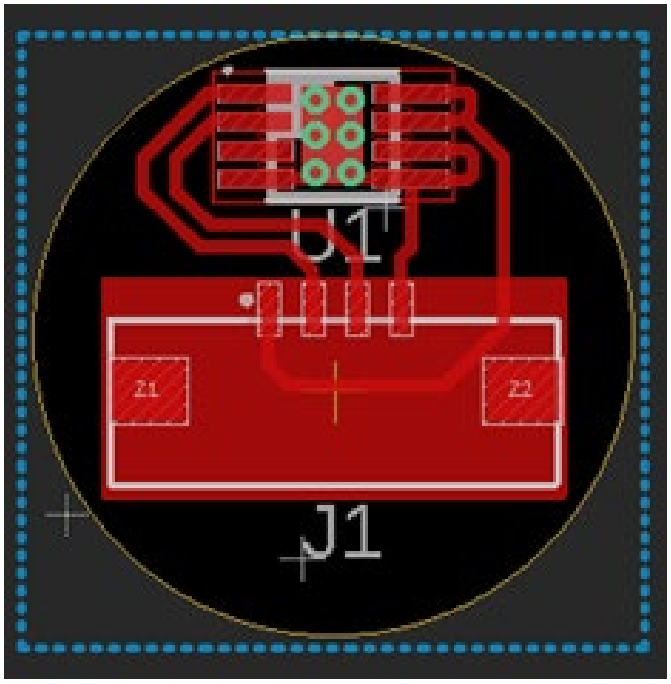
The objective of this project was to create Dolores, an age-appropriate chatbot for individuals living with chronic pain for two reason: to firstly analyse the intricacies of pain language in users across a large range, and secondly provide the user with a credible pain and general health education. The 'brain' of Dolores was developed during the vacation project to include topics such as pain history, social interactions, medications etc. Dolores also inquiries about the users pain, where it is located (via text or a drawing canvas), and what the pain feels like. Dolores is now being piloted at the Royal Brisbane and Women's Hospital and has had more than 15 chats with children, teenagers and adults about their pain.

Project: Smart foot monitoring for diabetic foot care and amputation prevention

Student: Thevindu Weerasuriya, Queensland University of Technology

Supervisor: Christian Redd

Diabetes is a global health issue, and nationally, with approximately five percent of Australians being diagnosed with diabetes. Resulting complications from diabetes such as poor vascularisation and peripheral neuropathy mean that foot trauma often goes unnoticed. If untreated it can lead to ulceration, which can be a risk factor for, precursor for or lead to amputation. This project focuses on the development of a wearable device for long term monitoring of foot temperature, which can be used to track the inflammatory response preceding ulceration. The differential temperature between corresponding contralateral sites of the foot is used to forecast ulceration.



Printed circuit board (PCB) design for the diabetic foot sensing system. Using a miniature temperature sensing integrated circuit (U1), the low profile PCB can be integrated into socks or footwear to continuously monitor skin health in persons at risk of diabetic ulcers.

A prototype of a low-power temperature monitoring wearable was created to evaluate the feasibility of foot temperature monitoring as a diagnostic tool. Initial trials were performed to test the performance of the prototype. The prototype behaves as expected, but further testing is required for prototype validation.

Project: Deriving empirical composite cognitive score via uniform manifold approximation and projection (UMAP)

Student: Erwin Chai, Curtin University

Supervisor: Rosita Shishegar

Dementia is a terminal illness and effective management of it is heavily reliant on early intervention. However, existing cognitive test scores that are used to track cognitive decline under-utilise existing information and hence may not be sensitive enough to track early cognitive decline. In this project, we proposed a data-driven cognitive composite score that is constructed using a non-linear dimension reduction technique known as Uniform Manifold Approximation and Projection (UMAP) to track cognitive decline in earlier stages of Alzheimer's Disease. The proposed score is shown to be effective at tracking cognitive decline in the early stages of the disease.

Project: Cortical surface retrieval via deformable models

Student: Darren Fu, University of Queensland

Supervisor: Rodrigo Santa Cruz, Leo Lebrat

In this short vacation project, we worked to adapt and apply Voxel2Mesh, a novel deep learning approach to model generation from volumetric data onto cortical surfaces. We achieved successful results with significantly reduced inference time in comparison to existing methods, but at reduced model resolution (number of vertices). Results from this work are to be used in a future approach to cortical surface modelling.

Examples of cortical surfaces estimated from an MR image using the developed model.

Project: Wrist fracture detection: An experimental study using deep learning to improve ED outcomes

Student: Aditya Gupta, University of Western Australia

Supervisor: Sajib Saha

The project's aim was to classify wrist radiographs as containing fractures/no fractures from both a large open sourced dataset, MURA, as well as a privately collected dataset by CSIRO from the public Fiona Stanley Hospital (FSH) in Western Australia. The exploration involved training multiple deep learning algorithms using Convolutional Neural Networks (CNNs), to assess the feasibility of CNN-based wrist fracture detection at the emergency department. The results justified the feasibility of such approach, and based on the results we have further collaboration agreement with the clinical partner to perform an extensive study including more radiographs along with implementation of advanced methodologies to justify the decision of CNN with that of human experts.

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 aims to harness 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 on 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: Professor S. S. Vasan, 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 knowledgebases of disease-associated variants 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 percent salary for a postdoc within the Genome Insights team for three 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: 2020–23

Chief Investigator: Professor David Coman, University of Queensland

AEHRC Investigators: Dr Jason Dowling

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

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

Years funded: 2020–24

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

AEHRC Investigators: Dr Simon Puttick, Professor Stephen Rose

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

National Health and Medical Research Council (NHMRC)

NHMRC Early diagnosis and early intervention for infants with cerebral palsy: implementation of international evidence-based guidelines into practice

Years funded: 2022–23

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: Exploiting anti-capsid humoral immunity induced in infants receiving gene therapy for Spinal Muscular Atrophy (NHMRC Marshall and Warren Ideas Grant Award)

Years funded: 2021–23

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 MRFF ICTC: The AUstralian-multidomain Approach to Reduce Dementia Risk by PrOtecting Brain Health With Lifestyle Intervention (AU-ARROW) study

Years funded: 2020–24

Chief Investigator: Professor Ralph Martins, Macquarie University

AEHRC Investigators/Chief Investigator G: Dr Samantha Burnham

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

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

Years funded: 2020–22

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

Collaboration Lead for JPND: Professor Daniel C Alexander, UCL

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

NHMRC Project Grant: Developing an innovative mobile health Avatar to enhance smoking cessation

Years funded: 2020–25

Chief 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 for Pulmonary disease

Years funded: 2020–21

Chief Investigator: Tamera Corte, University of Sydney

AEHRC Investigators: Dr Jason Dowling, Dr James Doecke

CSIRO assisted project investigators with statistical analysis of data from the Australian Idiopathic Pulmonary Fibrosis Registry and the development of a patient outcomes prediction tool.

NHMRC Centre for Research Excellence in Digital Health

Years funded: 2018–22

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: 2020–24

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 two years age.

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

Years funded: 2019–21

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 aims to evaluate the effects of "GAME" (Goals Activity Motor Enrichment, an early training intervention) versus traditional passive early intervention on gross and fine motor skills at two years of age. We will also evaluate the secondary outcomes of neuroplasticity on MRI, cognitive skills and quality of life.

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

Years funded: 2019–22 (Cancer Australia)

Chief Investigator: Professor Jarad Martin, University of Newcastle

AEHRC Investigators: Dr Jason Dowling

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

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

Years funded: 2019–21

AEHRC Investigators/Chief Investigator A: Dr Samantha Burnham

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

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

Years funded: 2019–24

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 (2014–19) and assessed using MRI and clinical assessments in the newborn period and at two years, will return for follow-up MRI and clinical assessments at six years. 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: 2019–24

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: Nanomedicine strategies for early detection and treatment of brain metastases

Years funded: 2019–21

Chief Investigator: Professor Sunil Lakhani, University of Queensland

AEHRC Investigators: Dr Simon Puttick, Professor Stephen Rose

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

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

Years funded: 2019–21

Chief Investigator: Associate Professor Simon Laws, Edith Cowen University

AEHRC Investigators/Chief Investigator: Dr Samantha Burnham

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

NHMRC Dementia Research ADNET

Years funded: 2018–23

Chief Investigator: Professor Chris Rowe

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

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

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

Years funded: 2018–21

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: 2018–21

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 two 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: 2017–22

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

Years funded: 2017–21

Chief Investigator: Professor Ashley Bush

AEHRC Investigators: Dr Pierrick Bourgeat, Dr Amir Fazlollahi

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

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

Years funded: 2016–21

Chief Investigator: Professor Michael Breakspear

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

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

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

Years funded: 2016–20

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

AEHRC Investigators: Dr Denis Bauer

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

NHMRC Australian Genomics Health Alliance

Years funded: 2016–21

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

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

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

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

Years funded: 2016–21

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

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

Australian Research Council

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

Years funded: 2020–22

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.

Publications 2020–21

Journal Papers

Note for readers: Due to system changes this list of publications is incomplete and a final list will be available on our website in due course

1. A. Nicolson, K. Paliwal, "On training targets for deep learning approaches to clean speech magnitude spectrum estimation", *The Journal of the Acoustical Society of America*, pp. 3273-3293, May 2021.

2. A. Fazlollahi, P. Bourgeat, P. Raniga, P. Yates, A. Bush, O. Salvado, S. Ayton, "Restricted effect of cerebral microbleeds on regional magnetic susceptibility", *Journal of Alzheimer's Disease*, pp. 571-577, Jul 2020.

3. A. Nicole, C. Chi-Wen, D. Ireland, M. Varnfield, "Overactivity assessment in chronic pain: The development and psychometric evaluation of a multifaceted self-report assessment", *European Journal of Pain*, pp. 225-242, Sep 2020.

4. H. Scells, G. Zuccon, B. Koopman, "Do better search engines really equate to better clinical decisions? If not, why not?", *Journal of the Association for Information Science and Technology*, pp. 0.

5. C. Farah, S. Fox, K. Shearston, L. Newman, Babic Sharon, M. Vacher, "Lichenoid dysplasia is not a distinct pathological entity", *Oral Oncology*, pp. 119, Jan 2021.

6. C. Snoswell, G. Chelberg, K. de Guzman, L. Caffery, H. Haydon, E. Thomas, A. Smith, "The clinical effectiveness of telehealth: A systematic review of meta-analyses from 2010 to 2019", *Journal of Telemedicine and Telehealth*, pp. 1-16, Jun 2021.

7. C. Dehghani, S. Frost, R. Jayasena, C. Fowler, C. Masters, Y. Kanagasingam, H. Jiao, J. Lim, H. Chinnery, L. Downie, "Morphometric changes to corneal dendritic cells in individuals with mild cognitive impairment", *Frontiers in Neuroscience*, pp. Article 556137, Dec 2020.

8. C. Groot, V. Dore, J. Robertson, S. Burnham, G. Savage, R. Ossenkoppele, C. Rowe, V. Villemagne, "Mesial temporal tau is related to worse cognitive performance and greater neocortical tau load in amyloid-β–negative cognitively normal individuals", *Neurobiology of Aging*, pp. 41-48, Jan 2021.

9. D. Ireland, D. Bradford, E. Szepe, E. Lynch, M. Martyn, D. Hansen, C. Gaff, "Introducing Edna: a trainee chatbot designed to support communication about additional (secondary) genomic findings", *Patient Education and Counseling*, pp. 739-749, Nov 2020.

10. D. Bauer, L. Wilson, "A Navigation System for Base Editing: Are We There Yet?", *The CRISPR Journal*, pp. 224-225, Jul 2020.

11. D. Bauer, A. Metke Jimenez, S. Maurer-Stroh, L. Wilson, Y. Jain, K. Ebrill, D. Hansen, V. Vasan, "Interoperable medical data: the missing link for understanding COVID-19", *Transboundary and Emerging Diseases*, pp. 18, Oct 2020.

12. D. Bauer, N. Twine, "Genetic Analysis of Tryptophan Metabolism Genes in Sporadic Amyotrophic Lateral Sclerosis", *Front. Immunol,,* pp. 701550, Jun 2021.

13. D. Kannenkeril, S. Frost, J. Nolde, M. Kiuchi, R. Carnagarin, L. Lugo-Gavidia, J. Chan, A. Joyson, V. Mathews, L. Herat, O. Azzam, M. Schlaich, "Microvascular Changes at Different Stages of Chronic Kidney Disease", *Journal of Clinical Hypertension*, pp. 309-316, Dec 2020.

14. E. Shen, A. Lord, J. Doecke, K. Hanigan, J. Irwin, R. Cheng, G. Radford-Smith, "A validated risk stratification tool for detecting high-risk small bowel Crohn's disease", *Aliment Pharmacol Ther* ., pp. 0.

15. E. Paige, K. Doyle, L. Jorm, E. Banks, M. Hsu, L. Nedkoff, T. Briffa, D. Cadilhac, R. Mahoney, J. Verjans, G. Dwivedi, M. Inouye, G. Figtree, "A Versatile Big Data Health System for Australia: Driving Improvements in Cardiovascular Health", *Heart, Lung and Circulation*, pp. 1-10, Jun 2021.

16. G. Chelberg, M. Neuhaus, A. Mothershaw, R. Mahoney, L. Caffery, “Mobile apps for dementia awareness, support, and prevention – review and evaluation”, *Disability and Rehabilitation*, pp. 1-12, May 2021.

17. G. Bischof, P. Bartenstein, H. Barthel, B. van Berckel, V. Dore, T. Van Eimeren, N. Foster, J. Hammes, A. Lammertsma, S. Minoshima, C. Rowe, O. Sabri, J. Seibyl, K. Van Laere, R. Vandenberghe, V. Villemagne, I. Yakushev, A. Drzezga, “Towards a Universal Readout for Fluorine-18 Labelled Amyloid Tracers: The CAPTAINs Study”, *The journal of Nuclear Medicine*, pp. 999-1005, Mar 2021.

18. H. Ding, R. Jayasena, S. Chen, A. Maiorana, A. Dowling, J. Layland, N. Good, M. Karunanithi, I. Edwards, “The effects of telemonitoring on patient compliance with self-management recommendations in chronic heart failure: outcomes of the ITEC-CHF study”, *Journal of Medical Internet Research*, pp. 12, Jul 2020.

19. H. Ding, S. Chen, I. Edwards, R. Jayasena, J. Doecke, J. Layland, I. Yang, A. Maiorana, “The effects of different telemonitoring strategies chronic heart failure care: systematic review and subgroup meta-analysis”, *Journal of Medical Internet Research*, pp. 20, Nov 2020.

20. H. Scells, G. Zuccon, B. Koopman, “A comparison of automatic Boolean query formulation for systematic reviews”, *Information Retrieval*, pp. 3-28, Oct 2020.

21. J. Nolde, M. Kiuchi, R. Carnagarin, S. Frost, D. Kannenkeril, L. Lugo-Gavidia, J. Chan, A. Joyson, V. Mathews, L. Herat, O. Azzam, M. Schlaich, “Supine blood pressure – A clinically relevant determinant of vascular target organ damage in hypertensive patients”, *Journal of Clinical Hypertension*, pp. 44-52, Dec 2020.

22. J. Buckley, J. Dowling, M. Sidhom, G. Liney, R. Rai, P. Metcalfe, L. Holloway, P. Keall, “Pelvic Organ Motion and Dosimetric Implications During Horizontal Patient Rotation for Prostate Radiation Therapy”, *Medical Physics*, pp. 397-413, Jan 2021.

23. J. Buckley, A. Smith, M. Sidhom, R. Rai, G. Liney, J. Dowling, P. Metcalfe, L. Holloway, P. Keall, “Measurements of Human Tolerance to Horizontal Rotation within an MRI Scanner: Towards Gantry-Free Radiation Therapy”, *Journal of Medical Imaging and Radiation Oncology*, pp. 112-119, Feb 2021.

24. J. Charng, D. Xiao, M. Mehdizadeh, M. Attia, S. Arunachalam, T. Lamey, J. Thompson, T. Mclaren, J. De Roach, D. Mackey, S. Frost, F. Chen, “Deep learning segmentation of hyperautofluorescent fleck lesions in Stargardt disease”, *Scientific Reports*, pp. Article 16491, Oct 2020.

25. J. Dowling, L. O’Connor, “Deformable Image Registration in Radiation Therapy”, *Journal of Medical Radiation Sciences*, pp. 257-259, Dec 2020.

26. J. Urriola Yaksic, P. Nichols, S. Miller, T. Bjorkman, K. Mahady, V. Vegh, F. Nasrallah, C. Winter, “Blood-brain barrier dysfunction significantly correlates with serum matrix metalloproteinase-7 (MMP-7) following traumatic brain injury”, *NeuroImage: Clinical*, pp. 102741-102749, Jun 2021.

27. J. Beaumont, G. Gambarota, S. Herve, O. Acosta, J. Ferre, P. Raniga, J. Fripp, “High resolution multi T1-weighted contrast and T1 mapping with reduced B1+ sensitivity using the FLAWS sequence at 7T”, *Magnetic Ressonance in Medicine*, pp. 1364-1378, Sep 2020.

28. J. George, P. Colditz, M. Chatfield, S. Fiori, K. Pannek, J. Fripp, A. Guzzetta, S. Rose, R. Ware, R. Boyd, “Early clinical and MRI biomarkers of cognitive and motor outcomes in very preterm born infants”, *Pediatric Research*, pp. 1-8, Feb 2021.

29. J. Mayer, R. Brown, K. Thielemans, E. Ovtchinnikov, E. Pasca, D. Atkinson, A. Gillman, P. Marsden, M. Ippoliti, M. Makowski, T. Schaeffter, C. Kolbitsch, “Flexible Numerical Simulation Framework for Dynamic PET-MR Data”, *Physics in Medicine and Biology*, pp. 145003, Jul 2020.

30. J. Woodford, A. Gillman, P. Jenvey, J. Roberts, S. Woolley, B. Barber, M. Fernandez, S. Rose, P. Thomas, N. Anstey, J. McCarthy, “Positron emission tomography and magnetic resonance imaging in experimental human malaria: greater early splenic tropism in Plasmodium vivax than Plasmodium falciparum infection”, *PLOS Medicine*, pp. e1003567, May 2021.

31. L. Ayton, J. Rizzo, I. Bailey, A. Colenbrander, G. Dagnelie, D. Geruschat, P. Hessburg, C. McCarthy, M. Petoe, G. Rubin, P. Troyk, M. Bach, N. Barnes, R. Ferris, C. Johnson, A. Bittner, J. Keeffe, D. Birch, L. Frishman, V. Odom, D. Rathbun, E. Cohen, I. Fine, R. Hornig, V. Bismuth, M. Jackson, S. McSweeney, C. Owsley, R. Finger, S. Bentley, J. Stelmack, M. Flax, J. Weiland, R. Woods, A. Kusnyerik, C. Mann, E. Zrenner, E. Fernandez, K. Stingl, L. Merabet, C. Abbott, P. Allen, A. Amedi, T. Brawn, P. Degenaar, J. Dorn, T. Edwards, C. Erickson-Davis, V. Gabel, D. Gamm, D. Goldman, R. Guymer, A. Jalligampala, J. Jolly, B. Lepri, Y. Mandel, F. O’Hare, P. Walter, J. Walker, “International Consensus Document for the “Harmonization of Outcomes and Vision Endpoints in Vision Restoration Trials” (HOVER) Taskforce”, *Translational Vision Science & Technology*, pp. 64, Jul 2020.

32. L. Beauchamp, V. Villemagne, D. Finkelstein, V. Dore, A. Bush, K. Barnham, C. Rowe, "Reduced striatal vesicular monoamine transporter 2 in REM sleep behavior disorder: imaging prodromal parkinsonism", *Scientific Reports*, pp. 1-7, Oct 2020.

33. L. van Eijk, N. Hansell, L. Strike, B. Couvy-Duchesne, G. de Zubicaray, P. Thompson, K. McMahon, B. Zietsch, M. Wright, "Region-specific sex differences in the hippocampus", *NeuroImage*, pp. 11, Jul 2020.

34. L. Selvadurai, N. Georgiou-Karistianis, R. Shishegar, C. Sheridan, G. Egan, M. Delatycki, E. Storey, I. Harding, L. Corben, "Longitudinal structural brain changes in Friedreich ataxia depend on disease severity: The IMAGE-FRDA Study", *Journal of Neurology*, pp. 12p, Apr 2021.

35. L. Lorenzi, H. Chiu, F. Cobos, S. Gross, P. Volders, R. Cannoodt, J. Nuytens, K. Vanderheyden, J. Anckaert, S. Lefever, A. Tay, E. de Bony, W. Trypsteen, F. Gysens, M. Vromman, T. Goovaerts, T. Hansen, S. Kuersten, N. Nijs, T. Taghon, K. Vermaelen, K. Bracke, Y. Saeys, T. Meyer, N. Deshpande, G. Anande, T. Chen, M. Wilkins, A. Unnikrishnan, K. De Preter, J. Kjems, J. Koster, G. Schroth, J. Vandesompele, P. Sumazin, P. Mestdagh, "The RNA Atlas expands the catalog of human non-coding RNAs", *Nature Biotechnology*, pp. 23, Jun 2021.

36. M. Bucci, I. Savitcheva, G. Farrar, G. Salvado, L. Collij, V. Dore, J. Gispert, R. Gunn, B. Hanseeuw, O. Hansson, R. Lhommel, J. Molinuevo, C. Rowe, C. Sur, C. Buckley, A. Nordberg, "A multisite analysis of the concordance between visual image interpretation and quantitative analysis of [18F] flutemetamol amyloid PET images", *European Journal of Nuclear Medicine*, pp. 2183-2199, Apr 2021.

37. M. Marcello, J. Denham, A. Kennedy, A. Haworth, A. Steigler, P. Greer, L. Holloway, J. Dowling, M. Jameson, D. Roach, D. Joseph, S. Gulliford, D. Dearnaley, M. Sydes, E. Hall, M. Ebert, "Increased dose to organs in urinary tract associates with measures of genitourinary toxicity in pooled voxel-wise analysis of 3 randomised phase 3 trials", *Frontiers in Oncology*, pp. 1-20, Jul 2020.

38. M. Marcello, J. Denham, A. Kennedy, A. Haworth, A. Steigler, P. Greer, L. Holloway, J. Dowling, M. Jameson, D. Roach, D. Joseph, Gulliford, D. S, S. D, H. M, E, M. Ebert, "Relationships between rectal and perirectal doses and rectal bleeding or tenesmus in pooled voxel-wise analysis of 3 randomised phase 3 trials", *Radiotherapy and Oncology*, pp. 281-292, Sep 2020.

39. M. Marcello, J. Denham, A. Kennedy, A. Haworth, A. Steigler, P. Greer, L. Holloway, J. Dowling, M. Jameson, D. Roach, D. Joseph, S. Gulliford, D. Dearnaley, M. Sydes, E. Hall, M. Ebert, "Reduced dose posterior to prostate predicts for increased treatment failure in pooled voxel-wise analysis of 3 randomised phase 3 trials", *International Journal of Radiation Oncology Biology Physics*, pp. 1304-1318, Dec 2020.

40. M. Simunovic, J. Boyle, P. Baker, B. Erbas, J. Davies, "Spatiotemporal characteristics of asthma emergency department presentations in diverse geographical and climatic regions, Queensland Australia.", *Emergency Medicine Australasia*, pp. 623-630, Nov 2020.

41. M. Simunovic, B. Erbas, J. Boyle, Baker Philip, J. Davies, "Characteristics of emergency patients admitted to hospital with asthma: A population-based cohort study in Queensland, Australia", *Emergency Medicine Australasia*, pp. Online Version of Record before inclusion in an issue, May 2021.

42. M. Varnfield, C. Redd, L. Higgins, R. Stoney, N. Scolari, R. Warwick, J. Iedema, J. Rundle, W. Dutton, "M♡THer, a mHealth System to Support Women with Gestational Diabetes Mellitus – Feasibility and Acceptability Study", *Diabetes Technology & Therapeutics*, pp. 358-366, Dec 2020.

43. H. Scells, G. Zuccon, B. Koopman, "Appraisal of digital home-based 6-Minute Walk Test for use in remote healthcare delivery", *European Heart Journal – Digital Health*, pp. 75-76, Mar 2021.

44. M. Cabanes-Creus, C. Hallwirth, A. Westhaus, B. Ng, S. Liao, E. Zhu, R. Navarro, G. Baltazar, M. Drouyer, S. Scott, G. Logan, G. Santilli, A. Bennett, S. Ginn, G. McCaughan, A. Thrasher, M. Agbandje-McKenna, I. Alexander, L. Lisowski, "Restoring the natural tropism of AAV2 vectors for human liver", *Science Translational Medicine*, pp. eaba3312, Sep 2020.

45. M. Cabanes-Creus, R. Navarro, S. Liao, G. Baltazar, M. Drouyer, E. Zhu, S. Scott, L. Wilson, I. Alexander, L. Lisowski, "Single amino acid insertion directs functional transduction of natural human liver tropic capsids to murine hepatocytes", *Molecular Therapy-Methods & Clinical Development*, pp. 607-620, Jun 2021.

46. M. Mehdizadeh, C. MacNish, D. Alonso Caneiro, J. Kugelman, M. Bennamoun, "Deep Feature Loss for OCT Image Denoising using Deep Neural Networks", *Biomedical Optics Express*, pp. 18, Apr 2021.

47. M. Jackson, M. Cavuoto, R. Schembri, V. Dore, V. Villemagne, M. Barnes, F. O'Donoghue, C. Rowe, S. Robinson, "Severe Obstructive Sleep Apnea Is Associated with Higher Brain Amyloid Burden: A Preliminary PET Imaging Study", *Journal of Alzheimer's Disease*, pp. 611-617, Nov 2020.

48. M. Lupton, G. Robinson, R. Adam, Rose, Stephen, G. Byrne, O. Salvado, N. Pachana, O. Almeida, K. Mcaloney, S. Gordon, P. Raniga, A. Fazlollahi, Y. Xia, A. Ceslis, S. Sonkusare, Y. Ren, Q. Zhang, M. Kholghi, M. Karunanithi, P. Mosley, J. Lv, J. Adsett, N. Garden, J. Fripp, N. Martin, C. Guo, M. Breakspear, "A prospective cohort study of prodromal Alzheimer's disease: Prospective Imaging Study of Ageing: Genes, Brain and Behaviour (PISA)", *NeuroImage: Clinical*, pp. 2213-1582, Dec 2020.

49. M. Estai, Walsh, Jennifer, K. Maddison, Shepherd, Kelly, D. Hillman, McArdle, Nigel, V. Baker, King, Stuart, Z. Al-Obaidi, Bamagoos, Ahmad, R. Parry, Langdon, Claire, R. Trzaskowski, Harris, Geraldine, K. Brookes, Blacker, David, P. Eastwood, "Sleep-disordered breathing in patients with stroke-induced dysphagia", *Journal of Sleep Research*, pp. e13179, Aug 2020.

50. M. Estai, Y. Kanagasingam, M. Mehdizadeh, J. Vignarajan, R. Norman, B. Huang, H. Spallek, M. Irving, A. Arora, E. Kruger, M. Tennant, "Mobile Photographic Screening for Dental Caries in Children: Diagnostic Performance Compared to Unaided Visual Dental Examination", *Journal of Public Health Dentistry*, pp. 1-10, Jan 2021.

51. N. Krishnadas, V. Dore, F. Lamb, C. Groot, P. McCrory, R. Guzman, R. Mulligan, K. Huang, M. O'Donnell, J. Ponsford, M. Hopwood, V. Villemagne, C. Rowe, "Case Report: 18F-MK6240 Tau Positron Emission Tomography Pattern Resembling Chronic Traumatic Encephalopathy in a Retired Australian Rules Football Player", *frontiers in Neurology*, pp. 598980-598980, Dec 2020.

52. N. Krishnadas, V. Villemagne, V. Dore, C. Rowe, "Advances in Brain Amyloid Imaging", *Seminars in Nuclear Medicine*, pp. 241-252, Jan 2021.

53. N. Gholizadeh, J. Simpson, S. Ramadan, J. Denham, P. Lau, S. Siddique, J. Dowling, J. Welsh, S. Chalup, P. Greer, "Voxel based supervised machine learning of peripheral zone prostate cancer using non-contrast multiparametric MRI", *Journal of Applied Clinical Medical Physics*, pp. 179-191, Oct 2020.

54. P. Wright, S. Scott, S. Shetty, B. Kahler, L. Walsh, "Resistance to compressive force in continuous chelation", *Australian Endodontic Journal*, pp. 0, Sep 2020.

55. P. Bourgeat, V. Dore, J. Doecke, D. Ames, C. Masters, C. Rowe, J. Fripp, V. Villemagne, "Non-negative matrix factorization improves Centiloid robustness in longitudinal studies", *NeuroImage*, pp. 117593, Feb 2021.

56. P. Gates, K. Gough, H. Dhillon, C. Wilson, E. Hawkes, V. Dore, Y. Perchyonok, C. Rowe, A. Walker, J. Vardy, M. de Ruiter, M. Krishnasamy, "Longitudinal exploration of cancer-related cognitive impairment in patients with newly diagnosed aggressive lymphoma: protocol for a feasibility study", *BMJ Open*, pp. 1-9, Sep 2020.

57. R. Austin, M. Quinn, C. Afoakwah, A. Metke Jimenez, H. Leroux, J. Atherton, J. Brown, L. Wornham, I. Macciocca, M. de Silva, T. Thompson, E. Martin, D. Hilton, S. Devery, K. Wu, M. Jackson, G. Correnti, A. Overkov, S. Elbracht-Leong, J. Ingles, P. Scuffham, C. Semsarian, J. McGaughran, "Investigation of current models of care for genetic heart disease in Australia: A national clinical audit", *International Journal of Cardiology*, pp. 0.

58. R. Mito, T. Dhollander, Y. Xia, D. Raffelt, O. Salvado, L. Churilov, C. Rowe, A. Brodtmann, V. Villemagne, A. Connelly, "In vivo microstructural heterogeneity of white matter lesions in healthy elderly and Alzheimer's disease participants using tissue compositional analysis of diffusion MRI data", *NeuroImage: Clinical*, pp. Article 102479, Oct 2020.

59. R. Finnegan, L. Orlandini, X. Liao, J. Yin, J. Lang, J. Dowling, D. Fontanarosa, "Feasibility of using a novel automatic cardiac segmentation algorithm in the clinical routine of lung cancer patients", *PLoS ONE*, pp. e0245364, Jan 2021.

60. R. Finnegan, E. Lorenzen, J. Dowling, I. Jensen, M. Berg, M. Thomsen, G. Delaney, E. Koh, D. Thwaites, C. Brink, B. Offersen, L. Holloway, "Analysis of cardiac substructure dose in a large, multi-centre danish breast cancer cohort (the DBCG HYPO trial): Trends and predictive modelling", *Radiotherapy & Oncology*, pp. 130-138, Dec 2020.

61. H. Scells, G. Zuccon, B. Koopman, "Understanding Inherent Image Features in CNN-based assessment of diabetic retinopathy", *Scientific Reports*, pp. 1-12, May 2021.

62. R. Kumar, A. Nicolson, K. Paliwal, "DeepLPC: A Deep Learning Approach to Augmented Kalman Filter-Based Single-Channel Speech Enhancement", *IEEE Access*, pp. 64524-64538, Apr 2021.

63. R. Kumar, A. Nicolson, K. Paliwal, "DeepLPC-MHANet: Multi-Head Self-Attention for Augmented Kalman Filter-Based Speech Enhancement", *IEEE Access*, pp. 70516-70530, May 2021.

64. S. Saha, Y. Kanagasingam, "Visualizing and Understanding Inherent Features in SD-OCT for the Progression of Age-related Macular Degeneration using Deconvolutional Neural Networks", *Applied AI Letters*, pp. 1-11, Oct 2020.

65. S. Bullich, N. Roé-Vellvé, M. Marquié, S. Landau, H. Barthel, V. Villemagne, Á. Sanabria, J. Tartari, O. Sotolongo-Grau, V. Dore, N. Koglin, A. Müller, A. Perrotin, A. Jovalekic, S. De Santi, L. Tárraga, A. Stephens, C. Rowe, O. Sabri, J. Seibyl, M. Boada, "Early detection of amyloid load using 18F-florbetaben PET", *Alzheimer's Research & Therapy*, pp. 1-15, Apr 2021.

66. S. Abu, S. Saha, G. Rahaman, Atiqur, T. Ghosh, Y. Kanagasingam, "An Innovate Approach for Retinal Blood Vessel Segmentation using Mixture of Supervised and Unsupervised Methods", *IET Image Processing*, pp. 180-190, Nov 2020.

67. S. Hussain, D. Silvera, G. Farr-Wharton, "Technology Assessment Framework for Precision Health Applications", *International Journal of Technology Assessment in Health Care*, pp. e67, May 2021.

68. S. Moussavi Nik, T. Porter, M. Newman, B. Bartlett, I. Khan, M. Sabale, M. Eccles, A. Woodfield, D. Groth, V. Dore, V. Villemagne, C. Masters, R. Martins, R. Laws, M. Lardelli, G. Verdile, "Relevance of a Truncated PRESENILIN 2 Transcript to Alzheimer's Disease and Neurodegeneration", *Journal of Alzheimer's Disease*, pp. 1479-1489, Apr 2021.

69. S. Frost, J. Nolde, J. Chan, A. Joyson, C. Gregory, R. Carnagarin, L. Herat, V. Mathews, L. Robinson, J. Vignarajan, D. Prentice, Y. Kanagasingam, M. Schalich, "Retinal capillary rarefaction is associated with arterial and kidney damage in hypertension", *Scientific Reports*, pp. Article 1001, Jan 2021.

70. S. Zhang, S. Yang, P. Xu, G. Zhou, X. Ou, R. We, M. Lan, D. Fontanarosa, X. Wang, J. Dowling, S. Lin, J. Yi, Y. Sun, C. Hu, J. Lang, "Variations of Clinical Target Volume Delineation for Primary Site of Nasopharyngeal Cancer among Five Centers in China", *Frontiers in Oncology*, pp. 1572, Aug 2020.

71. V. Buss, S. Leesong, M. Varnfield, M. Barr, M. Harris, "Primary prevention of cardiovascular disease and type 2 diabetes mellitus using mobile health technology: a systematic review of the literature", *Journal of Medical Internet Research*, pp. e21159, Oct 2020.

72. V. Villemagne, B. Lopresti, V. Dore, D. Tudorascu, M. Ikonomovic, S. Burnham, D. Minhas, T. Pascoal, S. Mason, B. Snitz, H. Aizenstein, C. Mathis, O. Lopez, C. Rowe, W. Klunk, A. Cohen, "What Is T+? A Gordian Knot of Tracers, Thresholds, and Topographies", *The Journal of Nuclear Medicine*, pp. 614-619, May 2021.

73. V. Dore, N. Krishnadas, P. Bourgeat, K. Huang, S. Li, S. Burnham, C. Masters, J. Fripp, V. Villemagne, C. Rowe, "Relationship between amyloid and tau levels and its impact on tau spreading", *European Journal of Nuclear Medicine and Molecular Imaging*, pp. 2225-2232, Feb 2021.

74. W. Ghandourh, J. Dowling, P. Chlap, A. Oar, S. Jacob, V. Batumalai, L. Holloway, "Assessing Tumour Centrality in Lung Stereotactic Ablative Body Radiotherapy (SABR): The Effects of Variations in Bronchial Tree Delineation and Potential for Automated Methods", *Medical Dosimetry*, pp. 94-101, Feb 2021.

Conferences

1. A. Tay, C. Hosking, B. Hosking, S. Scott, D. Reti, A. O'Brien, D. Bauer, L. Wilson, "Developing a computational safegard to detect gene drivers in wild populations", *ABACBS*, Virtual, 24 to end of 26 Nov 2020.

2. A. Fazlollahi, P. Raniga, P. Bourgeat, P. Yates, A. Bush, O. Salvado, S. Ayton, "Limited cerebral microbleeds effect on regional magnetic susceptibility measured by MRI", *Alzheimer's Association International Conference*, virtual, July 27, 2020.

3. B. Brown, M. Vacher, L. Milicic, T. Porter, S. Rainey-Smith, M. Peretti, H. Sohrabi, R. Martins, J. Peiffer, S. Laws, "Alzheimer's disease-related gene expression is reduced following six months of high-intensity exercise", *Australian Dementia Forum*, Adelaide, 31/05/2020.

4. B. Yu, L. Zhou, L. Wang, W. Yang, M. Yang, P. Bourgeat, J. Fripp, "Learning Sample-adaptive Intensity Lookup Table for Brain Tumor Segmentation", *MICCAI*, Lima, Peru, October 4th to 8th, 2020.

5. C. Chris, D. Silvera, "Robot handshake in space: touch and liveness-to-hand in human-technology relations", *Robophilosophy*, Aarhus University, Denmark, 18-21 August 2020.

6. D. Bauer, L. Wilson, N. Twine, D. Reti, B. Hosking, A. Tay, Y. Jain, S. Scott, P. Szul, L. Sng, P. Ramarao-Milne, "When DNA meets the cloud: supercharging human health research", *AWS Community day*, virtual, 22 Mar 2021.

7. D. Bauer, L. Wilson, N. Twine, D. Reti, B. Hosking, A. Tay, Y. Jain, S. Scott, P. Szul, L. Sng, P. Ramarao-Milne, "Scaling Machine Learning to Uncover the Genome's Role in Complex Diseases", *AWS Global Health Care and Life Science Day*, virtual, 18 May 2021.

8. D. Bauer, L. Wilson, N. Twine, D. Reti, B. Hosking, A. Tay, Y. Jain, S. Scott, P. Szul, L. Sng, P. Ramarao-Milne, "Artificial intelligence solutions for COVID-19 knowledge discovery", *Precision Medicine Conference*, virtual, 21 May 2021.

9. D. Bauer, L. Wilson, N. Twine, D. Reti, B. Hosking, A. Tay, Y. Jain, S. Scott, P. Szul, L. Sng, P. Ramarao-Milne, "Cloud-based Machine Learning for Genome Engineering", *ITEEE EMBS*, virtual, 14 Jun 2021.

10. D. Bauer, L. Wilson, N. Twine, D. Reti, B. Hosking, A. Tay, Y. Jain, S. Scott, P. Szul, L. Sng, P. Ramarao-Milne, "Scaling Machine Learning to Uncover the Genome's Role in Complex Diseases", *Precision Medicine Leaders Forum*, virtual, 21 Jun 2021.

11. D. Bauer, L. Wilson, N. Twine, D. Reti, B. Hosking, A. Tay, Y. Jain, S. Scott, P. Szul, L. Sng, P.≈Ramarao-Milne, "Cloud-based Machine Learning in the fight against COVID-19", *Digital Health festival*, virtual, 21 Jun 2021.

12. D. Vaghjiani, S. Saha, Y. Connan, S. Frost, Y. Kanagasingam, "Visualizing and Understanding Inherent Image Features in CNN-based Glaucoma Detection", *Digital Image Computing: Techniques and Applications (DICTA)*, Lima, Peru, 4/10/2020 to 8/10/2020.

13. E. Kenny, H. Hassanzadeh, S. Khanna, J. Boyle, S. Louise, "Patient flow simulation using historically informed synthetic data", *Digital Health Institute Summit*, Brisbane, 10-25 November 2020.

14. F. Rusak, R. Fonseca de Santa Cruz Oliveira, P. Bourgeat, J. Fripp, O. Salvado, "3D Brain MRI GAN-Based Synthesis Conditioned on Partial Volume Maps", *Simulation and Synthesis in Medical Imaging – MICCAI*, Lima, Peru (Online), 04/10/2020.

15. G. Farr-Wharton, J. Li, S. Hussain, J. Freyne, "Mobile Supported Health Services: Experiences in Orthopaedic care", *IEEE Computer-based Medical Systems 2020*, Rochester, MN, USA, 22-24 June 2020.

16. H. Qambari, S. Saha, S. Seal, C. Dehghani, K. Edwards, N. Pritchard, A. Russell, R. Malik, N. Efron, M. Tennant, Y. Kanagasingam, S. Frost, "Longitudinal analysis of retinal microvascular changes and its association with diabetic retinopathy", *ARVO 2021*, Virtual event, 2-5 May 2021.

17. H. Leroux, "Pathology and Clinical Data Integration for Infectious Disease Monitoring in a Hospital Setting", *The Australasian Instititute of Digital Health Summit*, Virtual Summit across five Australian cities, 05 to end of 26 Nov 2020.

18. J. Hughes, N. Brown, T. Vu, A. Nguyen, "Towards Automatic and Interpretable Assignments of Patients Presenting with Pain to the Emergency Department", *Digital Health Institute Summit 2020*, Brisbane, 10-25 November 2020.

19. K. Loi, D. Truran, M. Zhang, "ECL in the wild: Making ECL work in practice", *SNOMED CT Expo*, Virtual, 08 October 2020.

20. L. Milicic, M. Vacher, T. Porter, V. Dore, V. Villemagne, J. Doecke, S. Laws, "Disproportionate biological ageing and Alzheimer's disease phenotypes in the AIBL cohort", *Australian Society for Medical Research*, Perth, 20 to end of 23 May 2021.

21. H. Scells, G. Zuccon, B. Koopman, "Self-reported sleep and hippocampus volume relationship in mid-life to older cognitively unimpaired individuals", *Australian Dementia Forum 2021*, Online, 31 May 2021.

22. H. Scells, G. Zuccon, B. Koopman, "The association between self-reported sleep and hippocampus volume in mid-life to older cognitively unimpaired individuals", *The Alzheimer's Association International Conference 2021*, Amsterdam, Netherlands and Online, 25 July 2021.

23. M. Estai, M. Watson, Y. Kanagasingam, J. Daire, J. Grigg, P. McCluskey, "Incentives and barriers to diabetic retinopathy screening in Australian general practices", *Association for Research in Vision and Ophthalmology (ARVO)*, USA virtual, 06 May 2020.

24. P. Bourgeat, V. Dore, D. Ames, R. Martins, C. Masters, C. Rowe, J. Fripp, V. Villemagne, "Improved Centiloid robustness using non-negative matrix factorisation", *AAIC*, Amsterdam, Netherlands, Jul 26-30, 2020.

25. R. Fonseca de Santa Cruz Oliveira, L. Lebrat, P. Bourgeat, C. Fookes, J. Fripp, O. Salvado, "DeepCSR: A 3D Deep Learning Approach for Cortical Surface Reconstruction", *The IEEE Winter Conference on Applications of Computer Vision (WACV))*, Virtual, 5-9 January 2021.

26. R. Fonseca de Santa Cruz Oliveira, L. Lebrat, P. Bourgeat, V. Dore, J. Dowling, J. Fripp, C. Fookes, O. Salvado, "Going Deeper With Brain Morphometry Using Neural Networks", *2021 IEEE 18th International Symposium on Biomedical Imaging (ISBI)*, Nice, France, 13-16 April 2021.

27. S. Saha, M. Watson, C. Dehghani, K. Edwards, N. Pritchard, R. Malik, N. Efron, S. Frost, Y. Kanagasingam, "Artificial Intelligence-based Detection of Diabetic Retinopathy using Retinal Imaging and Traditional Risk Factors", *ARVO 2021*, In-person (San Francisco) and virtual, 2-6 May.

28. S. Ayton, M. Woodward, K. Ellis, Y. Lim, P. Maruff, P. Desmond, O. Salvado, A. Fazlollahi, A. Bush, "Deferiprone to delay dementia (The 3D trial)", *Alzheimer's Association International Conference*, virtual, 27 July 2020.

29. T. Vu, N. Dat Quoc, A. Nguyen, "A Label Attention Model for ICD Coding from Clinical Text", *The 29th International Joint Conference on Artificial Intelligence*, Yokohama, Japan / Virtual, 11-17/07/2020.

30. V. Lo, V. Dore, Y. Xia, A. Fazlollahi, P. Bourgeat, V. Villemagne, Rowe Christopher, J. Fripp, E. Coulson, "Basal forebrain atrophy and tau pathology occur prior to hippocampal atrophy in prodromal AD", *Alzheimer's Association International Conference*, Virtual Event, July 27-31, 2020.

31. Y. Jain, B. Hosking, N. Twine, L. Wilson, A. Zarnegar, M. Rophina, V. Scaria, D. Bauer, "sBeacon: cloud-native genomic data exchange", *ABACBS-2020*, Virtual, 24 November 2020.

32. Y. Xiao, D. Silvera, M. Pagnucco, "Autonomous Behaviour Planning for Socially-Assistive Robots in Therapy and Education", *Australasian Conference on Robotics and Automation*, Brisbane, December 7.

33. Y. Xia, A. Fazlollahi, P. Yates, N. Yassi, P. Desmond, O. Salvado, V. Villemagne, C. Rowe, J. Fripp, C. Masters, P. Raniga, "Amyloid angiopathy may contribute to white-matter hyperintensities in Alzheimer's disease", *Alzheimer's Association International Conference*, Amsterdam, Netherlands, July 26-30, 2020.

34. Z. O'Reilly, D. Silvera, D. Tan, I. Zurr, "Validation of a Novel Theory of Mind Measurement Tool: The Social Robot Video Task", *International Conference on Human-Robot Interaction*, USA, 8 March 2021.

Reports

1. A. Thabit, P. Bourgeat, “PET Image Harmonization Using Conditional GANs”, CSIRO Internal Report Number: EP207593, Sep 2020.

2. B. Koopman, D. Bradford, D. Hansen, “Exemplars of Artificial Intelligence and Machine Learning in Healthcare: Improving the safety, quality, efficiency and accessibility of Australia’s healthcare system”, CSIRO Internal Report Number: EP203543, Jul 2020.

3. Y. Gao, M. Kholghi, I. Koprinska, Q. Zhang, “AEHRC: Progress against 2017-2022 Strategy Goals”, CSIRO Internal Report Number: EP2021-0334.

4. G. Farr-Wharton, D. Silvera, S. Hussain, “Precision Health Innovation Assessment Framework”, CSIRO Internal Report Number: EP204254, Aug 2020.

5. J. Atherton, D. Bradford, A. Metke Jimenez, D. Hansen, “Digital tools to support patients and clinicians through the genomics journey”, CSIRO Internal Report Number: EP208712, Dec 2020.

6. J. Boyle, R. Sparks, A. Nguyen, T. Vu, “Final Report – SA Syndromic Surveillance Initial Pilot Activities”, CSIRO Internal Report Number: EP206532, Aug 2020.

7. J. Boyle, J. Vignarajan, “Progress Report on CRCNA Project H.5.1718035 Lessons Learnt to Date – What have we learnt 2 years in?”, CSIRO Internal Report Number: EP207119, Sep 2020.

8. L. Lorenzi, H. Chiu, F. Cobos, S. Gross, P. Volders, R. Cannoodt, J. Nuytens, K. Vanderheyden, J. Anckaert, S. Lefever, A. Tay, E. de Bony, W. Trypsteen, F. Gysens, M. Vromman, T. Goovaerts, T. Hansen, S. Kuersten, N. Nijs, T. Taghon, K. Vermaelen, K. Bracke, Y. Saeys, T. Meyer, N. Deshpande, G. Anande, T. Chen, M. Wilkins, A. Unnikrishnan, K. De Preter, J. Kjems, J. Koster, G. Schroth, J. Vandesompele, P. Sumazin, P. Mestdagh, “Syndromic Surveillance and Analytics to inform the health system during pandemics and other disasters”, CSIRO Internal Report Number: EP2021-1198.

9. M. Simunovic, B. Erbas, J. Boyle, Baker Philip, J. Davies, “Statistical Process Control for Quality and Safety Monitoring”, CSIRO Internal Report Number: EP2021-1008.

10. K. Mann, H. Hassanzadeh, A. Brankovic, S. Khanna, N. Good, “Predicting Patient Deterioration”, CSIRO Internal Report Number: EP2021-1127.

11. K. Loi, D. Truran, M. Kemp, R. Richards, M. Zhang, K. Ebrill, M. Lawley, “Genomics community project”, CSIRO Internal Report Number: EP211000, Feb 2021.

12. H. Scells, G. Zuccon, B. Koopman, “Evaluating the impact on genetic services of paediatrician requested genomic testing”, CSIRO Internal Report Number: EP21543, Dec 2020.

13. M. Estai, J. Vignarajan, Y. Kanagasingam, “Final progress report for Financial Market Foundation for Children”, CSIRO Internal Report Number: EP211387.

14. N. Krishnadas, V. Villemagne, V. Dore, C. Rowe, “Hospital Standardised Mortality Ratio (HSMR) for summary mortality reporting. Usability and alternative approaches.”, CSIRO Internal Report Number: EP2021-1557.

15. N. Krishnadas, V. Villemagne, V. Dore, C. Rowe, “Risk-adjustment models for unplanned readmission indicators. Jurisdictional scan of the literature and discussion of methodological approaches.”, CSIRO Internal Report Number: EP2021-1558.

16. S. Louise, D. Rolls, S. Khanna, N. Good, R. Jayasena, “Return to acute care following hospitalisation for Total Hip Replacement and AMI: Exploring initial risk adjusted models”, CSIRO Internal Report Number: EP206985, Sep 2020.

17. S. Khanna, H. Hassanzadeh, “COVID-19 Analytics”, CSIRO Internal Report Number: EP2021-1128.

18. S. Frost, J. Vignarajan, M. Estai, H. Hassanzadeh, J. Boyle, S. Louise, S. Khanna, D. Hansen, “2020 CSIRO ATRDG Projects, Interim Reports reporting progress to November 2020”, CSIRO Internal Report Number: EP21082, Jan 2021.

19. H. Scells, G. Zuccon, B. Koopman, “Retinal Imaging in Resistant Hypertension – Project Final Report”, CSIRO Internal Report Number: EP21685, Feb 2021.

AEHRC – our people, students and visitors

Our people

Dr David Hansen, Chief Executive Officer

Dr Jill Freyne, Deputy Research Director

Ms Marianne Chalk, Program Support Officer/ Office Manager

Dr Janet Fox, Business Development Manager

Ms Ofa Fitzgibbons, Communications Advisor

Ms Katie Forestier, Project Development Analyst

Indigenous Health

Dr Ray Mahoney, Senior Research Scientist, Indigenous Health

Ms Georgina Chelberg, PhD Candidate

Mr Andrew Goodman, PhD Candidate

Dr Kaley Butten, Postdoctoral Fellow (QAIHC/AEHRC)

Mr Jed Fraser, PhD Candidate

Health Informatics Group

Dr Michael Lawley, Group Leader and Principal Research Scientist

Mr Derek Ireland, Team Leader and Senior Software Engineer

Dr Anthony Nguyen, Team Leader and Principal Research Scientist

Dr Alejandro Metke, Team Leader and Senior Research Scientist

Ms Kylynn Loi, Team Leader and Senior Research Scientist

Dr Jim Steel, Team Leader and Senior Software Engineer

Ms Kate Ebrill, Product Manager, Clinical Terminology

Mr Dion McMurtrie, Principal Research Consultant

Dr Hugo Leroux, Senior Research Scientist

Ms Donna Truran, Senior Engineer

Dr Andrew Patterson, Senior Research Scientist

Dr Hoa Ngo, Research Scientist

Ms Madonna Kemp, Senior Engineer

Ms Robyn Richards, Senior Research Scientist

Mr Matthew Cordell, Research Consultant

Dr Bevan Koopman, Senior Research Scientist

Dr Thanh Vu, Postdoctoral Fellow

Mr Ming Zhang, Senior Engineer

Mrs Deanne Ukovich, Senior Engineer

Mr Simon Gibson, Senior Engineer

Ms Karen Harrap, Senior Engineer

Dr Elizabeth Cooper-Williams, Senior Engineer

Ms Tracey Wright, Senior Software Engineer

Mr John Grimes, Principal Research Consultant

Mr Attila Edelenyi, Senior Experimental Scientist

Mr David Conlan, Senior Software Engineer

Dr David Ireland, Senior Research Scientist

Dr Linda Bird, Visiting Scientist

Leibo Liu, Postgraduate Student

Jinghui Liu, Postgraduate Student

David Fraile Navarro, Postgraduate Student

Oisin Fitzgerald, Postgraduate Student

Health System Analytics Group

Dr Rajiv Jayasena, Group Leader and Principal Research Consultant

Mr Norm Good, Team Leader and Principal Research Consultant

Dr Sankalp Khanna, Team Leader and Principal Research Scientist

Dr Kay Mann, Postdoctoral Fellow

Ms Philippa Niven, Senior Experimental Scientist

Dr Justin Boyle, Principal Research Scientist

Dr Hamed Hassanzadeh, Research Scientist

Dr Marcela Cespedes, Research Scientist

Dr David Rolls, Senior Research Scientist

Ms Kristin Edwards, Postgraduate Student

James Kemp, Postgraduate Student

Dr Vahid Riahi, Postdoctoral Fellow

Dr Aida Brankovic, Research Scientist

Biomedical Informatics Group

Dr Jurgen Fripp, Group Leader and Principal Research Scientist

Dr Jason Dowling, Team Leader and Principal Research Scientist

Dr Vincent Doré, Team Leader and Senior Research Scientist

Dr James Doecke, Team Leader and Principal Research Scientist

Dr Dana Kai Bradford, Team Leader 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 Jeremy Beaumont, Postgraduate Student

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, Postdoctoral Fellow

Ms Julie Trinder, Research Assistant

Dr Rodrigo Santa Cruz, Postdoctoral Fellow

Dr Rosita Shishegar, Postdoctoral Fellow

Dr Miranda Li, Postdoctoral Fellow

Dr Simon Puttick, Senior Research Scientist

Dr. Léo Lebrat, Postdoctoral Fellow

Dr Shenpeng Li, Postdoctoral Fellow

Vanessa Lo, Postgraduate Student

Dr Timothy Cox, Postdoctoral Fellow

Dr Janine Walker, Senior Research Scientist

Mr Abdullah Thabit, Masters Student

Dr Hang Min, Affiliate Postdoc

Ms Szenung Leung, Postgraduate Student

Mr Siyu Liu, Postgraduate Student

Dr Philip Mosley, Research Scientist

Dr Aaron Nicolson, CERC Postdoctoral Fellow

Ms Nancy Kaur, Postgraduate Student

Darren Fu, Industrial Trainee

Mr Febrio Lunardo, Postgraduate Student

Liza van Eijk, Visiting Scientist (Affiliate)

Javier Urriola Yaksic, CERC Postdoctoral Fellow

Jake Palmer, CERC Postdoctoral Fellow

Filip Rusak, Postgraduate Student

Transformational Bioinformatics Group

Dr Denis Bauer, Group Leader and Senior Research Scientist

Dr Natalie Twine, Team Leader

Dr Laurence Wilson, Team Leader

Mr Brendan Hosking, Engineer

Dr Aidan Tay, Postdoctoral Fellow

Dr Suzanne Scott, Postdoctoral Fellow

Mr Yatish Jain, IT Advisor

Ashleigh Geiger, Postgraduate Student

Mr Mischa Lundberg, Postgraduate Student

Jacob Bradford, Postgraduate Student

Andrey Verich, Postgraduate Student

Letitia Sng, CERC Postdoctoral Fellow

Dr Priya Ramarao-Milne, CERC Postdoctoral Fellow

Aravind Venkateswaran, Industrial Trainee

Carol Lee, CERC Postdoctoral Fellow

Health Services Group

Dr Mohan Karunanithi, Group Leader and Principal Research Scientist

Dr Marlien Varnfield, Team Leader and Senior 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, Senior Research Scientist

Dr Jane Li, Senior Experimental Scientist

Dr Christian Redd, Research Scientist

Miss Vanessa Smallbon, Engineer

Dr Mahnoosh Kholghi, Postdoctoral Fellow

Ms Julia Bomke, Project Support Service Centre Officer

Ms Liesel Higgins, Project Manager Research and Development

Ms Parvaneh Shayegh Boroujeni, Postgraduate Student

Dr Mohamed Estai, Postdoctoral Fellow

Ms Yashodhya Wijesinghe, Postgraduate Student

Saminda Balasuriya, PhD Student

Dr Wei Lu, Postdoctoral Fellow

Dr Angelina Duan, Postdoctoral Fellow

Dr Sajib Saha, Research Scientist

Ms Maryam Mehdizadeh, Senior Software Engineer

Ms Vera Buss, Postgraduate Student

Yang Gao, Postgraduate Student

Hassanain Qambari, Postgraduate Student

Janis Nolde, Postgraduate Student

Basheer Bennamoun, Volunteer Fellow

Future Science Platform

Prof Stephen Rose, Future Science Platform Leader

Vacation Scholarship Students

Mr Saurav Kumar, University of Queensland

Mr Thevindu Weerasuriya, Queensland University of Technology

Mr Juhua Huang, University of Queensland

Tze Yong Chai, Curtin University

Mr Chanon Kachornvuthidej, University of Queensland

Ms Lucinda Nott, Queensland University of Technology

Aditya Gupta, University of Western Australia

Mr Lachlan O'Neil, Monash University

Mr Aviral Jain, University of Queensland

Ms Leonie Dickson, University of New South Wales

Mr Darren Fu, University of Queensland

Mr Min Han Quah, University of Wollongong

Visitors

Prof Mark Braunstein, Georgia Institute of Technology, Atlanta, USA
July 2018 – June 2021

Kun Huang, Site Visitor
December 2019 – current

Dr Linda Bird, Visiting Scientist
March 2021 – Current

Liza van Eijk, Visiting Scientist
November 2019 – December 2020

Support

Finance
Kellie Tighe

HR
Laurie Mackenzie

Finance Support
Rebecca Mok
Kim Tran

Contract Support
Sandy Farnworth

Health, Safety and Environment Support
Megan Tilley

Special Purpose Financial Report

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

SPECIAL PURPOSE FINANCIAL REPORT

30 JUNE 2021

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 2021 and its performance for the year ended on that date in accordance with the terms of the joint venture agreement and the accounting policies described in Note 1 to the financial statements.

This declaration is made in accordance with a resolution of the Board.

Director

Victoria
Date: 23 August 2021

Director

Brisbane
Date: 13 AUG 2021

Director

Victoria
Date: 23 August 2021

Director

Brisbane
Date: 13 AUG 2021

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 2021, 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 2021 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.

Chatswood Office:
Suite 302, 12 Help Street Chatswood NSW 2067 Australia
PO Box 5485 West Chatswood NSW 1515 Australia
T 61 2 9410 6999

Katoomba Office:
94 Lurline Street Katoomba NSW 2780 Australia
PO Box 670 Katoomba NSW 2780 Australia
T 61 2 4782 2587

mail@trumans.com.au | www.trumans.com.au | ABN 19 787 119 376

- 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

Trumans

Peter Bray
Partner

Chatswood

Dated: 24 August 2021

Chatswood Office:
Suite 302, 12 Help Street Chatswood NSW 2067 Australia
PO Box 5485 West Chatswood NSW 1515 Australia
T 61 2 9410 6999

Katoomba Office:
94 Lurline Street Katoomba NSW 2780 Australia
PO Box 670 Katoomba NSW 2780 Australia
T 61 2 4782 2587

mail@trumans.com.au | www.trumans.com.au | ABN 19 787 119 376

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us
1300 363 400
csiro.au/contact
csiro.au

For further information
The Australian e-Health Research Centre
Surgical Treatment and Rehabilitation Service – STARS Building
296 Herston Road
Herston QLD 4029 Australia

+61 7 3253 3600
enquiries@aehrc.com
aehrc.csiro.au

B&M | 21-00358